Geology and Ore Deposits of the La Plata District Colorado

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By Edwin B. Eckel

ABSTRACT

This report embodies the results of a three-season field study of the ore deposits of the La Plata mining district, which lies within the La Plata Mountains in southwestern Colorado. This rugged mountain group lies between the main San Juan Mountains and the Colorado Plateau. Although its climate is rigorous the area is well-watered, and much of the 120 square miles studied is covered by moderately heavy vegetation. An excellent example of the laccolithic type of mountain group, the La Plata Mountains were carved from a domal uplift of sedimentary rocks intruded by numerous stocks, dikes, and sills of igneous rock.

The sequence of the sedimentary formations exposed within the district is shown in the following table. Their character and distribution are discussed rather fully in the body of the report.

Sedimentary rocks of the La Plata district

Age	Formation	Member	Thickness (feet)
Upper Cretaceous.	Mancos shale.		1,200
	Dakota (?) sandstone.		100–150
Upper Jurassic.	Morrison formation.	Shale.	400–625
	Junction Creek sandstone.		160–500
	Wanakah formation.	Marl and Bilk Creek sandstone.	25–125
		Pony Express limestone.	0–25
	Entrada sandstone.		100–265
Jurassic (?) and Upper Triassic.	Dolores formation.		500–750
Permian.	Cutler formation.		1,500–2,200
	Rico formation.		100–300
Pennsylvanian.	Hermosa formation.		2,750

These formations are underlain by several hundred feet of Cambrian, Devonian, and Mississippian strata, and by pre-Cambrian granite and hornblendites, whose general character is known from exposures in nearby areas. They were at one time overlain by a great thicknes of Upper Cretaceous and Tertiary rocks; these rocks once formed part of the dome but have been removed by erosion. Recognition and mapping of the stratigraphic units listed in the table above aided materially in acquiring a more complete understanding of the structure of this complex mountain group than has been available heretofore.

The igneous rocks are all of late Cretaceous or Tertiary age and are all intrusive. They vary widely in composition and form, but two general types are easily distinguished—porphyritic and nonporphyritic. The porphyritic rocks, most of which are intermediate between diorite and monzonite in composition, are more abundant than the nonporphyritic rocks and occur as more or less contemporaneous stocks, sills, and dikes. The nonporphyritic rocks, in general somewhat younger than the porphyries, form irregular stocks and associated dikes. They consist of syenite, monzonite, and diorite. The porphyry bodies were intruded forcibly between the layers of sedimentary rock and were thus a major factor in the formation of the La Plata dome, but there is clear evidence that the nonporphyritic rocks during their intrusion replaced or assimilated the country rocks. The intrusion of the porphyries was unaccompanied by metamorphism, whereas the nonporphyritic stocks are surrounded by an aureole of more or less intensely altered sedimentary rocks.

The most pronounced structural feature of the La Plata Mountains is a domal uplift of the sedimentary beds, about 15 miles in diameter, which blends somewhat into the southwestern flank of the much broader San Juan uplift. This dome is partly outlined by a steep, horseshoe-shaped hinge fold, open at the south, which nearly encircles the central part of the mountains. Within this hinge fold the rocks are rather thoroughly silicified, but outside it they are relatively unaltered except very locally. On the south side of the hinge and along the northern and northwestern margin of the dome several strong faults have uplifted the rocks toward the center of the dome. These major structural features were formed as a result of the intrusion of the porphyry and preceded the emplacement of the granular stocks and the development of metamorphism. During the doming process, a large number of short, discontinuous faults of small displacement were formed. Many of them trend east, but a few radiate from the center of the dome. After the emplacement of the nonporphyritic stocks, some of these faults were reopened and new ones were formed. These new faults became the loci of many of the ore deposits.

Spanish explorers visited the La Plata Mountains in the 18th century and possibly found ore there, but the first definitely recorded discovery of ore was in 1873. Between 1873 and 1900 many mines were opened, but their production was comparatively small. Between 1900 and 1937, however, several highly productive deposits were uncovered. These, together with the smaller deposits which were discovered, had yielded nearly $6,000,000 worth of ore by the end of 1937. More than half this total came from two mines, the May Day and Idaho, and four others yielded an aggregate of more than $1,000,000. Gold has always been the most valuable product of most of the mines, but over 2,000,000 ounces of silver and several hundred thousand pounds of lead and copper have also been recovered.

More than 60 mineral species whose character and mutual relations are described in the text are known or have been reliably reported to occur in the district. By far the most important are native gold and the various telluride minerals, particularly those of gold and silver.

The district is best known for its veins and replacement deposits of gold-bearing and silver-bearing telluride ores, from which the greater part of the production has come. In addition to these it contains a surprising variety of types of deposits within a small area. These types include deposits of dissemi-

nated platinum-bearing chalcopyrite, gold-bearing contact ore, veins of mixed base-metal sulfides containing silver or native gold, chalcocite veins, and veins of ruby silver ore. The gold-bearing placers have not been very productive.

Relations between the different types of deposit are far from clear, but it seems certain that they were formed through a wide range of temperature and possibly of pressure. Some evidence of zoning is found, and several lines of evidence point to the conclusion that all the deposits were formed during one general period of hydrothermal activity that followed closely on the emplacement of the nonporphyritic rocks.

Ore shoots are almost wholly confined to rocks that were able to maintain open spaces along fractures. Ore shoots can be expected only in places where one or more favorable structural features combine with rocks that either were originally favorable to ore deposits or were made so by areal or local (wall-rock) alteration.

Future production may well equal if not exceed the past production. Suggestions for prospecting both for new deposits and for other ore shoots in known mines are presented. The report closes with descriptions of nearly all the mines in the district.

INTRODUCTION

LOCATION AND POPULATION

The La Plata mining district, also known as the California district, lies within the La Plata Mountains in southwestern Colorado, 8 to 20 miles northwest of Durango (fig. 1). It includes parts of La Plata and Montezuma Counties, which had populations of 12,975 and 7,798, respectively, in 1930.

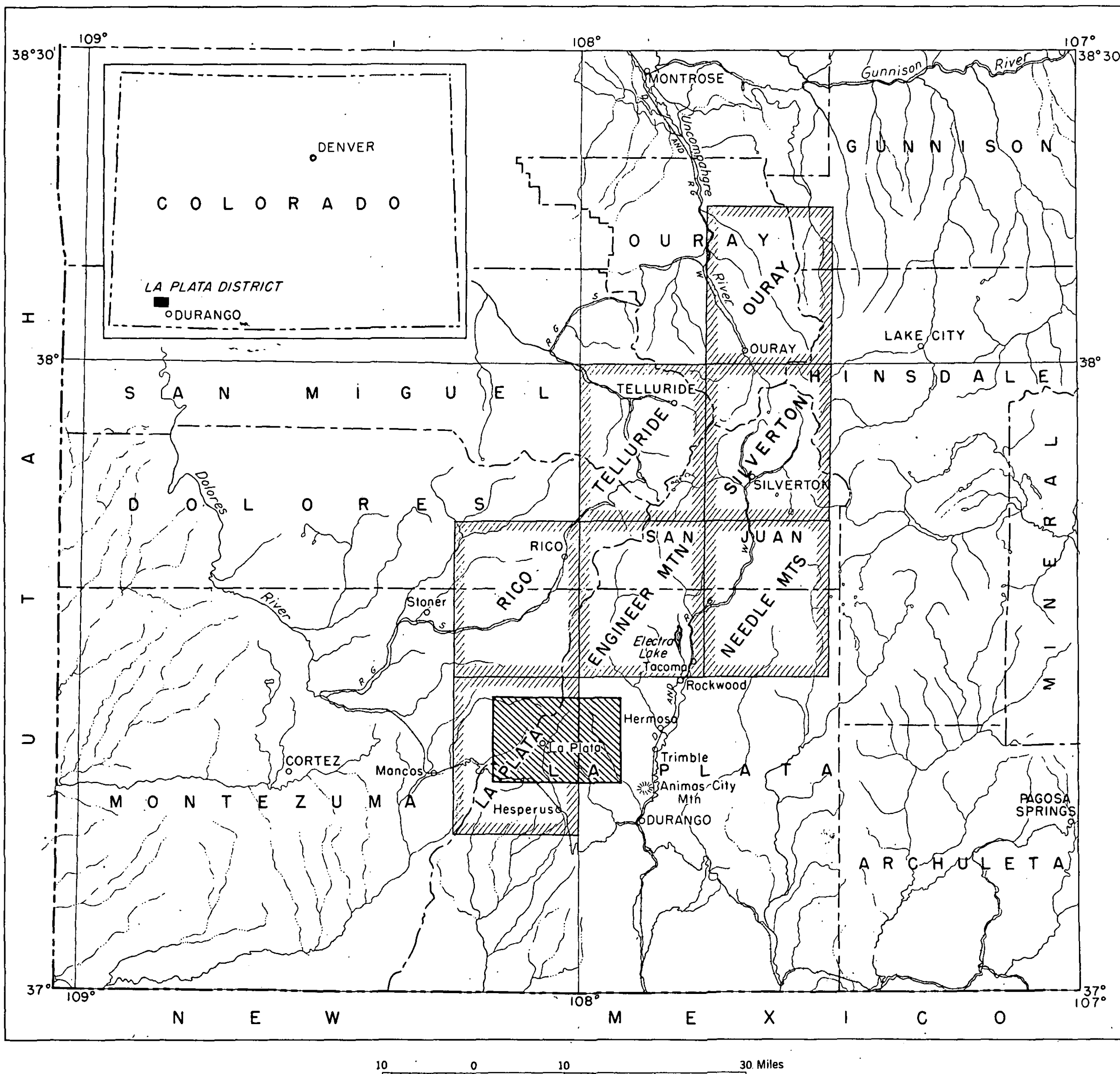

FIGURE 1.—Index map of southwestern Colorado showing location of the La Plata mining district and of geologic folios published by the Geological Survey.

The only settlements in the district are the old mining town of La Plata, locally known as La Plata City, which had a population of 33 in 1930, and Mayday which is about the same size. A school is maintained at La Plata in some years and at Mayday in others, the location for each year depending on the relative concentration of children in the two towns. Mayday is near the site of Parrott, which was the first settlement in La Plata County and was once the county seat. A high-tension line, paralleled by a telephone line, furnishes electric power for the May Day, Idaho, and Gold King mines. Daily stage and mail service is maintained between the Gold King mill and Hesperus, a small town 8½ miles south of La Plata. The principal supply point is Durango, which had 5,400 inhabitants in 1930, but Mancos with a population of 646 serves the East Mancos sector.

TRANSPORTATION AND INDUSTRIES

The narrow-gage Rio Grande Southern Railroad skirts the south edge of the mountains and connects with the Denver & Rio Grande Western Railroad, also narrow-gage, at Durango. The nearest shipping points at present are Hesperus and Brayton switch, near the East Mancos River; but a spur, unused for many years, connects Mayday with the main line. In addition to the paved State highway that connects Durango and Mancos, the counties maintain graded roads that follow the courses of Junction and Lightner Creeks and the La Plata and East Mancos Rivers. Parts of the district are accessible only by mountain trails, some of which are kept in good condition, but there are several wagon roads that could be made usable at the cost of a little work. Parts of the main roads and nearly all of the trails are closed by snow during winter, and much of the region is then virtually inaccessible.

The only industries other than mining are lumbering and stock raising. As shown in plate 1, the area described includes parts of the Montezuma and San Juan National Forests. The Forest Service provides and maintains trails in the mountains, gives protection against forest fires, and supervises grazing and the cutting of timber. Cattle are confined to the lower slopes, in general below 9,000 feet, but several thousand head of sheep are grazed on the higher slopes each summer, being moved in from the winter ranges of the San Juan Basin soon after the spring thaws, pushed higher as the snows recede, and finally taken out for winter pasture or for market in the late fall. Lumbering operations, except for some local cutting for mine timbers, have been confined in late years to the yellow-pine stands west of the East Mancos River. In the early days of the district, however, much cutting was done throughout the district, and some of the old roads are lumber roads.

Durango and Mancos are the supply centers not only for the metal-mining community but also for the large and prosperous farming industry of the San Juan Basin. Much coal is mined in the vicinity of both these towns and also near Hesperus. Since the closing, late in 1930, of the American Smelting & Refining Co.'s lead bullion-copper matte smelter at Durango, which treated the La Plata ore for many years, most of the ore produced has been shipped by truck or train to smelters at Leadville and Salt Lake City or to the Golden Cycle mill at Colorado Springs.

TOPOGRAPHIC FEATURES

The La Plata Mountains lie about 20 miles southwest of the main San Juan Mountain front. The intermediate space is a heavily timbered region of rugged hills carved from sedimentary rocks of Paleozoic and early Mesozoic age. The mountains rise abruptly on the west, south, and southeast from the comparatively level Colorado Plateau. They are thus situated on the border line between the well-watered and heavily forested San Juan region and a succession of arid mesas, plateaus, and canyons that extend far into Utah, Arizona, and New Mexico.

All the principal peaks of the La Plata Mountains lie within a 9-mile circle centering in the valley of the La Plata River near the mouth of Tirbircio Creek (pl. 1). The lesser summits and outlying ridges fall within an oval area from 12 to 15 miles in diameter. The higher peaks are situated along the narrow divides on each side of the La Plata River or on spurs extending from these divides. The lowest point in the area shown in plates 1 and 2, in the southeast corner, is 7,250 feet above sea level, but 79 percent of the area is above 9,000 feet and nearly 19 percent is above 11,000. The highest peak is Hesperus Peak, which rises to 13,225 feet, but Mount Moss, Babcock Peak, and Spiller Peak are nearly as high, and several other summits exceed 12,000 feet.

Except in the outlying parts of the mountain group most of the slopes are steep, and many of those above timber line are extremely rugged. In some comparatively large areas the rocks are bare, but in a large part of of the district exposures of bedrock are obscured by vegetation, talus, alluvium, or morainal material. Much of the geologic mapping shown in plate 2 is, in fact, based solely on traverses up and down the ravines, which for many areas present the only exposures of bedrock.

DRAINAGE

The mountains have resulted from the dissection by erosion of a domal uplift. Consequently the drainage system, all of which is ultimately tributary to the Colorado River, radiates in general from the central part of the group. The master stream, the La Plata River, has cut almost through the north rim of the mountains by headward erosion. This stream has a drainage area of 37 square miles above the gaging station at Hesperus, where it had an average discharge of 47.9 second-feet during the years 1917–35.[1] There is one diversion for irrigation above the gaging station. The greatest flow yet recorded at Hesperus was 1,460 second-feet on June 28, 1927, but during the flood of 1911, for which there are no records, the discharge was probably even larger. The La Plata flows south from the mountains and empties into the San Juan River in New Mexico.

The eastern parts of the mountain group are drained by Hermosa, Lightner, and Junction Creeks, which enter the Animas River, an important tributary of the San Juan, near Durango. Bear Creek, which empties into the Dolores River, a branch of the Colorado, drains the north-central part of the mountains. All the western part is drained by tributaries of the Mancos, of which the East and West branches are the largest. With a drainage area of 73 square miles, this stream discharged a maximum of 506 second-feet past the Mancos gaging station during the years 1931–36. Between 1933 and 1936 the average annual discharge varied from 15.7 to 54.5 second-feet, but there are several diversions above the gaging station.[2]

TOPOGRAPHIC MAPS

The topographic maps available for this survey were old and in many respects inadequate as bases for detailed geologic mapping. The mountains lie within the La Plata and Durango 15-minute quadrangles mapped by the United States Geological Survey in 1895 and 1907, respectively. These maps were published on a scale of 1: 62,500, or approximately a mile to the inch, but photographic enlargements of parts of them, on a scale of 1: 24,000, or 2,000 feet to the inch, were used for field mapping. During the present investigation the cultural features were completely revised and much of the topography was corrected, but in many places it was found necessary to generalize the geologic mapping to make it fit the topographic maps.

[1] Grover, N. C., and others, Surface water supply of the United States, 1936, part 9, Colorado River Basin: U. S. Geol. Survey Water-Supply Paper 809, p. 122, 1937.

[2] Idem, p. 126.

CLIMATE

In the rigor of its climate the area here described resembles the mining camps of the San Juan Mountains, but the La Plata Mountains, because of their exposed position on the edge of the Colorado Pleateau, probably receive even more rain and snow than the main San Juan Mountains. The nearest weather stations are at Durango and Mancos, both at considerably lower altitudes than any place within the district. The following table however, gives some idea of the conditions in the La Plata Mountains at comparable altitudes. Terminal Dam is near the Animas River about 16 miles northeast of the central part of the mountains. Savage Basin between Telluride and Ouray is 40 miles from the district, but it is the nearest station where records of precipitation at high altitudes have been kept.

The winters in the district are long, and in the mountainous areas they are generally characterized by heavy snow. Snowslides, some of great size and velocity, occure frequently and there are many snowslide scars on the steeper slopes. Some of the slides recur annually, and their scars remain virtually bare of vegetation from year to year. Others occur at infrequent intervals and allow the growth of heavy stands of aspen in their scars. The most destructive slide on record took place in February 1934 on Jackson Ridge. It destroyed the new mill and other buildings at the Doyle mine and took a toll of eight lives. Snowbanks remain in many protected places to the end of July or August, and a few of them, particularly in the upper part of Tomahawk Basin, often survive from one year to the next.

The spring months, especially May and June, are generally the driest of the year, and the clear cool weather of that season is favorable to field work. Precipitation during the summer varies widely from year

Precipitation and snowfall at stations near La Plata district [a]

Place	Altitude (feet)	Years of record	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average monthly and annual precipitation, in inches															
Durango	6, 589	38	1. 67	1. 74	1. 84	1. 54	1. 11	0. 86	2. 09	2. 16	1. 93	1. 92	1. 35	1. 77	19. 98
Terminal Dam	8, 300	24	2. 49	2. 47	2. 32	1. 99	1. 36	1. 14	2. 98	2. 64	2. 63	2. 29	1. 74	2. 25	26. 30
Rico	8, 824	29	2. 67	2. 71	2. 85	1. 63	1. 59	1. 20	3. 09	2. 54	2. 75	1. 56	1. 49	2. 04	26. 12
Silverton	9, 400	24	2. 10	1. 83	2. 87	1. 69	1. 38	1. 62	3. 07	3. 30	2. 98	2. 50	1. 44	1. 91	26. 69
Savage Basin	11, 522	16	3. 43	4. 00	4. 57	4. 44	2. 68	. 75	3. 02	3. 32	2. 80	3. 00	2. 93	3. 11	38. 05
Average monthly and annual snowfall, in inches															
Durango	6, 589	28	16. 5	16. 4	7. 8	2. 4	0. 7	0. 0	0. 0	0. 0	Tr.	1. 4	5. 8	16. 0	67. 0
Terminal Dam	8, 300	24	29. 1	28. 8	21. 5	13. 4	3. 1	Tr.	. 0	. 0	0. 2	6. 0	15. 7	27. 6	145. 4
Rico	8, 824	25	30. 3	29. 1	29. 9	15. 5	6. 0	. 2	Tr.	Tr.	1. 7	8. 3	18. 6	24. 9	164. 5
Silverton	9, 400	24	25. 3	27. 5	30. 9	16. 7	3. 7	. 4	. 0	. 0	1. 3	8. 9	18. 6	24. 4	157. 7
Savage Basin	11, 522	15	52. 5	55. 4	64. 8	61. 1	36. 1	4. 9	. 1	. 2	7. 8	31. 5	40. 0	45. 8	400. 2

[a] Sherier, J. C., section 22: Western Colorado, climatic summary of the United States, U. S. Weather Bureau, 1934.

to year. It commonly comes in the form of sudden and more or less local thundershowers, but in some years there are many days of almost continuous rain. The first snow usually falls in late September or early October. It is often followed by a month or more of clear, crisp weather, the boasted Indian summer of the Colorado Rockies; not infrequently, however, winter weather sets in immediately after the first snows.

In summer the days are comfortably cool except on the brush-covered lower slopes, and the nights are always cold enough, even at the lowest levels, to require the use of blankets. In the highest parts of the area the average annual temperature is very low and frost may occur at any time. The portals of some abandoned mine workings, notably those of the Cumberland, are partly or completely blocked with ice the year round; the Muldoon workings were lined with beautiful ice crystals when the mine was examined in August 1936.

VEGETATION

A large part of the district is more or less heavily timbered (pl. 3 *A* and 21). The lower slopes, especially in the southern and southwestern parts of the mountains, are largely covered with thick stands of Rocky Mountain white oak (scrub oak) intermixed with some dwarf maple, western chokecherry, and western serviceberry. These trees give way upward to comparatively pure stands of aspen. In some places, as in the region west of the East Mancos River, the aspen trees are 40 feet or more in height and 12 to 18 inches in diameter. Narrow-leaf cottonwood, alder, and willow grow along the banks of most of the streams, forming nearly impenetrable masses in some places. On the higher parts of the mountains the deciduous trees give way to evergreens, of which Douglas and white fir, Engelmann and blue spruce, and western yellow pine are the most abundant species. Many of the higher groves of aspen mark places where forest fires have destroyed the evergreens; but the gulch along Burnt Timber Creek, which was laid bare by fire at some time between 1875 and 1895, is still almost entirely bare of trees.

Grass-covered slopes and open parks are comparatively rare below timberline, which ranges from 10,000 to 12,000 feet in altitude; but many large areas above timberline are covered with grasses, sedges, dwarf willows, and a profusion of exquisitely colored and fragrant alpine flowers. Among the most notable of these upland meadows are three: one in Cumberland Basin, one in the divide north of Diorite Peak, and one near the head of Starvation Creek.

WILDLIFE

Deer, bear, beaver, coyote, and numerous smaller mammals, together with a few wildcat and cougar, inhabit the district throughout the year. Elk are occasionally seen in the more inaccessible parts, but they commonly remain in the remote parts of the Hermosa Creek drainage basin until late in fall, after the domestic sheep have been taken from the La Plata Mountains. Grouse are relatively abundant in many thick groves of spruce, but ptarmigan are very scarce. Several of the streams, including Junction Creek and its tributaries, Bear Creek, and the western tributaries of the Mancos River, afford good trout fishing.

FIELD WORK AND ACKNOWLEDGMENTS

The field work on which this report is based was begun in June 1935. A total of 50 weeks was devoted to field work during the seasons of 1935, 1936, and 1937. F. W. Galbraith, of the University of Arizona, acted as field assistant for all but the last few weeks of the first two seasons, and he and the writer mapped most of the mines together. Galbraith, and A. C. Spencer of the Geological Survey, who was associated with the party in 1936 and 1937, took almost full responsibility for the mapping of large parts of the district, and it is difficult to express adequately the writer's indebtedness to both of them. Others who ably assisted for certain periods were R. S. Moehlman, who replaced Galbraith toward the close of the first season; V. H. Steele, who acted as rodman and guide during 1937; and A. W. Parker, Jr., and his associate, E. A. Bennett, who supplied horses and acted as packer and cook, respectively, when the party was in camp in 1937. James Steele Williams, of the Geological Survey, spent 6 weeks in the field at the beginning of the project. His stratigraphic and paleontologic studies provided a working basis for recognition and differentiation of the sedimentary formations in the metamorphic area.

Except for the sections on paleontology, mineralogy, and the chalcocite deposits of Bear Creek, contributed by J. S. Williams, F. W. Galbraith, and E. N. Goddard, respectively, the report was prepared by the writer. Few people—including many writers of official reports—realize the contributions made by others to a work of this kind, nor do they sense the complex evolutionary process by which the author's ill-formed field notes, maps, and ideas are given form and palatability. Throughout his office work, the writer had the advantage of constant advice from and discussion with Mr. Spencer and other members of the Survey's professional staff. W. S. Burbank read the entire manuscript and, during the writer's absence on other field work, generously assumed many of the burdens of putting it in final form. F. C. Calkins edited the final manuscript; to him is due most of the credit for any virtues of readability that the report may possess. To these men, and to the illustrators, typists, editors, and others who in various ways furthered the preparation of the report, hearty acknowledgment is due. Mrs. LaCharles G. Eckel assisted materially by giving constant encouragement throughout the project.

Mining men and others in the district and in nearby towns without exception were hospitable and courteous

and cooperated in every way possible. Among those who deserve special thanks are R. M. Wheeler, W. A. Fleming, and W. F. Allen, Jr., successive managers of the Gold King mine, who generously provided accommodations for the party throughout most of the field work and rendered many other services. J. A. Pratt, F. C. Bowman, and L. B. Graff of the Doyle mine, I. E. Goodner and Orville Bates of the Idaho mine, and R. H. Toll of the Comstock mine were very helpful, as were the officials of nearly all the other operating mines and prospects. The following mining and business men were particularly helpful: A. M. Camp, J. P. Channel, A. L. Kroeger, and Robert Yeager, of Durango; T. R. Mahan, of Mancos; and William Barlow, Dan Cason, August Ekburg, R. D. McCausland, and Peter and Joseph Minoletti, of Hesperus. J. F. Beckstrom, in charge of the State Planning Commission's Mineral Resources project, gave access to the reports and mine maps collected by that organization in 1935 and 1936.

As indicated by recent production figures for individual mines, there was little activity in the district during the war years, and it was not revisited by the writer. The Copper Hill, Allard, and Honeydew deposits were later examined, however, by G. M. Schwartz and D. J. Varnes, of the Geological Survey, and were sampled and partly explored by the Bureau of Mines. The results of these investigations are included herein.

PREVIOUS GEOLOGIC WORK

The La Plata Mountains were studied by geologists of the Hayden Survey shortly after the discovery of the ore deposits. The most complete report upon the geology, however, is contained in the Geological Survey's La Plata folio, prepared by Whitman Cross and his associates in 1896-97 and published in 1899. This report was used as a starting point in all the present work, and large parts of plate 2 are taken without essential change from Cross' map; but the larger scale used by the writer, the great increase in underground exposures due to the discovery and development of new mines, and advances in knowledge of the stratigraphy of southwestern Colorado during the past 40 years, made extensive revision and refinement of Cross' maps both desirable and possible. No detailed maps of the part of the district within the Durango quadrangle have been published, but an unpublished field map prepared by Cross and his associates for the Geological Survey during the years 1897-1905 was very helpful, and parts of it are reproduced here with little change. The following publications include all those known that relate significantly to the geology and ore deposits of the district.

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GENERAL GEOLOGY

GENERAL RELATIONS

The La Plata Mountains have been long known as an example of the laccolithic type of mountain group.[3] They were carved from a domal uplift of sedimentary rocks into which numerous stocks, dikes, and sills of igneous rock were intruded.

In general the strata, which range in age from Pennsylvanian through Upper Cretaceous, dip away from the central higher areas. A horseshoe-shaped hinge fold along which the dips are very steep nearly encircles the central part of the mountains. On both sides of this fold the dips are relatively flat. Several faults of rather large displacement cut the outer parts of the dome, and in the main body of the dome there are many other fractures and small faults.

The igneous rocks vary widely in composition and in form, but all of them can be grouped in two general types—porphyritic and nonporphyritic. The most abundant igneous rock in the district is diorite-monzonite porphyry. The rock occurs as essentially contemporaneous sills, stocks, and dikes, which were emplaced largely by forcible intrusion. The nonporphyritic rocks, in general younger than the porphyry, consist of syenite, monzonite, and diorite and occur as irregular stocks associated with many dikes. The extensive metamorphism of the sedimentary rocks in the central part of the district is related to these stocks. The stocks were formed in large part by replacement or assimilation of the older sedimentary and igneous rocks.

The most productive of the ore deposits are veins and replacement bodies that yield gold and silver tellurides, but there are also deposits of pyrite and chalcopyrite enclosing native gold, of base-metal sulfides, and of chalcopyrite enclosing platinum. Many of the deposits are clearly related to the hinge fold and associated faults mentioned above.

The principal object of this study was to obtain and record up-to-date information on the ore deposits of this little-known mining camp, but the attainment of the object required comparatively detailed studies of the areal geology and revision of the stratigraphy in accordance with modern knowledge of the geology of southwestern Colorado. The study has therefore yielded a more complete picture of the geology of this highly complex laccolithic mountain group than was previously available.

PRE-CAMBRIAN BASEMENT ROCKS

Very little is known about the pre-Cambrian basement rocks beneath the La Plata Mountains, as they are buried under 3,000 to 8,000 feet of later rocks. The nearest exposure of the pre-Cambrian complex is on the Animas River near Baker Bridge and Rockwood, 14 to 16 miles north of Durango and 13 miles east of the center of the mountains.[4] The pre-Cambrian rocks there consist of schists and gneisses, with several large bodies and many dikes of coarse granite. The pre-Cambrian is much more extensively exposed farther east and south, especially in the Needle Mountains,[5] where there is a great diversity of pre-Cambrian rocks, including schists and gneisses, metamorphosed volcanic rocks, granite of several kinds, conglomerates, and quartzite.

Presumably the pre-Cambrian rocks beneath the La Plata Mountains are similar to those of the Needle Mountains. The only actual clue to their character, however, is afforded by the inclusions in the later igneous rocks. Most of the inclusions that were seen consist of coarse granite or of hornblendite, similar in almost every respect to the granite along the Animas River and to the Irving greenstone of the Needle Mountains.

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[3] Cross, Whitman, The laccolitic mountain groups of Colorado, Utah, and Arizona: U. S. Geol. Survey 14th Ann. Rept., pt. 2, pp. 157–241, 1893. Gilbert, G. C., Report on the geology of the Henry Hountains: U. S. Geog. and Geol. Survey, Rocky Mountain region (Powell Survey), 160, pp., 1877.

[4] Cross, Whitman, and Larsen, E. S., A brief review of the geology of the San Juan region of southwestern colorado: U. S. Geol. Survey Bull. 843, pp. 17–22, pl. 1, 1935.

[5] Cross, Whitman and others, U. S. Geol. Survey Geol. Atlas, Needle Mountains folio (no. 131), 1905.

This fact suggests that these two rocks underlie much of the La Plata area, but there may be others that for one reason or another are not adequately represented by inclusions in the later rocks.

SEDIMENTARY ROCKS

GENERAL SECTION

The sedimentary rocks exposed in the La Plata Mountains, as shown in the following table and in plate 2, range from the Hermosa formation, of Pennsylvania age, to the Mancos shale, of Upper Cretaceous age. Only the uppermost layers of the Hermosa formation are exposed within the district, but these are underlain by more than 2,000 feet of Hermosa beds and by several hundred feet of Cambrian, Devonian, and Mississippian sediments. Outside of the district the Mancos shale is overlain by a great thickness of Upper Cretaceous and Tertiary beds, which formerly covered the entire region and were involved in the uplift of the La Plata dome. They have since been removed from the mountainous area by erosion, and none of them was studied elsewhere during the present investigation.

The stratigraphic section described below differs considerably from that given by Cross in the La Plata folio.[6] The Rico and Cutler formations had not been distinguished at the time of Cross' field work, and he grouped them with the Dolores. The Hermosa beds on the La Plata River and Hermosa Creek were not recognized during the earlier work. Much confusion has existed regarding the terminology applied to the Jurassic rocks, and the La Plata sandstone originally defined by Cross in the La Plata folio is now subdivided into three formations. As these stratigraphic names are not yet all in general use in the district, the widely used local terms for the various stratigraphic units are used parenthetically throughout the report.

In the central part of the district intense metamorphism makes it difficult to distinguish some of the formations, or, in places, to determine whether a rock is of igneous or of sedimentary origin. The prevailing red colors have lightened to pale purplish and greenish tints or to gray, shale has been altered to hornfels, and sandstone to dense quartzite, and bedding has locally been obliterated. Contact-metamorphic minerals such as garnet, epidote, hornblende, specular hematite, and magnetite, have been formed in the calcareous beds. Fortunately all the formations occur unmetamorphosed and in their normal sequence not far outside the district, notably along the Animas River. Studies of these unmetamorphosed rocks by J. S. Williams and by the writer and his other associates resulted in the finding of good marker beds, diagnostic fossils, and other distinguishing characteristics. A sufficient number of beds thus identified could be correlated with their metamorphosed equivalents within the district to make it possible to distinguish the formations with some degree of certainty, even where they were strongly metamorphosed.

The sequence and general character of the sedimentary rocks of the district are summarized in the table on page 9.

PRE-HERMOSA ROCKS

The sedimentary rocks that lie between the pre-Cambrian complex and the base of the Hermosa formation are buried so deeply beneath younger beds in the La Plata area that they are of little economic interest. They include the Upper Cambian Ignacio quartzite, the Upper Devonian Elbert formation and Ouray limestone, the Mississippian Leadville limestone, and the Pennsylvanian Molas formation. All these formations are well exposed along the Animas River, in the Needle Mountains, and elsewhere, and they have been described and mapped by several geologists.[7]

The Molas formation lies between the Leadville limestone and the base of the Hermosa in the Needle Mountains and Engineer Mountain quadrangles. It apparently pinches out toward the southwest, however, and was not recognized during the present navigation in the vicinity of Baker Bridge and Pinkerton Hot Springs along the Animas River. It may be represented there by beds concealed in an interval of poor exposures at the base of the Hermosa, but no red shales similar to those of the typical Molas were seen.

PENNSYLVANIAN SERIES

HERMOSA FORMATION

CHARACTER AND DISTRIBUTION

The Hermosa formation, typically exposed along Hermosa Creek and the Animas River a few miles east of the La Plata Mountains, consists chiefly of several thousand feet of interbedded sandstones, grits, limy shales, and limestones, with some black shales and gypsum. Many of the limy beds contain abundant Pennsylvanian fossils. Within the area shown in plate 2, exposures of the formation are confined to a small area along the La Plata River and Lewis Creek, and to an even smaller area, not examined in the course of this study, along Clear Creek in the extreme northeast corner of the area mapped. As the limestone beds of the Hermosa almost certainly underlie the whole of the district, and as they are the chief ore-bearing beds in the neighbor-

[6] Cross, Whitman, Spencer, A. C., and Purington, C. W., U. S. Geol. Survey Geol. Atlas, La Plata folio (no. 60), 1899.

[7] Cross, Whitman, A new Devonian formation in Colorado: Am. Jour. Sci., 4th ser., vol. 18, pp. 254–252, 1904. Cross, Whitman, and Howe, Ernest, U. S. Geol. Survey Geol. Atlas, Silverton folio (no. 120), 1905. Cross, Whitman, and Howe, Ernest, Red beds of southwestern Colorado and their correlation: Geol. Soc. America Bull., vol. 16, pp. 447–498, 1905. Cross, Whitman, and others, U. S. Geol. Survey Geol. Atlas, Needle Mountains folio (no. 131), 1905; Cross, Whitman, and Hale, A. D., U. S. Geol. Survey Geol. Atlas, Engineer Mountain folio (no. 171), 1910. Cross, Whitman, and Larsen, E. S., on cit. (Bull. 843). Kirk, Edwin, The Devonian of Colorado: Am. Jour. Sci. 5th ser., vol. 22, pp. 222–240, 1931. Spencer, A. C., Devonian strata in Colorado; Am. Jour. Sci., 4th ser., vol 9, pp. 125–133, 1900.

Sedimentary rocks of the La Plata district, Colorado

Age	Formation names in current use by Geological Survey	Member	Name in local use	Name used in La Plata folio 60	Thickness (feet)	Character
Upper Cretaceous.	Mancos shale.		Mancos shale.	Mancos shale.	1,200	Soft dark-gray to black carbonaceous shale with thin lenses and concretions of impure limestone. Only the lower part is exposed within the La Plata district.
	Dakota(?) sandstone.		Dakota sandstone.	Dakota sandstone.	100–150	Gray or brown sandstone with variable conglomerate at or near base. Carbonaceous shale partings and coal at several horizons. Forms cliffs. Should be favorable to ore, but little of it occurs in the mineralized area.
Upper Jurassic.	Morrison formation.		McElmo formation.	McElmo formation.	400–625	Alternating friable fine-grained yellowish-brown to gray sandstones and variegated shales, with one or more lenses of conglomerate near top. Largely altered to dense light-colored quartzite and hornfels in central part of district. Generally unfavorable to ore deposits.
	Junction Creek sandstone.		Upper La Plata sandstone.	La Plata sandstone.	160–500	Massive friable white sandstone, distinctly crossbedded. Altered to hard white to brown quartzite in central part of district. Contains much ore in several places.
	Wanakah formation.	Marl and Bilk Creek sandstone.	Middle La Plata shale.		25–125	Alternating pink to red sandy marls with lenses of friable white or light-colored sandstone. Similar to Morrison formation where metamorphosed. Generally unfavorable to ore deposits.
		Pony Express limestone member.	La Plata limestone.		0–25	Medium-gray to black massive unfossiliferous limestone. Locally replaced by pyrite or by telluride minerals. Largely altered to contact-metamorphic minerals in central part of district. Contains much ore in several places.
	Entrada sandstone. ——Unconformity——		Lower La Plata sandstone.		100–265	Similar to Junction Creek sandstone.
Jurassic(?) and Upper Triassic.	Dolores formation.		Dolores formation; "red beds."	Dolores formation.	500–750	Salmon-pink to bright-red mudstones and fine-grained sandstones. Several beds and lenses of limestone-shingle conglomerate and of light-gray slabby sandstone at or near base. Where metamorphosed it has same character as shale of Morrison formation. Limestone conglomerate beds altered to contact-metamorphic minerals in places. Generally unfavorable to ore deposits.
Permian.	Cutler formation.		Cutler formation; "red beds."		1,500–2,200	Alternating dull-red arkosic sandstones, congolmerates, limy shales, and mudstones. Similar to Morrison where metamorphosed. Nodules of limestone, unaltered in places but elsewhere represented by garnet, epidote, etc. Favorable to ore deposits where rocks are silicified.
	Rico formation.		Rico formation.	Not recognized; included with Dolores in mapping.	100–300	Dull-red shale, sandstone, and thin beds of sandy fossiliferous limestones. Similar to Morrison where metamorphosed. Contains ore deposits in places.
Pennsylvanian.	Hermosa formation.		Hermosa formation.		2,800±	Alternating green to gray and occasionally dull-red arkosic sandstone, shale, fossiliferous limestone, and gypsum. Only the upper 500 feet is exposed within La Plata district. Favorability to ore deposits not known.
	Molas formation. ——Unconformity——				0–75(?)	Red limy shale. May not be present beneath La Plata district.
Mississippian.	Leadville limestone.				60(?)	Fossiliferous massive to laminated limestone.
Upper Devonian.	Ouray limestone.				75(?)	Fossiliferous limestone, sandy limestone, and quartzite.
	Elbert formation. ——Unconformity——				0–130(?)	Shale, limestone, and sandstone.
Upper Cambrian.	Ignacio quartzite. ——Unconformity——				50–100(?)	Massive to thin-bedded quartzite, with some conglomerate at base.

ing camp of Rico, the question of their probable ore-bearing character in the La Plata Mountains was considered an important part of the present investigation. For this reason much effort was made to obtain a complete section of the beds at the type locality and to find criteria that could be used for distinguishing the Hermosa formation within the mining district.

LITHOLOGY ALONG THE ANIMAS RIVER

The following composite section of the Hermosa was measured in 1935 by J. S. Williams, F. W. Galbraith, and the writer. Only a little more than half the beds are well enough exposed to permit detailed study of their character, but the measurements are believed the most accurate and complete that have been made at the type locality. The section was pieced together from several incomplete sections most of which are on the west bank of the Animas River between Pinkerton Hot Springs and the mouth of Hermosa Creek. A few parts of the section were measured on the east bank of the Animas River and along the lower reaches of Hermosa Creek. Some of the incomplete sections were tied together by "walking out" prominent beds; others, especially those on opposite sides of the Animas River, were united by projecting prominent beds or zones.

Composite section of Hermosa formation as exposed along the Animas River and the lower part of Hermosa Creek

[Measured by J. S. Williams, F. W. Galbraith, and E. B. Eckel]

Top of section.

Rico formation, red mudstones, sandstones, and thin limestones.

Hermosa formation:	Feet
1. Limestone, dark blue, containing Hermosa fossils, in beds up to 2 feet thick, separated by thinner layers of limy shale (fossil collections 8574 and 8575)	26
2. Sandstone, greenish-gray, slabby, cross-bedded	26
3. Covered interval	16
4. Sandstone, brown to light-gray, arkosic and coarse-grained	28
5. Shale and mudstone, maroon	50
6. Siltstone, gray with ill-defined green nodules	15
7. Shale and siltstone, red	11
8. Sandstone, green, micaceous. Forms bench (fossil collection 8573)	25
9. Mudstone, maroon	60
10. Grit, white. Forms prominent ledge	5
11. Shale, limy, gray	2
12. Covered interval	9
13. Grit, pink to gray, containing fragments of pink feldspar and green shaly particles	15
14. Sandstone and interbedded mudstone, maroon	15
15. Limestone, blue, fine-grained	9
16. Limestone, gray, coarsely crystalline	4
17. Shale, green, limy and sandy, with thin beds of fossiliferous limestone (fossil collection 8572)	11
18. Sandstone, green, micaceous	8
19. Covered interval	52
20. Sandstone, coarse, arkosic	15
21. Covered interval, probably red micaceous mudstone	48

Composite section of Hermosa formation as exposed along the Animas River and the lower part of Hermosa Creek—Continued

Hermosa formation—Continued	Feet
22. Sandstone, micaceous, fine-grained to medium-grained	6
23. Sandstone, gray, coarse-grained, and somewhat arkosic	3
24. Covered interval, probably gray shale	14
25. Limestone and shaly micaceous sandstone in thin alternating beds. Some layers are made up almost entirely of fossils, especially crinoid stems (fossil collection 8571)	26
26. Covered interval	20
27. Grit, pink to brown, with several thin beds of coarse conglomerate. Forms box canyons	70
28. Sandstone, green micaceous, with thin partings of shale	10
29. Shale, red and purplish-maroon, alternating with beds of shaly, limy sandstone containing nodules of limestone	16
30. Sandstone, greenish-gray, with limy lenses	16
31 Limestone, drak-gray, carbonaceous, fossiliferous (fossil collection 8568)	8
32. Sandstone, greenish-gray, micaceous, and shaly	8½
33. Sandstone, brown, coarse, arkosic	21
34. Sandstone, green, fine-grained, in 30-inch beds separated by beds of shale 8 to 10 inches thick; lenses of limestone and limy nodules	30
35. Limestone, fossiliferous, in beds 8 to 15 inches thick, alternating with beds of shale 1 foot to 3 feet thick (fossil collection 8567)	25
36. Covered interval, underlain in part if not wholly by black shale	65
37. Shale, black and dark-gray	11
38. Shale, light blue-gray	9
39. Covered interval, may be largely underlain by black shale	200
40. Shale, black, poorly exposed	65
41. Sandstone, green, micaceous	23
42. Limestone, black to blue	1
43. Covered interval	24
44. Shale, black	4
45. Limestone, in three beds	4½
46. Sandstone, micaceous, shaly	2
47. Shale, gray to black, with thin layers of limestone	17
48. Limestone, in two thin beds, separated by black shale	5½
49. Sandstone, green, coarse-grained, arkosic	7
50. Sandstone, green, micaceous, shaly; some beds relatively hard	44
51. Covered interval	100
52. Sandstone, greenish-gray, micaceous, shaly	20
53. Gypsum	12
54. Covered interval	6
55. Grit, fine-grained, brown	8
56. Sandstone, green, micaceous	5
57. Limestone, black, fossiliferous (fossil collection 8566)	3
58. Shale, black and fossiliferous shaly limestone; poorly exposed in lower part (fossil collection 8565)	65
59. Shale, black, with several layers of limestone up to 2 feet thick	20
60. Limestone, fossiliferous, interbedded with black shale	8
61. Partly covered interval, occupied in part by thin-bedded limestone (fossil collection 8564)	15

Composite section of Hermosa formation as exposed along the Animas River and the lower part of Hermosa Creek—Continued

Hermosa formation—Continued	Feet
62. Sandstone, micaceous, and sandy grit; contains plant remains	25
63. Sandstone, green, micaceous	10
64. Grit, fine-grained	7
65. Shale, micaceous, sandy, with limestone lenses	8
66. Sandstone, green, micaceous, with some fine grit. Limestone 6 to 8 inches thick at top. Forms box canyons and cliffs	50
67. Sandstone, coarse, arkosic	17
68. Shale, green, micaceous	4
69. Shale, black	1
70. Limestone, black	1
71. Sandstone, green, shaly	4
72. Covered interval	352
73. Sandstone, brown, coarse-grained, and grit. Contains some fragments of red feldspar	14
74. Covered interval	27
75. Sandstone, grayish-green	12
76. Covered interval	5
77. Grit, brown	22
78. Sandstone, poorly exposed	3
79. Covered interval	7
80. Limestone, dark-blue, in three to four beds, separated by shale partings	12
81. Covered interval	12
82. Grit, with some quartz pebbles up to ¾ inch	25
83. Limestone in thin beds, with shale partings	8½
84. Sandstone, green, micaceous, fine-grained to medium-grained	3
85. Grit, fine-grained	7
86. Covered interval, underlain in past by green sandstone	12
87. Limestone, blue to black, in three beds	9
88. Sandstone, micaceous	20
89. Sandstone and grit, green to greenish gray	35
90. Shale, dark gray, with thin beds of limestone	8
91. Limestone, blue	4½
92. Shale, grayish-green	4
93. Sandstone, coarse, arkosic	20
94. Sandstone, green, shaly	19
95. Shale, maroon and black, with 1-foot layer of limestone at top	19
96. Sandstone and shale, interbedded	8
97. Covered interval, underlain in part by sandstone and shale	20
98. Sandstone, green to maroon	11
99. Grit, finely conglomeratic	7½
100. Sandstone, maroon to green, shaly	13½
101. Grit, green	4½
102. Sandstone, green, shaly	11
103. Sandstone, green	4½
104. Covered interval, underlain in part by limy sandstone	5
105. Limestone and black shale, interbedded	4½
106. Sandstone, micaceous, with shale partings	6
107. Sandstone, greenish-gray, shaly	5
108. Grit	1
109. Sandstone, green, shaly	5½
110. Sandstone, coarse, with some red feldspar	8
111. Sandstone, coarse, green-gray, showing current ripple marks	11
112. Covered interval, probably underlain by shale	12
113. Gypsum	1
114. Limestone and black shale in thin beds	5
115. Covered interval, underlain in part by black shale	1
116. Sandstone, micaceous, and fine grit	8
117. Covered interval, underlain by some green to medium-gray shale and sandstone	48
118. Limestone	2
119. Sandstone, arkosic	4
120. Nearly all covered. A few thin beds of limestone and of green micaceous sandstone near base and scattered ones above. May be Molas formation in part, but no red or black shales were noted. Fusilinids were observed in some thin limestone beds in the lower third of this interval, but none were collected	290
	2,751½
Leadville limestone:	
121. Limestone, light-gray, friable, and finely crystalline, in beds at top of Leadville	5
122. Covered interval	12
123. Limestone, dark-gray to white, fossiliferous, and somewhat cherty (fossil collection 8563)	31
124. Limestone, blue, dense, fossiliferous	12
125. Mudstone, maroon	3
126. Limestone, blue to lead-gray	8
127. Remainder of Leadville not measured at the locality at which the section was begun. Formation consists largely of light-cream, buff, and light-grey limestone. It is exposed in cliffs and benches along the Durango-Ouray highway a few feet above the road level west and north of Pinkerton Hot Springs	2,814½

According to the foregoing section, the Hermosa is about 2,750 feet thick on the Animas River. It can there be separated on lithologic grounds into five divisions.

The lowest division, which includes beds 100–120, is about 450 feet thick. It weathers to form comparatively smooth slopes. The lower half of it is very poorly exposed in most places and is probably made up of shale in large part. The upper half is composed of alternate thin beds of greenish shaly sandstone, arkosic sandstone, and green, maroon, and black shale. A few beds of limestone from 1 foot to 2 feet thick and at least one thin bed of gypsum are interbedded with the shales.

The second lowest part of the formation, which consists of beds 73–99 and is about 350 feet thick, weathers to form prominent cliffs, benches, and box canyons. It is characterized by thick beds of green and brown sandstone and grit, some of which are conglomeratic, but it includes a few thin shaly beds between the beds of sandstone, and several 4-foot to 12-foot beds of dark-blue to black fossiliferous limestone.

The third division, which is about 1,225 feet thick and includes beds 36–72, is characterized by black bituminous shale, but it contains one or more thick beds of gypsum and a few thin beds of fossiliferous limestone; and thick beds of green micaceous and shaly sandstone, like those in the third division of the formation, occur near the base of the black shale series. In most places the rocks weather to form smooth slopes.

The fourth division is about 450 feet thick and includes beds 13–35. The lower third of it weathers to form slopes that blend into those of the underlying division, but the upper two-thirds commonly forms prominent cliffs and steep-walled box canyons. This fourth division is characterized by several beds of blue-gray fossiliferous limestone, from a few inches to 10 feet thick, and by almost equal quantities of maroon arkosic grits and sandstones in thick beds and of red to maroon shales, mudstones, and limy shales. Exclusive of limy shales and mudstones, a total of 21 feet of limestone was measured. Most of the beds of grits and sandstones are coarse-grained, and some of them are conglomeratic.

The fifth and uppermost division of the Hermosa formation, about 270 feet thick, includes beds 1–12. It is marked by dull-red or maroon colors that contrast with the gray, brown, and green colors of the lower beds, by an absence of thick beds of limestone, and by a predominance of shales and mudstones. The top of the formation is marked in the sections examined by a 25-foot zone of interbedded shale and fossiliferous limestone, underlain by a 50-foot bed of massive medium-grained arkosic sandstone.

The section described above represents the Hermosa formation in the particular area where it was studied, but it may not represent the formation as exposed in some area many miles distant. Many individual beds pinch out entirely, or change markedly in character, within a short distance along the strike. Spencer's statement [8] as to the general character of the Hermosa is significant. He says:

throughout the area of its occurrence it [the Hermosa formation] is not in general divisible, since individual beds and groups of strata change greatly in character from place to place, so that horizons cannot be definitely recognized in localities separated from one another by more that short distances.

Comparison of the section at Rico with that given above lends point to this statement. At Rico it is possible to divide the 1,800 feet of Hermosa beds into three approximately equal parts.[9] The upper third consists of black to gray shale alternating with green grits and sandstones. The middle third consists largely of blue bituminous limestone, and the lower third is made up of alternating beds of grit and dark shale and one or more thick beds of gypsum.

It may be said, nevertheless, that enough of the beds persist for fairly long distances without material change of character to permit accurate correlation between separate exposures.

LITHOLOGY IN LA PLATA DISTRICT

The uppermost Hermosa beds crop out not far from the center of the dome, along the bed and lower valley walls of the La Plata River and extend up Lewis Creek a little more than a mile (pl. 2). The relations are obscured in most places by the poor exposures and by sills and crosscutting bodies of porphyry. A thickness of somewhat less than 500 feet is exposed in this area. The formation here consists in large part of more or less highly silicified mudstone and sandstone indistinguishable from much of that in the overlying Rico and Cutler formations, but two or three beds of light-gray limestone, which have a maximum thickness of about 5 feet and contain characteristic Hermosa fossils, are exposed in several places along Lewis Creek. According to R. D. McCausland, who made a careful study of the Rico and Hermosa rocks in connection with the development of the Ashland-Ten Broeck vein by the Brawner tunnel, a bed of limestone 20 feet or more in thickness was formerly exposed in an open cut on the south bank of Lewis Creek, about 1,800 feet above its mouth,[10] but most of this exposure was covered over in 1935, and only about 3 feet of limestone could be seen. Many of the limestone beds are surprisingly free from alteration considering the marked silicification of other beds in the section, and in at least one place on the road up Lewis Creek determinable fossils occur in a limestone bed at its contact with the top of a porphyry sill.

The highest fossiliferous horizon was mapped as the top of the formation, but at many places where no exposures of fossiliferous beds were found, the top of the formation was taken to lie just above a thick bed of arkosic sandstone similar to that which occurs near the top of the Hermosa along the Animas River (bed 2 of section on page 10).

A diamond-drill hole that was sunk in search of ore at the mouth of Madden Creek in 1913–14 gives additional information as to the character of the upper part of the Hermosa formation. The complete core from this hole is on display in the Colorado Museum of Natural History at Denver. It was not studied in detail by the writer, but the exhibit is accompanied by a log and correlation prepared by R. C. Hills, who was responsible for the boring. This log and the original driller's log, the latter having kindly been lent to the Geological Survey by the museum, were checked against the core and appear to be approximately correct. The writer has taken the liberty, however, of substituting the term "mudstone and shale" for "schists," as recorded in the logs.

The "quartzites" noted in this log are largely silicified sandstones and grits, although they doubtless include some metamorphosed mudstones and siltstones. Most of the mudstones and shales recorded are mottled in color, more or less thoroughly silicified, and similar in most respects to the same rocks where seen in surface exposures. The "limestone" probably includes beds that once were limy shale, but much of it consists of

[8] Cross, Whitman, and Spencer, A. C., Geology of the Rico Mountains, Colo.: U. S. Geol. Survey 21st Ann. Rept. pt. 2, p. 48, 1900.

[9] Cross, Whitman, and Spencer, A. C., idem, pp. 48–59.

[10] McCausland, R. D., personal communication.

Log of diamond-drill hole at mouth of Madden Creek

[Formation names indicate probable approximate correlation]

	Thickness (feet)	Depth (feet)
Cutler formation:		
Fractured quartzite	70	70
Variegated mudstone, shale, and quartzite	140	210
Gray to mottled, fine-grained quartzite	180	390
Variegated mudstone and shale with 33-foot bed of quartzite near top	208	860
Porphyry	335	1, 195
Rico formation:		
Mudstone, shale, and quartzite	168	1, 363
Porphyry	42	1, 405
Quartzite, partly coarse grained	23	1, 428
Impure limestone	1	1, 429
Dark quartzite with some shale and mudstone	26	1, 455
Hermosa formation:		
Gray quartzite and shale	18	1, 473
Impure limestone	8	1, 481
Shale, mudstone, and impure limestone	13	1, 494
Porphyry	11	1, 505
Gray quartzite, with a little shale at top and bottom	69	1, 574
Sandy limestone, with 1 foot of pink quartzite and a little shale	47	1, 621
Dark shale and mudstone	15	1, 636
Sandy limestone	11	1, 647
Shale, mudstone, and quartzite, with a little coarse pink standstone	44	1, 691
Sandy limestone, with several 1-foot to 5-foot beds of shale	63	1, 754
Shale, mudstone, and quartzite	18	1, 772
Variegated impure limestone	48	1, 820
Shale and mudstone, with some quartzite	74	1, 894
Porphyry	92	1, 986
Quartzite	20	2, 006

marble and represents true limestone. Whether or not the correlations are correct, the log shows clearly that a part at least of the district is underlain by more limestone than is anywhere exposed on the surface, and by even more than is known to occur in the type section of the Hermosa.

PERMIAN SYSTEM

RICO FORMATION

CHARACTER AND DISTRIBUTION

The Rico formation, named for the nearby mining camp of Rico, where a typical section of it is exposed,[11] lies between the Hermosa and Cutler formations and is about 300 feet thick. It is made up chiefly of dull-red, maroon, or chocolate-colored sandstones, arkoses, and conglomerates and includes a minor proportion of interbedded shales and sandy or shaly fossiliferous limestones. In many respects it is transitional between the Hermosa and Cutler beds, but it resembles the Cutler more closely than the Hermosa. The top of the Rico at the type locality is of merely local significance, being defined by the highest known occurrence of Rico fossils and not by any recognizable lithologic or stratigraphic break. The base of the Rico was taken to lie just above the highest beds that were found to contain Hermosa fossils. Exposures of the formation are poor, however, in most places, many of its beds are more or less thoroughly silicified, and the occurrence of fossils is decidedly discontinuous, so that the boundaries as drawn on plate 2 are based on only a few actually determined points with interpolations that conform to known structural relations.

There is much uncertainty among paleontologists and stratigraphers as to the true character and age of the Rico, but for present purposes the formation is here classified as Permian, in accordance with previous Geological Survey reports on this area. The rocks mapped as Rico on plate 2 locally form a readily recognizable lithologic unit, characterized by red colors and by thin beds of impure limestone that contain a more or less characteristic assemblage of fossil forms. Recognition of this unit has been of much value in working out the structure of the La Plata dome.

There are three comparatively small exposures of the Rico within the district here described. One of them is on Clear Creek and is indicated in the northeast corner of plate 2; this exposure was not examined during the present investigation. All but the lowest beds of the formation are exposed along Junction Creek and Flagler Fork, and its full thickness is present above the Hermosa outcrops on the La Plata River and Lewis Creek.

LITHOLOGY

The following section, measured in the first gulch south of Basin Creek on the west side of the La Plata River, gives the best obtainable picture of the character of the Rico in the central part of the district. It is shown diagrammatically in figure 2. All the rocks are metamorphosed to some extent, and several beds that are normally red are brown here.

Section 1 of Rico formation in first gulch south of Basin Creek, west of La Plata River

[Measured by E. B. Eckel]

	Feet
1. Shale, red, limy, containing a few fossils, and capped by a thin layer of impure, richly fossiliferous limestone	2
2. Shale, red and gray, with a few limetone nodules. Beds are more limy and more massive in upper half. Medium-grained sandstone forms an 11-foot bed 50 feet below the top and a 6-foot bed in lower half	126
3. Sandstone, gray to brown, coarse, arkosic	23
4. Porphyry, sill-like at base, upper contact vertical	112
5. Sandstone, brown, coarse, arkosic	19
6. Shale, red to brown, sandy, with a 4-foot bed of coarse sandstone near the middle	20
7. Mudstone, red to brown, sandy	28
8. Sandstone, brown to red, medium-grained to coarse-grained, arkosic. Several shaly beds from 1 foot to 4 feet thick in lower 25 feet	73
9. Poryhyry sill, base unexposed, local structural relations indicate that sill is almost certainly underlain by Hermosa formation	190
Total thickness exclusive of porphyry	291

[11] Cross, Whitman, and Spencer, A. C., Geology of the Rico Mountains, Colo.: U. S. Geol. Survey 21st Ann. Rept., pt. 2, pp. 59–66, 1900.

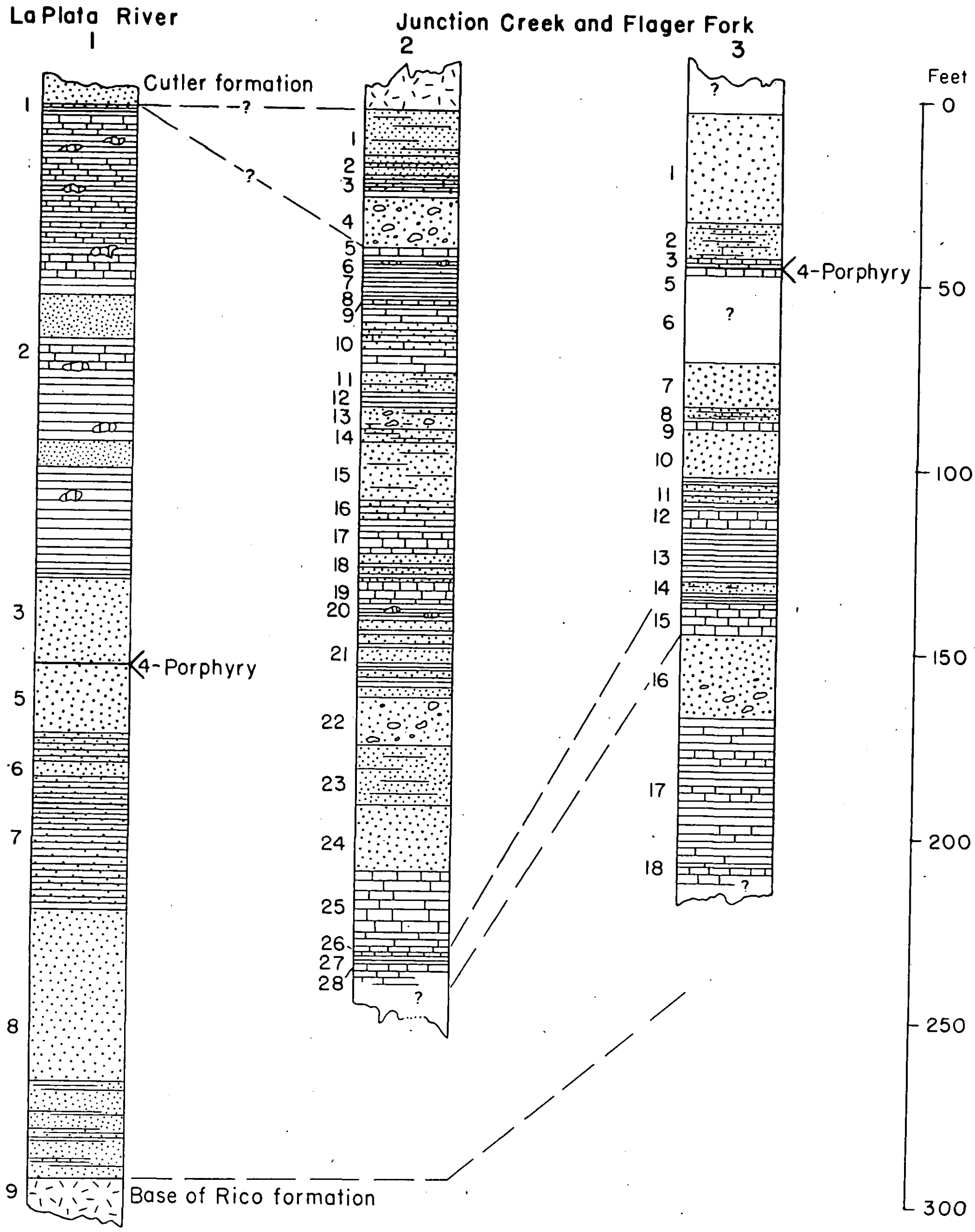

FIGURE 2.—Sections of Rico formation in La Plata district, showing tentative correlations.

The only other place in the central part of the district where the Rico is even moderately well exposed is along Amethyst Creek, one of the larger tributaries to Lewis Creek. Here the base is not exposed, being located in plate 2 by projection from other places. The beds assigned to the Rico are 275 to 300 feet in total thickness and do not differ materially in character from those described in the section above. About 170 feet above the base there is a 10-foot bed of red shaly limestone containing abundant Rico fossils of white calcite. The uppermost bed, about 15 feet thick, consists of red shale that becomes increasingly limy toward the top. At the top of this bed is a 3-inch layer of light-gray impure limestone which contains abundant fossil fragments and is similar to the layer that marks the top of the formation in the section given above. The limy shale is underlain by a 10-foot bed of conglomerate characterized by the presence of many large pebbles. This bed is entirely similar to the conglomerate beds in the overlying Cutler formation.

The top of the Hermosa formation and the lowermost beds of the Rico do not appear to be exposed along Junction Creek and Flagler Fork. The incomplete sections described below and shown diagrammatically in figure 2 indicate the character of the upper Rico beds in the two most complete exposures. Section 2 was measured in the cliffs west of Junction Creek, 2,000 feet south of Flagler Fork; section 3 is a composite of several exposures along Flager Fork and above Gaines Gulch.

Section 2 of upper part of Rico formation on west side of Junction Creek, 2,000 feet south of Flagler Fork

[Measured by E. B. Eckel and F. W. Galbraith]

	Feet
Top of section.	
Diorite-monzonite porphyry sill.	
Rico formation:	
1. Sandstone, dull purplish-red, shaly, micaceous	13
2. Sandstone, massive, micaceous, in two layers separated by a 1-foot bed of nodular limestone	5
3. Shale, red, sandy, micaceous	6
4. Arkose, fine-grained to medium-grained, cross-bedded, streaked in maroon and white. Contains a few quartz pebbles. This bed may possibly represent the base of the Cutler formation	14
5. Limestone, dull maroon, shaly, and somewhat nodular, unfossiliferous	2½
6. Poorly exposed, probably dull-red sandy shale with limy nodules	3
7. Mudstone, dull red, sandy, micaceous, with thin shaly partings	5
8. Shale, dull red, micaceous, fissile	3
9. Limestone, dull maroon, massive, unfossiliferous	½
10. Mudstone, dull red, micaceous, limy sandy in middle 5 feet	19
11. Arkose, white to gray, fine-grained, micaceous, cross-bedded, with a few thin shaly partings	5
12. Mudstone like bed 10 but not limy	4
13. Arkose, light gray, fine-grained to medium-grained, with streaks and lenses of dark-maroon sandy shale. Contains several thin lenses of conglomerate with shale and chert pebbles up to 1 inch in diameter	6½
14. Sandstone, maroon to dark-grey, shaly, micaceous, poorly consolidated	3½
15. Arkose, like bed 13	16
16. Shale, dull-maroon, very sandy, micaceous, limy	8
17. Limestone, dull-maroon, shaly near base and unfossiliferous throughout	6
18. Sandstone, light-colored, micaceous, alternating with dull-maroon sandy shale in beds 6 inches to 2 feet thick	8
19. Limestone, dull-maroon to blue-gray, somewhat nodular, in 2 or 3 massive irregular beds. Apparently fossiliferous, but no determinable fossils were obtained	5½
20. Shale, dull-maroon to dark-brown, micaceous, with many limy nodules	4½
21. Sandstone and shale like bed 18. Beds range up to 4 feet in thickness. A 6-inch to 18-inch bed of coarse arkose, sparingly fossiliferous, and containing many flakes of green shale, occurs 10½ feet below top	21
22. Arkose, massive, light-gray, poorly cross-bedded, medium coarse. Contains a few pebbles up to 3 inches diameter	13
23. Sandstone, dull-maroon, micaeous, somewhat shaly, shabby	16
24. Arkose, fine-grained to medium-grained. Massive when fresh but weathers slabby	18
25. Limestone, like bed 19	20½
26. Limestone, impure, gray, sparingly fossiliferous	2
27. Mudstone, red, micaceous	2½
28. Limestone like bed 26, exposed thickness	2
Lower beds not exposed.	
Total thickness exposed up to base of porphyry sill	233

Section 3 of lower part of Rico formation along Flagler Fork and above Gaines Gulch

[Measured by A. C. Spencer]

	Feet
Top of section.	
1. Arkose in alternating red and gray beds, with layers of finer sandstone	30
2. Sandstone, micaceous, shaly, with discontinuous layers of limy mudstone	10
3. Mudstone, limy, grading upward to earthy limestone with sparse fossil fragments	2
4. Diorite-monzonite porphyry sill, about	50
5. Limestone, earthy	2
6. Covered interval	23
7. Arkose, gray	12
8. Sandstone, shaly	4
9. Limestone, earthy, unfossiliferous	2½
10. Arkose, gray, flaggy, with some red fine-grained sandstone in upper 8 feet	13
11. Shale, silvery-gray, and red micaceous thin-bedded sandstone	9
12. Limestone, gray, earthy, unfossiliferous	5
13. Shale, red, micaceous, grading downward into lead-gray shale	14
14. Sandstone, limy; forms a definite ledge	3½
15. Shale, 4 feet, underlain by 7 feet of dense blue limestone in five layers. Exposed below falls above road crossing. These beds, though they contain no fossils, are probably to be correlated with the fossiliferous gray limestone exposed near mouth of Flagler Fork (base of section 2)	11
16. Arkose, massive, gray, and conglomerate, with one parting of fine-grained micaceous sandstone	23
17. Shale, black, limy, with layers of blocky, dense, black limestone. Poorly exposed; thickness estimated	40
18. Limestone, black, platy, with abundant crinoid stems; exposed thickness	3
Lower beds not exposed.	
Total thickness exposed, exclusive of porphyry sill	207

Comparison of the overlapping parts of these sections, and of both of them with the above-described Rico section near the La Plata River, brings out strongly the marked and rapid changes in lithology that characterize the Rico formation wherever it is known. Beds 26–28 of section 2 are tentatively correlated with beds 14 and 15 of section 3. If this correlation is correct, the total thickness measured is 259 to 297 feet, depending on whether the top of the Rico is placed at the base of the porphyry sill in section 2 or 38 feet below it. This sill clearly cuts across the beds at a slight angle and rises toward the southwest, but because of the uncertainties as to the position of the top of the Rico the sill is represented in plate 2 as marking the contact between it and the Cutler formation. Several layers of dark-gray to black shale containing abundant Rico fossils are exposed along the Junction Creek road near the mouth of Flagler Fork. No such accumulation of fossils was found at the places where the sections were measured, but bed 15 of section 2 above is probably the stratigraphic equivalent of the fossil-bearing beds.

CUTLER FORMATION

CHARACTER AND DISTRIBUTION

The Cutler formation, of Permian age, consists of 1,400 to 2,200 feet of typical redbeds made up of unfossiliferous mudstone, shale, sandstone, grit and conglomerate. It apparently thins rather rapidly toward the west and north. The section along the Animas River was not fully measured, but in the Durango quadrangle, to judge from Cross' manuscript map, the formation is about 2,200 feet thick. Its estimated thickness along Junction Creek is about 1,700 feet. As shown in the section below, it is 1,500 feet thick along the La Plata River, and in the Rico district, 20 miles to the north, it is only about 1,100 feet thick.[12]

Where the rocks are not metamorphosed the alternations of shaly and sandy beds generally produce step like topographic forms, made up of gentle slopes alternating with cliffs or steep slopes. In the central part of the district, where the rocks are metamorphosed and almost equally hard and durable, the slopes are more uniform and are commonly steep.

The Cutler formation is underlain by the fossiliferous Rico formation and overlain by the Dolores. It has the broadest distribution of any of the sedimentary formations in the La Plata district, being almost continuously exposed in the central and eastern parts of the district (pl. 2), except for its interruptions by many bodies of intrusive igneous rock. In this area it is bounded by the overlying Dolores except in the northeastern corner of the district, where the Cutler extends far to the north in the adjacent Rico and Engineer Mountain quadrangles.[13] Two comparatively small inliers of the Cutler are exposed along the East Mancos River and Bear Creek in places where the Dolores formation has been removed by erosion.

As explained above, the contact between the Rico and Cutler formations is arbitrarily placed at the top of the highest fossiliferous horizon. The beds now known as Cutler were included in the Dolores by Cross, although he recognized a marked lithologic difference between the upper and lower parts of the Dolores and foresaw the possibility of subdivision in the future.[14]

In the field work on which this report is based, the Dolores-Cutler contact was commonly drawn at the base of the limestone conglomerate and associated gray flaggy sandstone which characterize the lower Dolores. In some places, however, the top of the uppermost conglomerate of the Cutler was mapped as the base of the Dolores. According to Burbank,[15] the base of the Dolores in the San Miguel valley is in many places marked by a conglomerate with pebbles of quartz and chert or by a coarse crumbly grit, composed mainly of quartz. As shown by exposures at Ouray where there is an angular unconformity between the two formations, this bed belongs to the Dolores and not to the Cutler, although ordinarily it somewhat resembles the Cutler, especially where it is crumbly or ironstained. This bed attains a thickness of 30 feet in the San Miguel valley. In the La Plata district it was not recognized but may well be present at least locally. Because of the uncertainty regarding the position of the base of the Dolores, the boundary as shown on plate 2 may range stratigraphically through as much as 100 feet.

Section of Cutler formation on ridge east of Babcock Peak

[Measured by E. B. Eckel]

	Feet
Top of section.	
Dolores formation.	
Porphyry sill	193
Cutler formation:	
1. Sandstone, red to gray, coarse-grained, arkosic, with a few pebbles and many flakes of red shale. Contains one 3-foot bed of very limy mudstone	114
2. Mudstone, chocolate-brown to brick-red, limy in part	17
3. Sandstone, coarse-grained, arkosic, with a few small-sized to medium-sized pebbles	12
4. Mudstone, dull-red, sandy	43½
5. Conglomerate, light-buff, coarse-grained, arkosic at base, grading upward to dull-red, medium-grained shaly sandstone	51
6. Mudstone, dull-red, sandy	37
7. Sandstone, light-buff, arkosic, containing very few pebbles	47
8. Mudstone and shale, chocolate-brown to dull-red, with a few thin beds of shaly sandstone	135
9. Conglomerate, light-gray, coarse-grained, arkosic	33
10. Porphyry sill	680
11. Conglomerate, very coarse-grained, arkosic, containing many small pebbles, ⅛ inch to 2 inches in diameter	52
12. Mudstone, dark-brown to dark-gray, silicified, containing nodules of contact-metamorphic minerals	32
13. Covered interval	250
14. Sandstone, gray to reddish-purple, streaked, arkosic, containing a few pebbles of quartz and many flakes and fragments of red shale	17
15. Mudstone and shale, dull-red to chocolate-brown, sandy. A few beds are very limy	70
16. Sandstone, light-gray to brownish-gray, coarse-grained, arkosic, containing a few quartz pebbles	29
17. Mudstone, dull-red, in part very sandy and in part very limy	47
18. Sandstone, brown to light-gray, arkosic, containing a few pebbles	19
19. Porphyry sill, about two-thirds exposed	420
20. Sandstone, gray to brown, medium-grained, arkosic, containing no pebbles	11
21. Mudstone, brown to gray, silicified, cut by a vertical porphyry dike 8 feet wide	16
22. Conglomerate, reddish-brown, arkosic	58

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[12] Cross, Whitman, and Spencer, A. C., op. cit. (21st Ann. Rept), p. 68.

[13] Cross, Whitman, and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Rico folio (no. 130), 1905. Cross, Whitman, and Hole, A. D., Description of the Engineer Mountain quadrangle: U. S. Geol. Survey Geol. Atlas, Engineer Mountain folio (no. 171), 1910.

[14] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio), pp. 2–3.

[15] Burbank, W. S., personal communication.

Section of Cutter formation on ridge east of Babcock Peak—Continued.

	Feet
Cutler formation—Continued.	
23. Mudstone, dull-red, limy	18
24. Conglomerate, dull-red, coarse-grained, arkosic	37
25. Mudstone, dull-red to dark-gray and green, partly silicified. Very limy in upper 3 feet	34
26. Porphyry sill	18½
27. Conglomerate, dull-red, coarse-grained, arkosic. (May not be true thickness, some confusion being caused by northeastward-trending porphyry dike.)	81
28. Shale, red, grading upward to red mudstone, which is in part very limy, with several thin beds of shaly sandstone	35
29. Porphyry sill	87
30. Conglomerate, coarse-grained, arkosic, containing many large pebbles	46½
31. Poorly exposed. Rocks largely red shale and red mudstone but include several thin beds of shaly sandstone	70
32. Sandstone, brown, coarse-grained, arkosic, containing a few small pebbles	39
33. Shale, red, sandy, micaceous	16½
34. Porphyry sill	13
35. Mudstone, red, sandy	6
36. Sandstone, greenish-gray to brown, medium-grained to coarse-grained, arkosic; no pebbles	26
37. Shale, red, limy, containing no fossils. Assumed base of Cutler	6
Total thickness of Cutler section, exclusive of porphyry sills	1,505½
Rico formation; red and gray shales containing Rico fossils.	

As exhibited in this section and elsewhere, the Cutler is characterized by a succession of massive grits and conglomerates, which are interbedded with finer-grained sandstone and with shale and mudstone. With good exposures some strata could undoubtedly be traced for long distances, but as most of the beds are discontinuous and as the relations are obscured in most places by igneous rocks, by vegetation, or by talus, no subdivision of the Cutler can be made.

Dull-red and maroon colors prevail in the fresh rocks, though some beds are brown or greenish gray. In general there is a tendency toward a gradation upward from dull red near the base toward the brighter reds of the overlying Dolores. No beds of true limestone are known, but most of the shaly beds are limy, and in many places the lime carbonate is segregated into nodular masses of relatively pure limestone. Nearly all the beds are micaceous.

Grits, sandstones, and conglomerates are more abundant in the lower half of the formation, but there are two or more rather persistent layers near the top. One of them is immediately beneath the Dolores in places, but elsewhere the highest conglomeratic layer is 50 to 75 feet below the typical Dolores beds. The grits and conglomerates occur in massive beds up to 80 feet in thickness, but most of them are less than 50 feet thick. Being generally rich in pink feldspar and white quartz, they are lighter colored than the other beds. Some layers are gray or pink, but most of the grits is characterized by irregular streaks of red and white. Pebbles are scattered through all of them and are very abundant in some of the conglomeratic beds. Most of the pebbles are less than 3 inches in diameter, and most of them consist of quartzite or of granitic rocks, though a few are of limestone. Cross[16] notes the presence of dull, altered porphyry pebbles, but none were seen by the writer.

PALEONTOLOGY OF THE LEADVILLE, HERMOSA, AND RICO FORMATIONS

By James Steele Williams

Invertebrate fossils were collected in the course of the present study from three formations—the Leadville limestone, the Hermosa formation, and the Rico formation. Only the last two were recognized in the La Plata quadrangle itself. Because many of the beds are there highly metamorphosed and unfossiliferous, unmetamorphosed beds were studied, and a section of them measured, along the Animas River in the Durango quadrangle, which adjoins the La Plata quadrangle on the east. The section was studied in order to distinguish, if possible, faunal or lithologic zones or sequences that would enable the formations, and perhaps even zones within formations, to be identified in the metamorphosed rocks within the La Plata district. Unmetamorphosed or slightly metamorphosed beds belonging to the Rico formation also were studied along Junction Creek in the Durango quadrangle.

The identifications of the species were made in 1941, and changes in species names made since that date are not shown in this report.

COLLECTIONS FROM THE LEADVILLE LIMESTONE

Several collections were made from the Leadville limestone along the Animas River, in an effort to locate the Mississippian-Pennsylvanian contact in the section measured. The highest collection stratigraphically that was recognized as Leadville came from within 15 or 20 feet of the top of a series of limestone beds. All these beds are considered to be pre-Pennsylvanian, and the Mississippian-Pennsylvanian contact is placed at the top of the highest one. Two of the collections made from the Leadville limestone are described below.

Collection 8563.—This collection is from a bed about 15 to 20 feet below the top of the Leadville limestone, in the section measured along the Animas River. It is the highest collection made in the Leadville.

The locality is about 13 miles northeast of Durango, along the west side of the Animas River, in NW¼NW¼ sec. 25, T. 37 N., R. 9 W. The fossils were taken from the upper 10 feet of a 35-foot bed of tan crystalline limestone, which is cherty near the base. This limestone is exposed about 500 feet north of Pinkerton Hot Springs, on the west side of the highway, east of and about 60 feet vertically below the railroad track.

[16] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio), p. 3.

The collection was made on June 25, 1935, by J. S. Williams, E. B. Eckel, and F. W. Galbraith.

The following species were identified:

Schuchertella? sp. indet., fragment
Cranaena subelliptica hardingensis Girty?
Spirifer centronatus Winchell var. A

This collection is clearly Mississippian and probably of the same age as the Madison limestone.

Collection 8578.—This collection came from a bed of light tannish-gray crystalline limestone, about 80 feet below the top of the Leadville limestone. The locality is on the west side of the Animas River, about 13½ miles northeast of Durango and about ¾ mile north of Pinkerton Hot Springs at the top of the cliffs along the west side of the Durango-Silverton highway, due west of Baker Bridge over the Animas River. Collected by J. S. Williams, E. B. Eckel, and F. W. Galbraith, July 2, 1936.

The only two specimens collected were identified as *Schuchertella?* of *S. inaequalis* (Hall) and "*Productus*" (*Linoproductus*) sp. indet. Taken by itself, the collection clearly indicates post-Devonian age and suggests Mississippian, but the specimens are not complete enough to be positively identified as of Mississippian age. The stratigraphic position of the collection, being below that of collection 8563, makes it certainly Mississippian or older.

COLLECTIONS FROM THE HERMOSA FORMATION

Collections from the Hermosa formation were made along the Animas River in the Durango quadrangle, and along Lewis Creek within the La Plata quadrangle.

SECTION ALONG THE ANIMAS RIVER

Ten collections were made from beds described in the measured section along the Animas River. Four other collections were made from exposures along the Animas Valley that were not in the direct course of the section, but the stratigraphic positions of these additional collection can be estimated rather closely. The collections from the measured section are located in the description of the section on pages 10–11 of this report, and they are discussed in stratigraphic order below.

Collection 8575.—This collection is from the highest zone in the Hermosa, bed 1 of the section.

The locality is along the east side of Animas River, about 8 miles northeast of Durango and about 1¼ miles due east of Trimble, in SW¼NE¼ sec. 14, T. 36 N., R. 9 W., 470 feet (by hand level) above the road, in a series of shaly limestones and calcareous shales which is 18 feet thick. The collection was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on July 29, 1935.

The species identified were:

Campophyllum? sp. indet.
Crinoid columnals
Productus (*Dictyoclostus*) *hermosanus* Girty

Collection 8574.—This collection is from float. It is thought to have come from the same beds as collection 8575 and thus is probably from the uppermost 26 feet of the Hermosa.

The locality is the same as that of collection 8575 except it is 450 feet (by hand level) above the road, in float from limestone beds exposed above a series consisting mainly of greenish-gray sandstones and brown grits, but including at least one 30-inch layer of maroon mudstone. Collected by J. S. Williams, E. B. Eckel, and F. W. Galbraith, on June 29, 1935.

The collection consists of the following forms:

Lophophyllum? sp. indet.
Crinoid columnals
Euconospira sp. indet., fragment

Collection 8573.—This collection is from float that is thought to have come from bed 8 of the section along Animas River. This bed is about 170 feet below the top of the Hermosa formation.

The locality is the same as that of collection 8575, except that it is 310 feet (by hand level) above the road, in a 25-foot bed of green micaceous sandstone, which stands out as a prominent bench and which is 50 feet above a prominent 50-foot bed of white quartz and feldspar grit. The collection was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on June 29, 1935.

The collection contains the following:

Rhombopora? sp. indet.
Crinoid columnals
Composita sp. indet., young

Collection 8572.—This collection came from bed 17 of the section along Animas River, about 316 feet stratigraphically below the top of the Hermosa formation.

The locality is the same as that of collection 8575, except that it is only 200 feet above the road (by hand level). It is from 2-inch to 3-inch limestone beds, in an 11-foot zone of green shaly sandstone, stained pink immediately above a prominent bench-forming bed of sandy grit, below which is a 40-foot brush-covered interval. The collection was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on June 29, 1935.

Forms identified were:

Fenestrellina? sp. indet.
"*Productus*" (*Juresania*) *nebraskensis* Owen
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten
Spirifer (*Neospirifer*) *dunbari* (King)
Punctospirifer kentuckyensis (Shumard)
Cleiothyridina orbicularis (McChesney)
Composita subtilita (Hall)
Lima retifera Shumard

Collection 8571.—This collection came from bed 25 of the section along Animas River stratigraphically about 475 feet below the top of the Hermosa formation.

The locality is the same as that of collection 8575 except that collection 8571 came from a 26-foot series of hard and soft, shaly and micaceous black limestones exposed 50 feet above the road, at a place where 25-foot cliffs of grit are exposed along the road. The collection was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on June 29, 1935.

The following forms were identified:

Fenestrellina? sp. indet.
Crinoid columnals and plates
Derbya? of *D. crassa* (Meek and Hayden)
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten
"*Productus*" (*Linoproductus?*) *platyumbonus* (Dunbar and Condra)?, incomplete specimen
Spirifer occidentalis (Girty)
Spirifer (*Neospirifer*) *dunbari* (King)
Punctospirifer kentuckyensis (Shumard)
Composita subtilita (Hall)
Astartella? sp. indet.
Aviculopecten? sp. indet.

Collection 8568.—This collection came from bed 31 of the section along the Animas River, about 630 feet stratigraphically below the top of the Hermosa formation. According to the map, the locality is at an altitude of about 8,000 feet in the canyon shown on the topographic sheet as having its mouth in the NW¼-NW¼ sec. 36, T. 37 N., R. 9 W., about 11 miles northeast of Durango and 1.7 miles south of Pinkerton Hot Springs. The fossils came from an 8-foot bed of hard neutral-gray limestone, below greenish-stained and reddish-stained grits and shales, about 50 feet below the bottom of the second "box canyon" tributary to this canyon. The collection was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on June 26, 1935.

The collection is a small one. It includes the following forms:

Crinoid columnals and plates
"*Productus*" (*Dictyoclostus*) *hermosanus* Girty
Composita subtilita (Hall)
Spirifer sp. A

Collection 8567.—This collection is from bed 35 of the section along Animas River (p. 10) about 700 feet stratigraphically below the top of the Hermosa formation.

The locality is nearly the same as that of collection 8568 but farther down the canyon in a series of thin-bedded light-blue limestones with shale partings, directly above a thick zone of black shale and about 100 feet below the mouth of the second "box canyon" in this canyon. The collection was made on June 26, 1935, by J. S. Williams, E. B. Eckel, and F. W. Galbraith.

The following forms were identified:

Fenestrellinoid bryozoan
"*Productus*" (*Dictyoclostus*) *hermosanus* Girty
"*Productus*" (*Juresania*) *nebraskensis* Owen
"*Productus*" (*Linoproductus*) *platyumbonus* (Dunbar and Condra)
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten var. A
Squamularia perplexa (McChesney)
Spirifer (*Neospirifer?*) sp. indet., fragment
Spirifer sp. A.
Cleiothyridina orbicularis (McChesney)
Composita subtilita ovata Mather
Bellerophontid gastropod fragment

Collection 8566.—This collection is from bed 57 of the section along Animas River described on page 10 about 1,350 feet stratigraphically below the top and about 1,400 feet above the base, of the Hermosa formation.

The locality is the same as that of collection 8568 but in a muddy dark-blue limestone bed in place at the top of the black-shale zone, about 660 feet stratigraphically below collection 8567. The collection was made on June 26, 1935, by J. S. Williams, E. B. Eckel, and F. W. Galbraith.

The following forms were identified:

Lophophyllum? sp. indet.
"*Productus*" (*Dictyoclostus*) *hermosanus* Girty
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten var. A
Spirifer sp. A
Composita sp. indet., immature individual

Collection 8565.—This collection came from float probably derived from bed 58 of the section along Animas River (p. 10), 1,360 feet stratigraphically below the top of the Hermosa formation.

The locality may be described in the same terms as that of collection 8568, but the fossils were in float from a bed of black shale about 665 feet stratigraphically lower than collection 8567. The collection was made on June 26, 1935, by J. S. Williams, E. B. Eckel, and F. W. Galbraith.

The following forms were identified:

Bryozoans, several species
Cleiothyridina orbicularis (McChesney)
Spirifer sp. A
Gastropod fragment, possibly *Worthenia* sp. indet.

Collection 8564.—This collection came from float probably derived from bed 61 (p. 10), which is about 1,450 feet stratigraphically below the top, and 1,300 feet above the base, of the Hermosa formation.

The locality is the same as that of collection 8568. The fossils are in float from a series of thin limestones and black shales in a zone consisting predominantly of shale, exposed upstream from the first "box canyon" above the mouth of the main canyon. The collection was made on June 26, 1935, by J. S. Williams, E. B. Eckel, and F. W. Galbraith.

The forms identified are:

Bryozoan, probably *Rhombopora*
"*Productus*" (*Dictyoclostus*) sp. indet., fragments
"*Productus*" (*Linoproductus*) *prattenianus*? fragments Norwood and Pratten
Squamularia perplexa (McChesney)
Spirifer sp. A

Spiriferina? sp. indet.
Cleiothyridina orbicularis (McChesney)
Composita sp. indet., immature individual

Four collections from two areas not in the direct course of the section measured along Animas River are nevertheless from localities close enough to the course of this section to be rather definitely assignable to zones within it. One of these collections is from a locality on Buck Hollow, a tributary to Hermosa Creek. The remaining three collections are from a single locality, the Knapp ranch, on the west side of Animas River, about three-quarters of a mile below Hermosa Creek.

Collection 8570.—This collection is from Buck Hollow. It is from a bed regarded as approximately equivalent to bed 31 of the Animas River section (p. 10) and therefore about 630 feet stratigraphically below the top of the Hermosa.

The locality is about 11 miles due north of Durango and 1¾ miles northwest of Hermosa, in beds exposed on a flat shown on the map as about 7,400 feet altitude, almost due north of the end of the road up Buck Hollow, and about 50 feet below the top of the first steep grade up Buck Hollow trail west of Hermosa Creek. The fossils came from a thin bed of limestone above a bed of massive grit 150 to 200 feet thick and below an unexposed zone that is probably of shale. The collection was made by J. S. Williams and F. W. Galbraith on June 28, 1935.

The forms identified in the collection are as follows:

Fenestrellinoid bryozoan
Chonetes (*Mesolobus*) *mesolobus euampygus* Girty
"*Productus*" (*Dictyoclostus*) *hermosanus* Girty
"*Productus*" (*Juresania*) *nebraskensis* Owen
"*Productus*" (*Linoproductus*) *platyumbonus* (Dunbar and Condra)?
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten
Spirifer (*Neospirifer*) *dunbari* (King) n. var.
Composita subtilita (Hall)
Aviculopecten? sp. indet., fragment

The three collections from the Knapp ranch are numbered 8579, 8583, and 8593. As they are from the same rather circumscribed outcrops and from a small thickness of beds (most of the speciments in all the collections having come from the same bed), they are consolidated here. The horizon is believed to be that of bed 58 in the section along Animas River, which is about 1,360 feet below the top and about 1,400 feet above the base of the Hermosa formation.

The locality is on the west side of the Animas River, about 9 miles northeast of Durango and about three-quarters of a mile southwest of the place where the Durango-Silverton highway crosses Hermosa Creek, about a quarter of a mile southwest of a house on A. E. Knapps' farm in SE¼SW¼ sec. 3, T. 36 N., R. 9 W. The fossils are from dark-gray limestones in a shale zone, in an east-facing cliff on the west side of a small tributary of Hermosa Creek.

Collection 8579 was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on July 3, 1935. Collection 8583 was made by J. S. Williams on July 12, 1935, and collection 8593 by E. B. Eckel and A. C. Spencer in 1936.

The forms in the three collections are listed below:

Fusulina n. sp. (identified by L. G. Henbest)
Campophyllum? sp. indet.
Fenestrellinoid bryozoan
Crinoid columnals and plates
Chonetes granulifer Owen?
"*Productus*" (*Dictyoclostus*) cf. *P. hermosanus* Girty
"*Productus*" (*Echinoconchus*) *semipunctatus* Shepard?
"*Productus*" (*Echinoconchus*) sp. indet., fragment
"*Productus*" (*Juresania*) *nebraskensis* Owen
"*Productus*" (*Juresania?*) sp. indet.
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten var. A
Marginifera wabashensis (Norwood and Pratten)
Rhynchopora magnicosta Mather
Squamularia perplexa (McChesney)
Spirifer (*Neospirifer*) *dunbari* (King)
Cleiothyridina orbicularis (McChesney)

The collections made from beds that can be placed in their stratigraphic position in the section measured along the Animas River are either too small, or contain too few diagnostic forms, to allow the Hermosa to be divided into faunal zones that could be used with confidence. Taken collectively, however, they enable one to refer all but the uppermost four or five hundred feet of the formation definitely to a position low in the Pennsylvanian, and they give little reason to suppose that the uppermost beds are younger than lower Pennsylvania. The occurrence of *Spirifer occidentalis* Girty in a collection that came from beds within 475 feet of the top strongly suggests that all beds below this one are of Des Moines age or older. Other species collected in connection with this investigation that suggest a Des Moines age are *Chonetes mesolobus euampygus* Girty, which occurs within 630 feet of the top, and *Fusulina* n. sp., which occurs in beds about the middle of the formation, 1,360 feet from the top. Henbest[17] regards the *Fusulina* as indicating middle Des Moines age. Girty[18] had previously reported the two brachiopod species listed above from the upper Hermosa, but had not stated precisely from which beds they came. Roth[19] has reported *Fusulina meeki* as occurring within 450 feet of the top of the Hermosa along the Animas River, *Fusulina hartvillensis* within 467 feet of the top, and *Prismopora* within 332 feet of the top. All of them suggest Des Moines age. In the absence of forms above these in stratigraphic position suggesting a younger age, the whole of the Hermosa is considered to

[17] Henbest, L. G., memorandum dated March 7, 1941.

[18] Girty, G. H., The Carboniferous formations and faunas of Colorado: U. S. Geol. Survey Prof. Paper 16, 1903.

[19] Roth, Robert, Type section of Hermosa formation, Colorado: Am. Assoc. Petroleum Geologists Bull., vol. 18, No. 7, pp. 944–947, 1934.

be Des Moines. Roth[20] considered the Hermosa to be "not younger than Cherokee." However, the occurrence in our collections of *Marginifera wabashensis* (Norwood and Pratten), *Chonetes mesolubus euampygus* Girty, and *Fusulina* n. sp. suggests, if it does not prove, that the upper part of the Hermosa may be as young as upper Des Moines, possibly as young as the Fort Scott limestone.

LOCALITIES IN THE LA PLATA QUADRANGLE

All the collections from the Hermosa formation in the La Plata quadrangle came from along Lewis Creek below Ashland Gulch. Three collections made along this creek are thought to have come from beds about 100 feet stratigraphically below the top of the Hermosa. These are collections 8587 and 8588. The other collection, 8589, is thought to have come from beds about 200 feet lower.

Collection 8584.—This collection came from a locality about 2 miles north of La Plata, on the road that goes along the north side of Lewis Creek up to the Gold King mine, about half a mile above the place where this road leaves the La Plata River, about 1¼ miles below the mine, and about half a mile below Ashland Gulch. The fossils are from a 1½-foot to 2-foot bed of altered limestone that is cut by a porphyry sill and is exposed along the side of the road at the steepest part of the switch-back where the road goes eastward. The collection was made by J. S. Williams on July 15, 1935.

The forms identified in it are as follows:

Branching bryozoan, probably *Rhombopora*
Crinoid columnals
Derbya? crassa (Meek and Hayden)
"*Productus*" (*Juresania*) cf. *P. ovalis* (Dunbar and Condra)
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten
Spirifer (*Neospirifer*) *dunbari* (King)
Punctospirifer kentuckyensis (Shumard)

Collection 8587.—This collection came from a locality about 2 miles air line northeast of La Plata, on the switch-back road to the Gold King mine, at the switch-back 2,250 feet northeast of the junction of Lewis Creek and the La Plata River. The fossils are from a 5-foot to 10-foot bed of bluish-gray limestone that directly overlies a porphyry sill alongside the road. The collection was made by E. B. Eckel and R. Wheeler on August 11, 1935.

The forms identified are:

Fenestrellinoid bryozoan
Rhombopora? sp. indet.
Crinoid columnals
Derbya? crassa (Meek and Hayden)
"*Productus*" (*Juresania*) sp. indet.
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten? var. A
Punctospirifer kentuckyensis (Shumard)
Astartella sp. indet., fragment
Sevillia? trinucleata (Herrick)

[20] Roth, Robert, op. cit.

Collection 8588.—This collection came from a 10-foot zone of interbedded limestone and limy shale exposed below the road to the Gold King mine, about 2 miles northeast of La Plata and 3,000 feet N. 74° E. of the junction of Lewis Creek and the La Plata River at an altitude of 10,250 feet. The collection was made by E. B. Eckel and R. Wheeler on August 11, 1935.

The species identified are:

"*Productus*" (*Dictyoclostus*) *hermosanus* Girty
"*Productus*" (*Juresania*) cf. *P. ovalis* (Dunbar and Condra)
"*Productus*" (*Linoproductus*) sp. indet., two fragments.
Composita subtilita (Hall)

Collection 8589.—This collection was made in the same general vicinity as collections 8584, 8587, and 8588, but about 200 feet lower stratigraphically. It came from a hard silicified limestone, sometimes covered with water, in the bed of Lewis Creek, at an altitude, as shown by the map of 10,000 feet. The locality is about a mile northeast of La Plata and about 800 feet west of the junction of Ashland Gulch and Lewis Creek. The collection was made by E. B. Eckel in August 1935.

The following forms are identified:

Crinoid columnals
"*Productus*" (*Dictyoclostus*) cf. *P. hermosanus* Girty, fragments
"*Productus*" (*Juresania?*) sp. indet., fragment
"*Productus*" (*Linoproductus*) *prattenianus?*, Norwood and Pratten

Although the collections from beds referred to the Hermosa in the La Plata quadrangle are all definitely of Hermosa facies, only one of them contains a species that definitely restricts it to a Des Moines or older age, the age of the Hermosa in the typical area. This is collection 8587, which contains the trilobite *Sevillia? trinucleata* (Herrick). The geographic and stratigraphic relations between the zone yielding this collection and the beds yielding the other collections reinforce the grounds afforded by general faunal facies and composition for referring all these beds to the Hermosa.

COLLECTIONS FROM THE RICO FORMATION

SECTION ALONG THE ANIMAS RIVER

No fossils were collected from rocks known to be in place in the part of the stratigraphic sequence designated Rico along the Animas River in the Durango quadrangle. Only two collections, both from float, could possibly have come from beds younger than Hermosa. The faunal data are inconclusive, however, and it seems highly probable that some mistake was made in labeling the locality for collection 8577.

Collection 8576.—This collection was made by F. W. Galbraith on June 29, 1935, along the east side of the Animas River, about 1½ miles due east of Trimble and in NE¼NW¼ sec. 14, T. 36 N., R. 9 W. The fossils came from float in an interval without exposures, about 480 feet above the road on a hillside a few feet above beds mapped as Rico. The soil here is reddish and is thought to be underlain by red shale or mudstone. Red mudstones are exposed about 25 feet above.

This collection contains only three species:

"Productus" (Linoproductus) prattenianus Norwood and Pratten
Composita subtilita (Hall)
Myalina, indet. fragment

This assemblage is of no value in distinguishing Rico from Hermosa.

Collection 8577.—According to the records this collection was made by J. S. Williams, E. B. Eckel, and F. W. Galbraith on July 1, 1935, at the same general locality as 8576 but about 1,800 feet above the road, and is supposed to have come from float in and above a thick series of light-red and maroon mudstones and pink and brown arkoses, from a knob probably in the SW¼SW¼ sec. 13, T. 36 N., R. 9W. The locality described would be 1,788 feet stratigraphically above the top of the Hermosa in this section, and the float therefore would have been found presumably above beds in place that are almost certainly Cutler as mapped. As the fossils suggest a Hermosa or Rico fauna—certainly not the unfossiliferous Cutler of southwestern Colorado—it is believed that an error must have been made in labeling.

The forms in this collection are:

"Productus" (Echinoconchus) semipunctatus Shepard
"Productus" (Dictyoclostus) hermosanus Girty
Marginifera? sp. indet.
Spirifer sp. A

BEDS MAPPED AS RICO ALONG JUNCTION CREEK AND ITS TRIBUTARIES

Four collections referred to the Rico formation were made in unmetamorphosed beds along Junction Creek and its tributary, Flagler Fork. None of these collections is from the measured sections 2 and 3 described on page 15, but all are from beds that would be within the limits of these sections.

Collection 8581.—This collection, the oldest of the four, was made at a locality about 12 miles northwest of Durango, on the east side of Flagler Fork of Junction Creek, about 1½ miles above Junction Creek and a few hundred feet below mouth of Gaines Gulch. The fossils are from a 5-foot limestone zone made up of beds 6 to 8 inches thick, below a 12-foot cliff of shaly mudstones and grits exposed at or near the level of the trail. The collection was made by J. S. Williams on July 9, 1935.

The following species have been identified:

"Productus" (Juresania) nebraskensis Owen?
"Productus" (Linoproductus) prattenianus Norwood and Pratten
Spirifer (Neospirifer) dunbari King?
Edmondia gibbosa Swallow
Allorisma terminale Hall

Collection 8595.—This collection, made in 1936 by E. B. Eckel, is from a bed exposed along Flagler Fork of Junction Creek, about 1,500 feet below the mouth of Gaines Gulch. It is from a horizon stratigraphically above that of collection 8581 and below that of 8580.

The following forms were identified:

Fenestrellinoid bryozoan
Rhombopora? sp. indet.
Crinoid columnals
Derbya? cf. *D. crassa* (Meek and Hayden)
"Productus" (Dictyoclostus) sp. indet., fragments
"Productus" (Juresania) cf. *P. symmetricus* McChesney
Productus (Linoproductus) prattenianus Norwood and Pratten
"Productus" (Linoproductus) prattenianus Norwood and Pratten var. C
Sprifer (Neospirifer) dunbari (King)?
Punctospirifer kentuckyensis (Shumard)
Schizodus meekanus Girty
Acanthopecten sp.
Myalina subquadrata Shumard
Myalina sp. indet, crushed. (This may be *M. perattenuata* Meek and Hayden.)

Collection 8580.—This collection came from beds stratigraphically above those that yielded collection 8595. The locality is about 11 miles airline northwest of Durango, on the northeast side of Junction Creek about 200 feet below mouth of Flagler Fork, along a trail about 10 feet above water level. The fossils were in a dark-blue dense limestone in a thin zone of limestone and shale, opposite a prominent sill in redbeds. The collection was made on July 9, 1935, by J. S. Williams.

The forms identified are:

Fenestrellinoid bryozoans
Rhombopora? sp. indet.
Crinoid columnals
Derbya? crassa (Meek and Hayden)
"Productus" (Juresania) cf. *P. symmetricus* McChesney
"Productus" (Linoproductus) prattenianus Norwood and Pratten
"Productus" (Linoproductus) prattenianus Norwood and Pratten var. C
Punctospirifer kentuckyensis (Shumard)
Schizodus cuneatus, Meek?
Schizodus meekanus Girty
Acanthopecten? carboniferus (Stevens)
Pseudomonotis equistriata Beede
Myalina cf. *M. perattenuata* Meek and Hayden
Myalina cf. *M. perniformis* Cox
Myalina subquadrata Shumard

Collection 8594.—This collection is the highest stratigraphically of the four made in the Rico along Junction Creek, but it is lower than any of the beds in section 3 described on page 15. It came from exposures of a single hard calcareous bed on Junction Creek, about 500 feet below the mouth of Flagler Fork and about 300 feet downstream from the locality of collection 8580. The collection was made by E. B. Eckel in 1936.

The forms recognized are as follows:

"Productus" (Dictyoclostus) hermosanus Girty
"Productus" (Dictyoclostus) n. sp. A

"*Productus*" (*Echinoconchus*) *semipunctatus* Shepard, crushed
"*Productus*" (*Jureania*) sp. indet., fragments
"*Productus*" (*Linoproductus*) *platyumbonus* (Dunbar and Condra)?
Spirifer (*Neospirifer*) *dunbari* (King)
Composita subtilita (Hall)
Bellerophontid gastropod

LOCALITIES IN THE LA PLATA QUADRANGLE

Fossils were collected from beds referred to the Rico in two areas in the La Plata quadrangle: along upper Lewis Creek and its tributaries, and along Lucky Strike Gulch, the first gulch south of Basin Creek entering the La Plata River from the west.

Four collections were made in the headwater basin of Lewis Creek. The two largest, 8585 and 8586, were made at a single locality, on Amethyst Creek, the first by J. S. Williams on July 15, 1935, and the second by Williams, E. B. Eckel, and F. W. Galbraith on July 20, 1935. The two collections are combined in the following description:

Collections 8585 and 8586.—The locality that yielded these collections is about 2½ miles airline northeast of La Plata, on Amethyst Creek, which, as shown on the topographic sheet, is the first tributary entering Lewis Creek from the north above Ashland Gulch. It is opposite the lower part of a waterfall on the east side of Amethyst Creek and about 400 feet above its mouth. The fossils were in an olive to maroon limy sandstone, which immediately underlies a maroon micaceous mudstone and overlies red mudstone and grits.

The species identified are as follows:

Branching bryozoa, probably *Rhombopora*
Derbya? cf. *D. crassa* (Meek and Hayden), fragment
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten var. A
"*Productus*" (*Juresania*) *nebraskensis* Owen
Spirifer (*Neospirifer*) sp. indet., fragment
Composita subtilita (Hall)
Edmondia cf. *E. mortonensis* (Geinitz)
Myalina cf. *M. perattenuata* Meek and Hayden
Myalina subquadrata Shumard

Collection 8591.—This collection, made by E. B. Eckel in August 1935, came from beds thought to occupy about the same stratigraphic position as the bed that yielded collections 8585 and 8586. It was made on the south side of Lewis Creek, 1,700 feet airline N. 62½° E. of the junction of Amethyst Creek and Lewis Creek, at a map altitude of 10,900 feet. It contains only crinoid columnals and indeterminate branching bryozoans.

Collection 8592.—This collection, made in August 1935 by E. B. Eckel, came from a 2-foot bed of red, micaceous, sandy and limy shale exposed in the Gold King mine, on the south wall of a drift of level number two, 120 to 165 feet east of the big raise. Its stratigraphic position is thought to be about the same as that of collections 8585, 8586, and 8591.

The forms identified are as follows:

Crinoid columnals
Fenestrellinoid bryozoan
Rhombopora? sp. indet.
Orbiculoidea sp. indet.
Derbya? cf. *D. crassa* (Meek and Hayden), fragment
Composita? sp. indet., immature individuals only
Myalina cf. *M. perattenuata* Meek and Hayden, fragment

Collection 8590.—This collection, made by E. B. Eckel on July 30, 1937, came from a 2-foot bed of red mudstone regarded as being at the top of the Rico formation (see stratigraphic section given on page 13). The locality is at an altitude of 10,025 feet according to the map, in Lucky Strike Gulch, which is the first one entering the La Plata River from the west below the mouth of Basin Creek.

The following forms were recognized:

Indeterminate bryozoa, both fenestrellinoid and branching types
Derbya? cf. *D. crassa* (Meek and Hayden), fragment
"*Productus*" (*Juresania*) *nebraskensis* Owen?
"*Productus*" (*Linoproductus*) *prattenianus* Norwood and Pratten var. B
Composita subtilita (Hall)
Myalina? sp. indet., fragment
Aviculopecten? sp. indet.
Other indeterminate pelecypods, possibly *Edmondia* and *Aviculopecten*

INTERPRETATION OF THE RICO COLLECTIONS

The age of the Rico formation has long been and still remains a matter of disagreement and uncertainty. The advisability of even recognizing the Rico as a formation has been questioned. It seems useful, however, for purposes of mapping and of deciphering structure, to recognize the Rico formation as a lithologic unit, characterized by red or maroon shales, grits, and thin limestone distinct from the typical Hermosa. But it must be borne in mind that this unit as defined in terms of lithology, may vary in stratigraphic position and in age limits from region to region. For this reason, a cautious investigator would feel safer in using a datum other than the Rico for long-distance correlations.

The collections made in connection with this report suggest that the exposures designated as Rico along Junction Creek are either of late Pennsylvanian or of early Permian age. A similar age is suggested, though less strongly, by the collections from upper Lewis Creek. The collections from Lucky Strike Gulch are not distinctive. Few of the invertebrate fossils collected, however, are restricted in range, and some of those that are supposedly restricted have been obtained so seldom, and from so few areas, that it is impossible to be certain that their stratigraphic ranges as published are really established. Only three of the species recognized in the collections suggest that the Rico in the Junction Creek and upper Lewis Creek areas is younger than the Hermosa of the type region. They are *Myalina perattenuata* Meek and Hayden, *Pseudomonotis* *equistriata* Beede, and *Edmondia gibbosa* Swallow. All of them occur in the collections from Junction Creek. Only the first is in the upper Lewis Creek collections.

None of these species, nor all of them together, suffice to determine whether the Rico, as exposed in the areas here considered, is Pennsylvanian or Permian. In other areas, paleontologic or stratigraphic evidence has been regarded as proving that the beds classified there as Rico were at least as young as the typical Wolfcamp beds of Texas and other formations that are of disputed Permian or Carboniferous age. To the writer, however, the evidence afforded by invertebrate fossils has seemed insufficient to justify so definite a reference even in these areas. It consists largely of the occurrence in the Rico strata of a few species of pelecypods that generally have been considered more characteristic of beds correlated with the Wolfcamp than of beds regarded as older.

From the type area of the Rico, *Chonetes mesolobus* Norwood and Pratten and other fossils that are generally considered to be characteristic of Des Moines (lower Pennsylvanian) age were recognized by Dr. G. H. Girty and recorded in the literature as early as 1900.[20a] Subsequently, both Girty and the writer have identified comparable lower Pennsylvanian assemblages in rocks assigned to the Rico in some other areas in Colorado. One might cite other areas, however, in which beds referred to the Rico formation have yielded species or genera that are definitely considered to be of post-Des Moines age, though it is impossible to be certain whether they are as young as Wolfcamp.

Beds exposed at certain localities have often been referred to the Rico, and beds at other localities to the Hermosa, mainly on the basis of the general character of the faunules, those containing a relatively larger proportion of pelecypods being called Rico, and those composed mainly of brachiopods being called Hermosa. But the use of this criterion when applied to isolated exposures and unsupported by species of restricted range, has resulted in misinterpretations. This is true because of the well-known effects of facies influences on the distribution of these classes, especially of the pelecypods, and because similar facies conditions at some time or other existed in both formations. Recognition of the Rico as a formation must be based on its lithologic uniformity and characteristics and on its general stratigraphic position. Beds in isolated exposures that cannot be identified by lithologic composition must, unless very close to definitely placed beds, be correlated with Rico or Hermosa sections on the basis of individual diagnostic species, and not merely on the basis of the general aspect of their faunules. During this investigation, faunas of so-called Hermosa aspect (consisting largely of brachiopods) have been collected above faunas of so-called Rico aspect—consisting largely of pelecypods and other mollusks.

[20a] Spencer, A. C. The sedimentary formations, in Cross, Whitman, and Spencer, A. C., Geology of the Rico Mountains, Colorado: U. S. Geol. Survey 21st Ann. Rept., pt. 2, p. 66, 1900.

JURASSIC (?) AND UPPER TRIASSIC ROCKS

DOLORES FORMATION

The Dolores formation, which lies between the Cutler formation and the Entrada sandstone, is made up of soft redbeds. It can locally be distinguished from the Cutler by the presence of characteristic limestone conglomerates, which contain vertebrate fossils, and by the absence of coarse grits except at the base. As noted on page 16, the position of the Cutler-Dolores contact as mapped during this investigation may range stratigraphically through as much as 100 feet. Furthermore, grit or conglomerate beds that are here included in the topmost part of the Cutler may actually belong to the basal Dolores. In parts of southwestern Colorado an angular unconformity marks this contact, but if the unconformity is present in the La Plata district the angular discordance is too small to have been found.

The formation ranges from about 400 to more than 700 feet in thickness. Along the Animas River it is about 660 feet. According to unpublished detailed field notes made by W. H. Emmons in 1904, the formation is only 440 feet thick along Falls Creek west of Trimble. The section on Junction Creek, described below, shows a thickness of 610 feet. H. S. Gane's unpublished field notes of 1896 contain sections measured near the main forks of Lightner Creek and on Indian Trail Ridge that indicate a total thickness of about 750 feet, but for both sections the thickness was in part estimated. Along the East Mancos River the formation is about 550 feet thick.

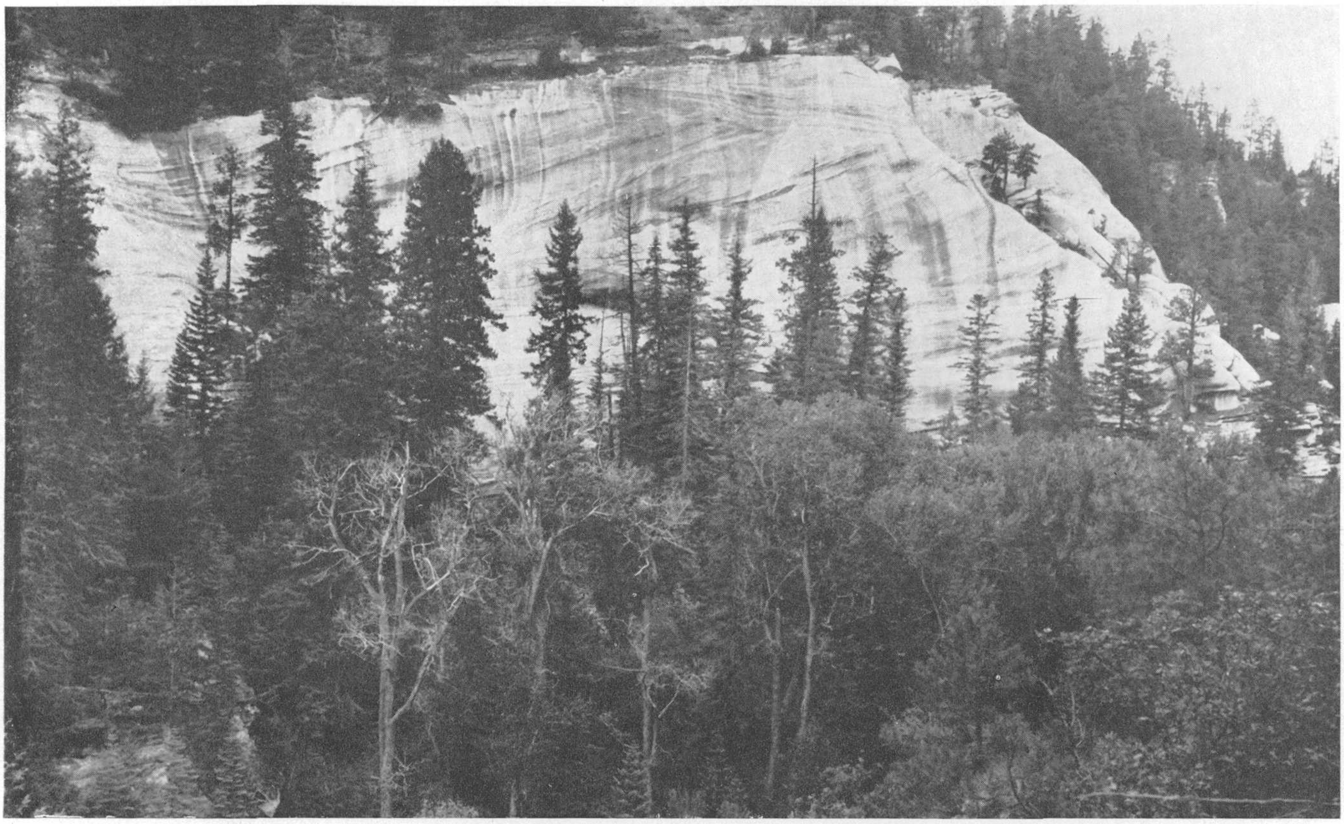
The formation crops out in a belt that nearly encircles the central and northeastern part of the district and that ranges from a few hundred feet to more than a mile in width. Outliers cap Monument Hill, the ridge between Cumberland Mountain and Lewis Mountain, the northwest spur of Baker Peak, and Deadwood Mountain. Small inliers are exposed on the lower East Mancos River, on Bear Sign Creek, and near the head of the West Mancos River.

The Dolores formation is almost perfectly exposed in a cliff on the west side of Junction Creek, 1.3 miles below the mouth of Castle Creek. This exposure, which is shown in plate 3 *B* and somewhat fully described below, may be considered typical of the Dolores formation as it occurs in the La Plata district.

Section of Dolores formation exposed in cliff on Junction Creek 1.3 miles below mouth of Castle Creek

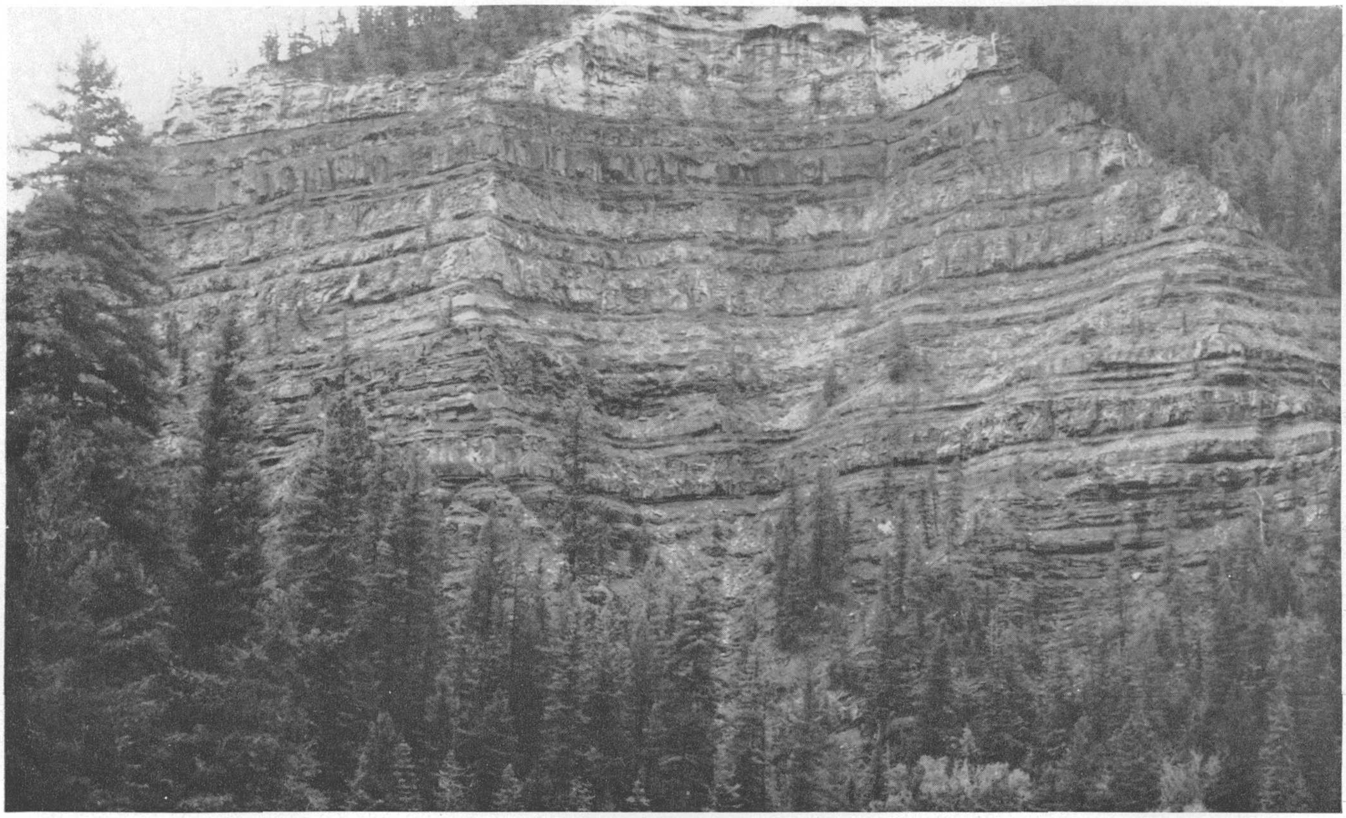
[Measured by E. B. Eckel and F. W. Galbraith]

	Feet
Entrada sandstone.	
Dolores formation:	
1. Mudstone, crumbly, brick-red very shaly	14
2. Mudstone, massive, brick-red	11
3. Mudstone, red, crumbly, shaly, with many nodules of red limestone ¼ to ¾ inch in diameter	10



A. VIEW OF TYPICAL EXPOSURE OF ENTRADA SANDSTONE ON WEST SIDE OF JUNCTION CREEK.

The thin Pony Express limestone member of the Wanakah formation caps the sandstone. This view also shows the character of the vegetation in much of the La Plata district. View 2½ miles below mouth of Castle Creek.



B. VIEW OF DOLORES FORMATION ON WEST SIDE OF JUNCTION CREEK

The white cliff at the top is Entrada sandstone. This is the best exposed section of the Dolores in the district and is described in the text. View 1.3 miles below mouth of Castle Creek.

Section of Dolores formation exposed in cliff on Junction Creek 1.3 miles below mouth of Castle Creek—Continued

	Feet
Dolores formation—Continued.	
4. Mudstone, massive, brick red	17½
5. Mudstone, mostly shaly and like bed 3, but in part more or less massive	15
6. Mudstone, massive, brick-red	25
7. Mudstone, shaly, like bed 3	5
8. Mudstone, massive, brick-red, in two thick layers, separated by a 3-foot bed of shale that weathers easily	50
9. Mudstone, dull-maroon to brick-red, very crumbly, in beds 3 inches to 8 feet thick. A 3-foot to 6-foot bed of massive, resistant mudstone occurs 15 feet above base	66
10. Arkose, coarse-grained, lenticular, grading within short distances to fine-grained arkose	½
11. Mudstone, massive, brick-red	5
12. Mudstone and shale, brick-red, sandy, micaceous, in alternating beds 2 to 6 feet thick. Small nodules of limestone distributed throughout. An 8-inch bed of limestone conglomerate, with red mudstone matrix, occurs 7 feet above base	51½
13. Mudstone, massive, brick-red. Westward the bed pinches to 2½ feet thick; eastward it thickens to 15 feet and is continuous across face of cliff	7
14. Mudstone, brick-red, sandy, micaceous, and red shale in alternating beds 2 to 6 feet thick. All beds are lenticular and grade from mudstone to shale within relatively short distances. Mudcracks are fairly abundant, ripple marks rare	52
15. Sandstone, dull-maroon, shaly, micaceous, in beds 3 to 12 inches thick alternating with red shale and mudstone. Several sandstone beds are nearly white. Color grades to brick red in upper 20 feet	72
16. Sandstone, light-gray to buff, slabby, fine-grained and even-grained, micaceous throughout, abundantly so on bedding planes. Becomes somewhat more shaly near top, where a few beds contain small flakes of green shale	49
17. Sandstone, massive, light-colored, fine-grained, in beds 2½ feet or more thick. Poorly exposed	25
18. Mudstone, dull-maroon, sandy, micaceous, in large part fissile. Most beds are minutely cross-bedded, which causes slabs to break with hackly surfaces. Contains at least one, and probably several, 3-inch to 6-inch beds of yellowish-green limestone and shingle conglomerate. Poorly exposed	100
19. Sandstone, light-gray, slabby, micaceous, fine-grained and even-grained, locally cross-bedded. Fairly massive near base, in beds 1 foot to 2 feet thick, but progressively thinner bedded toward top	27
20. Limestone conglomerate in beds 1 inch to 10 inches thick. Lower 2½ feet contains many rounded limestone pebbles in sandy matrix; upper 4½ feet resembles bed 19 but contains small scattered pellets of limestone	7
Total thickness	610½
Cutler formation, coarse-grained, arkosic conglomerate.	

The following section was measured along the east side of the Animas River, opposite Animas City Mountain. It is incomplete, but comparison with the Junction Creek section serves to bring out some of the variations in lithology that characterize the formation from place to place. The most significant difference perhaps is the fact that the upper part of the Junction Creek section is almost entirely mudstone, whereas the Animas City Mountain section contains much sandstone and a little limestone in its upper part.

Section of Dolores formation exposed on east side of Animas River opposite Animas City Mountain

[Measured by J. S. Williams]

	Feet
Entrada sandstone.	
Dolores formation:	
1. Sandstone, massive, fine-grained, salmon pink	22
2. Mudstone and siltstone, red and purplish-red, with 10-inch to 12-inch bed of limestone conglomerate near middle	68
3. Limestone conglomerate, lenticular	1½
4. Siltstone, red	2
5. Mudstone, purplish-maroon and red in alternating beds	68
6. Siltstone, red	6
7. Sandstone, fine-grained, salmon to pink to cream	6
8. Siltstone, massive, mottled gray-green	72
9. Interval of poor exposures; contains 18-inch bed of limestone conglomerate 22 feet above base	118
10. Mudstone and siltstone, red, with thin bed of conglomerate, containing clay pellets in lower part	27
11. Sandstone, gray, with lenses of limestone conglomerate	28
12. Unexposed; probably red and purple shale	54
13. Siltstone, red mottled with green, with two 3- to 6-inch beds of limestone conglomerate	30
14. Unexposed; dominant rock probably purplish-red shale, but there are at least two 2-foot beds of limestone conglomerate in lower 20 feet	76
15. Sandstone, greenish-gray, slabby, with lenses of limestone conglomerate	36
16. Limestone, shingle conglomerate	3
17. Sandstone, greenish-gray, fine-grained, underlain by Cutler formation	20
Total thickness	657½

As seen in the two exposures just described, and in other places throughout the district, the Dolores is made up in large part of mudstone, siltstone, and shale, with a few beds of sandstone and several lenses of limestone conglomerate. The color of the unaltered rock is distinctly brighter, in general, than that of the underlying Rico and Cutler beds, ranging from salmon pink through various shades of red and purplish red to maroon. A few beds are gray. In most places there is a gradation from dull colors near the base to bright brick red and vermillion red near the top.

The most distinctive feature of the Dolores is the presence of thin beds and lenses of limestone conglomerate, made up of round to rather angular pebbles and pellets of dense bluish-gray limestone, set in a matrix of earthy, sandy limestone or of limy shale. Small flattened pebbles of shale are not uncommonly present, and a few pebbles of quarzite, granite, and other rocks occur in places. Fragments of bones and fairly well preserved teeth of belodont crocodiles and megalosauroid dinosaurs, which have caused the enclosing rocks to

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be called "saurian conglomerates," are widespread though nowhere abundant, in the exposures examined. The limestone conglomerate beds are commonly less than a foot thick and rarely more than 5 feet thick; most of them are lenticular. Though several of them occur near the top of the formation, they are most common in the lower part, particularly in the lowest 100 feet. These beds are of the utmost importance in field mapping, because even where they have undergone extreme metamorphism they retain a distinctive texture and are easily recognized.

The lower half of the formation contains much more sandy material than the upper half, which is made up predominantly of mudstone and siltstone. The lowest 25 to 60 feet of the formation is characterized in most places by light-gray, micaceous, slabby sandstone, which contains several beds and lenses of limestone conglomerate. Poorly preserved plant remains occur locally in the sandstone. At some places, as in the Animas River section described above, the top of the formation is marked by a thick bed of fine-grained salmon-pink sandstone, which passes abruptly to the typical white sandstone of the overlying Entrada. Elsewhere along the Animas this salmon-pink sandstone is separated from the Entrada by a discontinuous bed of red shale. In still other places, as in the Junction Creek section given above, the sandstone is absent. On the east side of Bear Creek, a short distance north of the area shown in plate 2, a heavy white sandstone, similar in most respects to the Entrada, occurs in the upper part of the Dolores, but it was not seen elsewhere.

UPPER JURASSIC SERIES

GENERAL FEATURES AND NOMENCLATURE

The Upper Jurassic rocks include those that lie between the Dolores formation and the Dakota (?) sandstone. The subdivisions are shown in the table on page 27 and are described in the following paragraphs:

Confusion has existed for many years regarding the correlation of these rocks and the nomenclature to be applied to them. The table shows the nomenclatures that have been applied in parts of the San Juan region. The classification adopted by the Geological Survey for use in this report and applicable to the San Juan region in general is shown in the first column. As none of these names are yet in general use in the district, the widely used local terms "McElmo formation," "upper La Plata sandstone," "middle La Plata shale," "La Plata limestone," and "lower La Plata sandstone," shown in the second column, are used parenthetically throughout the report. No attempt is made here to correlate these units with Upper Jurassic beds in Utah and elsewhere.

ENTRADA SANDSTONE

The Entrada sandstone,[21] formerly known as the lower part of the La Plata sandstone [22] and still called the "lower La Plata sandstone" locally, is from 150 to 265 feet thick within and near the La Plata district. It is one of the most distinctive and easily recognized formations in the district and contains valuable ore deposits in several places. It is prominent on the divide between the La Plata River and the Bear Creek-East Mancos River drainage systems, and along both the last two streams. It is also well-exposed in a narrow but almost continuous band extending around the south and east sides of the mountains. Remnants cap Slide Rock Mountain, two of the ridges near the main forks of Lightner Creek, and Deadwood Mountain. The sandstone is also well-exposed in inliers along the lower East Mancos River and near the head of the West Mancos River. Along the Animas River it is 262 feet thick, on Junction Creek 235 feet, and on Jackson Ridge about 275 feet. Near the forks of Lightner Creek it is only 100 feet thick, and in the vicinity of the May Day and Idaho mines it ranges in thickness from 150 to 225 feet. The Entrada characteristically weathers to form sheer cliffs or smooth faces of bare rock, which present a striking contrast to the more rounded or terraced slopes assumed by the redbeds below it. (See pl. 3 *A*).

The lowest 40 to 50 feet of the formation consists in places of somewhat slabby buff to grayish-white or pinkish-white fine, even-grained sandstone. Elsewhere the slabby structure is poorly defined and the beds are massive and cross-bedded. The remainder of the formation is made up of massive, somewhat friable sandstone that is strikingly cross-bedded. Locally there are a few very thin partings of shale. The sandstone is mostly light gray or white, but in places it is pale cream to buff. Locally the uppermost 5 feet consists of slabby fine-grained beds.

A distinctive feature of the Entrada is that all but the bottom and topmost beds are largely made up of well-rounded, relatively coarse grains of glass quartz, in the interstices of which are much finer sand grains. Not uncommonly the coarser grains are arranged in more or less distinct layers, parallel to the cross bedding. A little calcareous cement is almost universally present, and in a few places an intricate pattern of secondary quartz veinlets appears, but this feature is less prominently displayed here than in the Junction Creek sandstone (upper La Plata sandstone of former reports).

The upper limit of the Entrada is marked almost everywhere in the La Plata Mountains by the basal Pony Express limestone member of the Wanakah (La Plata limestone of former reports). In most of the

[21] Gilluly, James, and Reeside, J. B. Jr., Sedimentary rocks of the San Rafael Swell and some adjacent areas in eastern Utah: U. S. Geol. Survey Prof. Paper 150–D, pp. 76–78, 1928. Baker, A. A., Dane, C. A., and Reeside, J. B., Jr., Correlation of the Jurassic formations, C. A., of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, pp 66., 1936.

[22] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio).

Comparative nomenclature of Upper Jurassic formations in San Juan region

<table>
<tr><th colspan="2">La Plata district, this report</th><th>La Plata district, local usage</th><th colspan="2">La Plata district, 1936, Eckel [1]</th><th colspan="2">La Plata Quadrangle, 1899, Cross, Spencer, and Purington [2]</th><th colspan="2">La Plata Mountains, 1941, Goldman and Spencer [3]</th><th>San Juan region, 1936, Baker, Dane, and Reeside [4]</th><th colspan="3">Ouray district, 1930, Burbank [5]</th><th colspan="2">Ouray district, 1940, Burbank [6]</th><th colspan="2">Ouray district, 1941, Burbank [7]</th><th colspan="2">Ouray (1907) and Telluride (1899) quadrangles, Cross and other [8]</th></tr>
<tr><td colspan="2" rowspan="2">Morrison formation.</td><td rowspan="2">McElmo formation.</td><td rowspan="6">Morrison formation.</td><td rowspan="6">Local names used for members.</td><td colspan="2" rowspan="2">McElmo formation.</td><td rowspan="6">Morrison formation.</td><td rowspan="2"></td><td rowspan="6">Morrison formation.</td><td rowspan="6">Morrison formation.</td><td colspan="2">Shale member.</td><td rowspan="6">Morrison formation.</td><td>Shale member.</td><td rowspan="6">Morrison formation.</td><td rowspan="3">Shale and sandstone (undivided).</td><td colspan="2" rowspan="4">McElmo formation.</td></tr>
<tr><td colspan="2">Sandstone member.</td><td>Sandstone member.</td></tr>
<tr><td colspan="2">Junction Creek sandstone.</td><td>Upper La Plata sandstone.</td><td rowspan="5">La Plata sandstone.</td><td>Upper sandstone.</td><td>Junction Creek sandstone member.</td><td colspan="2">Absent.</td><td rowspan="4">Wanakah member.</td></tr>
<tr><td rowspan="3">Wanakah formation.</td><td>Marl member.</td><td>Middle La Plata shale.</td><td rowspan="3">Middle calcareous member.</td><td>Wanakah marl member (restricted).</td><td rowspan="3">Wanakah member.</td><td>Shale.</td><td>Wanakah marl member.</td></tr>
<tr><td>Bilk Creek sandstone member.</td><td>Not named.</td><td>Bilk Creek sandstone member.</td><td>Sandstone.</td><td>Bilk Creek sandstone member.</td><td rowspan="3">La Plata sandstone.</td><td>Upper sandstone.</td></tr>
<tr><td>Pony Express limestone member.</td><td>La Plata limestone.</td><td>Pony Express limestone member.</td><td>Pony Express limestone.</td><td>Pony Express limestone member.</td><td>Limestone member.</td></tr>
<tr><td colspan="2">Entrada sandstone.</td><td>Lower La Plata sandstone.</td><td colspan="2">Entrada sandstone.</td><td>Lower sandstone.</td><td colspan="2">Entrada sandstone.</td><td>Entrada sandstone.</td><td colspan="3">Entrada sandstone or Jurassic sandstone.</td><td colspan="2">Lower La Plata sandstone of miners.</td><td colspan="2">Entrada sandstone.</td><td>Lower sandstone.</td></tr>
</table>

[1] Eckel, E. B., Resurvey of the geology and ore deposits of the La Plata mining district, Colorado: Colorado Sci. Soc. Proc., vol. 13, No. 9, pp. 507–547, 1936.
[2] Cross, Whitman, Spencer, A. C., and Purington, C. W., The La Plata quadrangle: U. S. Geol. Survey Geol. Atlas, La Plata folio (no. 60), 1899.
[3] Goldman, M. I., and Spencer, A. C., Correlation of Cross' La Plata sandstone of southwestern Colorado: Am. Asso. Petroleum Geologists, Bull. 25, pp. 1745–1767, 1941.
[4] Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, 66 pp., 1936.
[5] Burbank, W. S., Revision of geologic structure and strarigraphy in the Ouray district of Colorado, and its bearing on ore deposition: Colorado Sci. Soc. Proc., vol. 12, No. 6, pp. 151–232, 1930.
[6] Burbank, W. S., Structural control of ore deposition in the Uncompahgre district, Ouray County, Colo.: U. S. Geol. Survey Bull. 906–E, pp. 189–265, 1940.
[7] Burbank, W. S., Structural control of ore deposition in the Red Mountain, Sneffels, and Telluride districts of the San Juan Mountains, Colo.: Colorado Sci. Soc. Proc., vol. 4, No. 5, pp. 141–261, 1941.
[8] Cross, Whitman, Howe, Ernest, and Irving, J. D., The Ouray quadrangle: U. S. Geol. Survey Geol. Atlas, Ouray folio (no. 153), 1907. Cross, Whitman and Purington, C. W., The Telluride quadrangle: U. S. Geol. Survey Geol. Atlas, Telluride folio (no. 57), 1899.

few places where this limestone is absent there is an abrupt transition from white cross-bedded sandstone below to the red marl of the Wanakah formation (middle La Plata shale of former reports); but in some places the Entrada sandstone is overlain by 10 to 20 feet of even-bedded or nodular sandstone representing the Bilk Creek sandstone member of the Wanakah formation.

WANAKAH FORMATION

GENERAL FEATURES

The term Wanakah formation is here applied to the beds between the Entrada and Junction Creek sandstones. This definition of the term has been adopted by the Geological Survey for use in official reports on the San Juan region. The formation is equivalent to the La Plata limestone and the middle La Plata shale as these terms are applied by local miners, and to the middle part of the La Plata sandstone as defined in the La Plata folio and other early reports on parts of southwestern Colorado. In the La Plata district and elsewhere the rocks here placed in the Wanakah were formerly regarded as part of the Morrison formation.[23]

Throughout the district and the surrounding area the formation as now defined consists in most places of two easily recognized members, the Pony Express limestone and an overlying thicker marl member, which is unnamed. A thin sandstone member, the Bilk Creek sandstone, lying between the marl and the limestone, can be distinguished in a few places, and the limestone is locally absent. The two lower members are too thin to be shown separately in plate 2.

The formation as a whole is 25 to 150 feet thick. Its main belt of outcrop, which is 200 to 1,000 feet wide, skirts the southeastern and southern edge of the mountains and thence follows the west side of the East Mancos River and Bear Creek. Inliers are exposed on the West Mancos River and its north fork in the extreme northwest corner of the district. Remnants, some of them capped by the Junction Creek sandstone, occur on Indian Trail Ridge northward from Diorite Peak, on a summit just north of Gibbs Peak, on the ridge between the forks of Lightner Creek, and on Slide Rock Mountain.

PONY EXPRESS LIMESTONE MEMBER

Because it is the most distinctive and easily recognized horizon marker in the La Plata Mountains, and because it contains rich ore deposits in several places, the Pony Express limestone member, at the base of the Wanakah (locally called the "La Plata limestone") is one of the most important stratigraphic units in the district. It is a thin stratum of dense dark-blue or gray to nearly black relatively pure limestone. It is absent along the west side of Bear Creek and on Indian Trail Ridge between Fall Gulch and a point about a mile north of the mapped area (pl. 2). North of this point it reappears for at least a short distance but is only 6 inches thick. It is not present along the West Mancos River north of Jackson Ridge. Elsewhere in the district it varies in thickness from 6 inches to 30 feet, averaging about 3 feet. Its variations in thickness are irregular and were probably controlled by irregularities in the upper surface of the Entrada sandstone, on which the limestone was deposited.

In places the limestone consists of a single massive bed, but elsewhere it comprises three or more beds, each about a foot thick. In these places the upper beds are commonly massive and the lower ones thinly laminated. The top and bottom of the member are everywhere sharply defined, although in places the limestone shows a slight tendency to grade into the sandstone below and the shale above. In some layers there is a suggestion of oolitic or pisolitic structure, but this feature is by no means widespread and nowhere well-defined. Some, if not all, of the limestone is bituminous and gives forth a noticeable fetid odor when freshly broken.

The only place where the member is known to be more than 10 feet thick is on the ridge between the forks of Lightner Creek, where it is 25 to 30 feet thick. Here, according to H. S. Gane's field notes of 1896, the upper part is a massive gray limestone. This rock grades into an underlying series of limy shales, that become more sandy downward and rest upon the thin-bedded sandstone layer at the top of the Entrada. Gane found one fragment of a blue bone, probably that of a fish, in the limestone. This is the only recorded fossil from the Pony Express limestone in the La Plata district, but farther east, on the Piedra River, many fish scales and a few fish skeletons have been found.[24] No gypsum is associated with the limestone.

MARL MEMBER AND BILK CREEK SANDSTONE MEMBER

The Pony Express limestone member of the Wanakah is, as a rule, successively overlain by the Bilk Creek sandstone member and the marl member, and the marl member is everywhere overlain by the Junction Creek sandstone (upper La Plata sandstone of former reports). In the northern part of the district, the limestone member is not present. According to Goldman and Spencer, the sandstone that there underlies the marly beds is in most places the Bilk Creek sandstone and is 20 to 25 feet thick. In plate 2, however, it has been mapped as a part of the underlying Entrada.

[23] Burbank, W. S., Revision of geologic structure and stratigraphy in the Ouray district of Colorado, and its bearing on ore deposition: Colorado Sci. Soc. Proc., vol. 12, No. 6, 1930; Structural control of ore deposition in the Uncompahgre district, Ouray County, Colo.; U. S. Geol. Survey Bull. 906–E, 1940; Structural control of ore deposition in the Red Mountain, Sneffels, and Telluride districts of the San Juan Mountains, Colo.: Colorado Sci. Soc. Proc., vol. 14, No. 5, 1941. Goldman, M. I., and Spencer, A. C. Correlation of Cross' La Plata sandstone of southwestern Colorado: Am. Assoc. Petroleum Geologists, Bull. 25, pp. 1745–1767, 1941. Eckel, E. B., Resurvey of the geology and ore deposits of the La Plata mining district, Colorado: Colorado Sci. Soc. Proc., vol. 13, No. 9, 1936.

[24] Cross, Whitman, and Larsen, E. S., op. cit. (Bull. 843), p. 40.

The Bilk Creek sandstone is described by Goldman and Spencer as a sandstone or a succession of sandy beds, generally about 20 feet thick, rather soft, with prevailingly horizontal and locally nodular bedding; it is finer grained than the Entrada. The uppermost layer, about 1½ to 2 feet thick, is a hard calcareous sandstone, generally containing grains of red chert, scattered through it to some extent but more characteristically on its upper surface.

The marl member is 25 to 100 feet thick and consists of light pinkish-red to greenish-gray marls, mudstones, and sandstones in lenticular beds. In places, as on Jackson Ridge and in the Incas mine on Ohlwiler Ridge, a 4-foot to 6-foot bed of massive sandstone (possibly Bilk Creek) marks the base of the member, but in many places there is almost no sandstone in the entire section above the base of the marls. Some of the marly beds are concretionary, and in places these beds contain thin lenses of relatively pure limestone. Flakes of bright-green shale, small grains of carnelian, and concretions of red chert thinly coated with material of a rich dark-green color, are all characteristic of this member, as they are of the Morrison. It is difficult, therefore, to distinguish the marly member of the Wanakah from the Morrison formation (McElmo formation of former reports), except by noting its relation to the intervening Junction Creek sandstone (upper La Plata sandstone of former reports) or to the diagnostic cherty layers and the "carnelian sandstone" at the top of the Bilk Creek sandstone, as described by Goldman and Spencer.[25]

The accompanying section of beds between the Entrada sandstone and the Junction Creek sandstone, illustrates certain diagnostic features that are widely recognizable in southwestern Colorado. The following descriptive matter is taken from the notes of Goldman and Spencer and from their paper cited above, with appropriate changes to conform to the nomenclature used in this report.

Section of Wanakah formation exposed on Animas City Mountain

[Measured by M. I. Goldman and A. C. Spencer]

	Feet
Top of section.	
Junction Creek sandstone.	
Wanakah formation:	
Marl member:	
1. Marl, sandy, red, with limy concretionary layers and thin sandstone ledge	15
2. Sandstone, yellow-white, hard, massive, ledge-forming	7
3. Marl, sandy, red, with concretionary layers	13
4. Sandstone, yellowish-white, hard	3
5. Marl, red, with concretionary and red sandstone layers	30
6. "Green chert" layer; a bed containing concretions of red chert associated with green glauconitic mineral	.2
7. Marl, red, sandy, with layers of concretionary red sandstone	11

Section of Wanakah formation exposed on Animas City Mountain—Continued

	Feet
Wanakah formation—Continued	
Bilk Creek sandstone member:	
8. "Carnelian sandstone:" coarse sandstone with rounded grains; concretions of red chert near top	.5
9. Marl, sandy, red, concretionary	5.5
10. Sandstone, grayish-white to dull-red, soft, with hard concretionary layer at base	8
Pony Express limestone member:	
11. Limestone, oolitic and sandy, having irregular wavy contact with overlying sandstone	4
Total thickness	97.2
Entrada sandstone.	

As shown by this section, the division between the Bilk Creek sandstone and the marl member of the Wanakah is defined as the top of the "carnelian sandstone." From 10 to 15 feet above this sandstone there is usually found the "green chert" layer, containing a concretionary zone of authigenetic chert coated with associated dark-green glauconitic mineral. This relation is so nearly constant throughout the region from the San Miguel valley south to the La Plata Mountains that it is unquestionably diagnostic of the type "middle La Plata shale" sequence of Cross.

On Bear Creek, on the north flank of the La Plata Mountains, the Bilk Creek sandstone is 24 feet thick and includes a foot or two of "carnelian sandstone" at the top. The "green chert layer" lies 10 feet above this sandstone. On the west flank of the mountains, in the cliffs west of the East Mancos River, south of Helmet Peak, the Bilk Creek sandstone member is 25 feet thick with a foot or two of massive sandstone, carrying carnelian concretions, at the top. Seven feet of marly beds separate this sandstone from the overlying zone containing typical "green chert" concretions.

JUNCTION CREEK SANDSTONE

The Junction Creek sandstone ("upper La Plata sandstone" of former reports) lies between what were formerly reported as the two shaly members of the Morrison formation. It ranges in thickness from 200 to nearly 500 feet and is made up in large part of massive white cross-bedded sandstone closely resembling the Entrada. In most places the sandstone forms smooth cliffs, but they are rarely as steep or as prominent as those formed by the Entrada sandstone (pl. 3 *A*). Its outcrops along Junction Creek and the East Mancos River are marked by a multitude of spires and pinnacles of various shapes and by jumbles of great detached blocks of rock.

The greater part of the formation is typically composed of massive white to light bluff friable sandstone, which is strikingly cross-bedded. Thin lenticular beds of arkosic sandstone occur throughout the section, being especially numerous in the somewhat slabby uppermost part. Thin partings of greenish-gray or light-red shale are numerous in some places but absent in others.

[25] Goldman, M. I., and Spencer, A. C., op. cit. (Bull. 25), pp. 1749–1750.

Apart from stratigraphic position, no certain means of distinguishing between this sandstone and the Entrada have been found. Numerous local minor differences exist, however, and taken in combination they are often helpful. The Junction Creek tends to be more friable and less distinctly cross-bedded than the Entrada. Its quartz grains, though clear and glassy like those in the Entrada, are somewhat more angular. Furthermore, distinction between two dominant sizes of sand grains is not as marked in the Junction Creek sandstone, which contains more specks of dull-white material, possibly altered feldspar fragments. In places the Junction Creek sandstone contains a few minute grains of red or orange carnelian, none of which were found in the Entrada. Weathered surfaces of the Junction Creek are more likely than those of the Entrada to be marked with black specks or with small white to brown spheroidal protuberances.

Along the East Mancos River the Junction Creek has a different character from that which it exhibits elsewhere. On Jackson Ridge its appearance is typical. Toward the west end of the ridge, however, in the vicinity of the Lady Stafford mine, it interfingers with the shaly beds of the overlying Morrison (McElmo); there the slopes blend into those of the shales above and below, and nearly all distinction between the Junction Creek and the adjacent shaly rocks is lost. Farther to the southwest, about a mile northeast of Schubert Flat, the shales finger out and the sandstone resumes its normal character. Still farther southwest, below the Red Arrow mine, several lenticular sandstone layers that are prominent in the overlying Morrison merge with the Junction Creek and render it thicker than in most other places.

MORRISON FORMATION

Above the Junction Creek sandstone lie the shales and sandstones of the Morrison formation, formerly known as the McElmo formation or as the uppermost member of the Morrison. The formation as now defined is 400 to 625 feet thick and is made up of thin alternating layers of varicolored shales and sandstone. Flakes and lenses of brilliant-green shale are widespread and locally abundant and serve to distinguish the Morrison from all other units except the marl member of the Wanakah. The sandstone beds are light-colored and are similar in most respects to the Junction Creek sandstone. They are all lenticular, and some, like those on the lower East Mancos River that merge with the sandstone member, are rather thick. The Morrison is overlain by the conglomeratic Dakota (?) sandstone, and in most places the contact between the two is sharply distinct. On both sides of the lower East Mancos, however, the appearance of a lenticular bed of conglomerate about 75 feet below the top of the Morrison causes much confusion. This conglomerate, unlike that in the Dakota, contains much shaly material, however, and all the pebbles in it are coated with a dark-green substance. These features are sufficiently distinctive to permit the separation of the Dakota (?) from the Morrison, except where the rocks are altered and the green color has been obliterated.

The following section is representative of the member as a whole, but it must be emphasized that detailed matching of widely separated sections is not possible, since all the beds, so far as known, are rather lenticular.

Section of Morrison formation exposed on Animas City Mountain

[Measured by A. C. Spencer and F. W. Galbraith]

Top of section.	
Dakota (?) sandstone.	
Morrison formation:	*Feet*
1. Mudstone, greenish gray	21
2. Mudstone, maroon, grading into bed 1	34
3. Mudstone, greenish gray, poorly exposed	41
4. Sandstone, white to brownish-white, massive	6
5. Mudstone, greenish gray	13
6. Grit, fine-grained to medium-grained, with small angular pebbles scattered throughout. Contains several thin lenses of conglomerate and beds of brilliant-green sandstone. Fragments of silicified wood abundant near the base	76
7. Conglomerate, coarse, arkosic. Pebbles up to 1 inch in diameter, well rounded, largely of quartzite	4–6
8. Sandstone, fine-grained, white base not exposed. Thickness of exposed portion	4
9. Unexposed. Slope wash contains many fragments of green sandstone and nodular concretions of limestone	120
10. Sandstone, coarse-grained, white with abundant inclusions of green shale; stained green along fractures and joints	28
11. Unexposed. Slope wash contains fragments and blocks of green and brown sandstone	28
12. Sandstone, white, cross-bedded, fairly massive, stained green along fractures near top	43
13. Sandstone, greenish-gray, massive in lower 12 feet	30
14. Unexposed	48
15. Sandstone, gray to purple, gnarly	1
16. Mudstone, red	4
17. Sandstone, blocky	4
18. Unexposed	10
19. Sandstone, thin-bedded, shaly	43
20. Poorly exposed. At least half of thickness is made up of red siltstone	61
Total thickness	621
Junction Creek sandstone.	

UPPER CRETACEOUS SERIES

DAKOTA (?) SANDSTONE

The Dakota (?) sandstone is generally regarded as the basal formation of the Upper Cretaceous series. In parts of western Colorado, coal-bearing rocks regarded as the middle members of the formation have yielded plants of Lower Cretaceous age, but as no such evidence was found in the La Plata district, the customary age assignment has been accepted in this paper. As it has little relation to the known ore deposits of the district, the formation was not studied in detail. It crops out in an irregular band near the south edge of the mapped area (pl. 2), and it is almost continuously exposed along the western and northwestern sides of the dome. Small inliers are exposed along the West Mancos River and its tributaries, and one small outlier occurs near the top of Parrott Peak. The Dakota (?) is only about 100 feet thick within or near the district, but elsewhere it is 200 to 250 feet thick.[26]

The formation consists of conglomeratic sandstone with several layers and lenses of shale and impure coal. In general the lower part consists of a layer, from 5 to 50 feet thick, of white to gray or brown medium-grained to coarse-grained, cross-bedded, pebbly sandstone. Irregular lenses of cherty conglomerate are most abundant near the base of the layer. The white color and cherty composition of the pebbles serves to distinguish this horizon from the conglomerate layer that occurs locally near the top of the underlying Morrison formation (McElmo of former reports). This basal Dakota (?) sandstone is overlain in most places by 8 to 15 feet of carbonaceous shale, which contains abundant plant remains and one or two layers of impure coal a few inches to 3 feet thick. Some of the shale is sandy. Above this coaly parting is a bed of sandstone 25 to 40 feet thick that resembles the lower sandstone, but contains fragments and a few thin lenses of coaly material. Above the sandstone is a layer, 30 to 40 feet thick, of interbedded shale and sandstone with a little coal; the lower half of this layer is more shaly than the upper.

MANCOS SHALE

The Mancos shale, which is the youngest formation that occurs within the La Plata district, is extensively exposed in the northwestern part of the mapped area (pl. 2) and also crops out along its southern edge. Being even less directly related to the ore deposits than the Dakota (?) sandstone, it received but little attention during the present investigation, and its distribution as shown in plate 2 is largely taken from Cross' map of the La Plata quadrangle. Reeside[27] has described the lithology, fossils, and correlation of the Mancos in some detail.

Within the La Plata quadrangle the Mancos shale, so named because of its typical exposures near the town of Mancos, Colo., is about 1,200 feet thick, but near Durango it is 2,000 feet thick. It is an almost homogeneous body of soft dark-gray to nearly black clay shale. It contains a few thin layers, lenses, and concretions of shaly fossiliferous limestone, especially near the base and top. The concretions are characteristically yellow brown in color. A few thin beds of gray sandstone occur in places.

[26] Reeside, J. B., Jr., Upper Cretaceous and Tertiary formations of the western part of the San Juan Basin, Colo., and N. Mex.: U. S. Geol. Survey Prof. Paper 134, p. 9, 1924.

[27] Idem, pp. 9-13, 49.

POST-MANCOS UPPER CRETACEOUS AND TERTIARY ROCKS

To the west, south, and east of the La Plata Mountains the Mancos shale is overlain by a thick series of strata of Upper Cretaceous, Paleocene, and Eocene age. None of these strata occur within the district, although most if not all of them were doubtless present when the igneous rocks were intruded and the ore deposits formed. Detailed descriptions of all the post-Mancos formations are given by Reeside,[28] but the beds assigned an Eocene (?) age by him are now assigned by the Geological Survey chiefly to the Paleocene and partly to the Cretaceous. It will suffice here to say that they consist predominantly of shale and sandstone and include some layers of coal, conglomerate, and andesitic tuff. The post-Mancos Cretaceous rocks, as shown in the general sections given by Reeside in eastern La Plata County, have a total thickness of 4,100 to 4,300 feet. In southern La Plata County, and in northern San Juan County, N. Mex., they are 4,100 to 4,700 feet thick. The rocks assigned to the Tertiary are 3,670 feet thick in the eastern part of La Plata County and 1,400 to 2,450 feet thick in the southern part. The total thickness, therefore, of the rocks that once overlay the Mancos shale in the La Plata Mountains can hardly have been less than 4,100 feet or more than 8,000 feet.

QUATERNARY DEPOSITS

Unconsolidated deposits of Quaternary age obscure the bedrock in large parts of the La Plata area. They consist of glacial till and outwash gravels, landslide debris, talus, and alluvium. None of these deposits were studied in detail, and except for one large landslide body none have been shown on the geologic map (pl. 2). Most of the following description is based on the report of Atwood and Mather[29] and of Cross[30] and his associates.

GLACIAL DEPOSITS

In the La Plata Mountains, as in the main San Juan Mountains, there were three glacial stages during Quaternary time, but the first of them is not represented by any known deposits.

Three small bodies of till and other glacial deposits are ascribed by Atwood and Mather[31] to the second, or Durango, glacial stage. The largest is on a bench 200 to 500 feet above the valley of the West Mancos River, near the mouth of Echo Creek, at an altitude of about 10,000 feet. The other two bodies of Durango drift are on the sides of the valley of the La Plata River near Mayday. They are remnants of lateral moraines and are at an altitude of about 9,000 feet, or about 300 feet higher than the Wisconsin moraine on the valley floor.

[28] Reeside, J. B., Jr., op. cit., Prof. Paper 134.

[29] Atwood, W. W., and Mather, K. F., Physiography and Quaternary geology of the San Juan Mountains, Colo.: U. S. Geol. Survey Prof. Paper 166, 1932.

[30] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio).

[31] Atwood, W. W., and Mather, K. F., op. cit., p. 129.

The floors of many of the basins in which the streams head contain masses of stony till left by the Wisconsin ice. These masses are now largely buried beneath talus and alluvium. The interstream ridges west of the La Plata River and south of Babcock Peak are largely covered with fairly thick accumulations of glacial debris, which probably represents ground moraines as well as indistinct lateral moraines. Boulders of diorite, which could have come only from Lewis Mountain or Diorite Peak, occur as far south as Madden Creek. Similar but less well defined glacial deposits occur on the east side of the La Plata River. The small terminal moraine of the La Plata glacier is near Mayday. It dammed the valley and forced the stream to cut a narrow trough along its eastern edge. About a mile below Mayday the front of the moraine is bordered by the outwash gravel of a valley train, whose surface is about 30 feet above the modern flood plain of the river. Several small and inconspicuous lateral moraines lie on the slopes of Townsend Basin at altitudes of 9,000 to 10,500 feet, but no terminal moraine has been found in the East Mancos valley. The valleys of the twin forks at the head of the West Mancos River were occupied by Wisconsin ice, which left several morainal deposits near their junction. The ridge between the forks of Lightner Creek is covered by a medial moraine, and a small terminal moraine is plainly exposed on Lightner Creek about 1½ miles south of the mapped area.

LANDSLIDE DEBRIS

Small landslides have occurred in many places throughout the mountains, but the most conspicuous one is on the north side of Hesperus Peak (pl. 2). Cross [32] describes this slide as follows:

> The sliding has taken place, as is usual throughout this region, on the Mancos shale. The materials which now lie in an irregular mixture upon the shale comprise the igneous rock occurring in the ridge above the Dakota sandstone, and fragments from the McElmo formation. This anomaly is explained by the great fault which crosses the landslide area. The eastern part of the area is characterized by almost complete lack of drainage, little ponds being formed by crescent-shaped dams. Here large blocks are of infrequent occurrence. To the west of this there is an area where the whole surface is covered by huge blocks of Dakota in confused relation. On the north side of the ridge west of Mount Hesperus the talus covers the lower part of the Dakota sandstone.

Similar masses of debris are present in several places on the west side of the Sharkstooth and along the ridge northwest of it. The slopes near the headwaters of the Middle Mancos River, particularly to the northwest of Helmet Peak, are also marked by landslides.

TALUS, ALLUVIUM, AND SOIL

Except for the grass and flower-carpeted upland meadows, the greater part of the district above timberline consists of bare rock or of accumulations of coarse, angular talus. The talus forms a conspicuous feature of the landscape and conceals the lower slopes of most of the high basins. (See pls. 4, 5 *C*, and 6 *B*.) A boulder crashing from the cliffs, or a little avalanche rushing down a ravine, reminds one, now and again, that vigorous erosion is constantly adding to the talus. A small lake near Babcock Peak that was shown on the original topographic map of the La Plata quadrangle in 1896 had been completely obliterated by talus prior to 1935.

Large parts of the main stream valleys are filled with coarse gravel, boulders, and sand deposited by the streams since the last glaciation. Most of the side streams, because of their steeper gradients, are comparatively free from alluvium, although in places they flow between banks cut in older valley fill. Torrential fans have been formed at the mouths of several of the side streams.

Below timberline the soil is comparatively thin in most places, but it suffices to make bedrock exposures rare and to support heavy stands of vegetation. (See pls. 3, and 21.)

[32] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio), p. 6.

LATE CRETACEOUS OR TERTIARY IGNEOUS ROCKS

GENERAL FEATURES

The igneous rocks of the La Plata Mountains are of late Cretaceous or Tertiary age and are all intrusive. They vary widely in composition and in form, but all of them can be grouped in two general types—porphyritic and nonporphyritic. The porphyritic rocks, which are the more abundant, occur as more or less contemporaneous stocks, sills, and dikes. For the most part they are intermediate between diorite and monzonite in composition, but some bodies are syenitic or mafic. The nonporphyritic rocks, which are in general younger than the porphyries, consist of syenite, monzonite, and diorite and occur as irregular stocks accompanied by dikes. The porphyritic bodies were intruded forcibly between the layers of sedimentary rock and were thus a major factor in the uplifting of the La Plata dome, whereas the nonporphyritic rocks cut across the sedimentary formations and the sills, few of them having disturbed the preexisting attitude of the beds. There is clear evidence that the nonporphyritic rocks replaced or assimilated their wall rocks during invasion.

The intrusion of the porphyries was not accompanied by any considerable metamorphism, whereas the group of nonporphyritic stocks is surrounded by an aureole of rather intensely altered sedimentary rocks.

PORPHYRITIC ROCKS

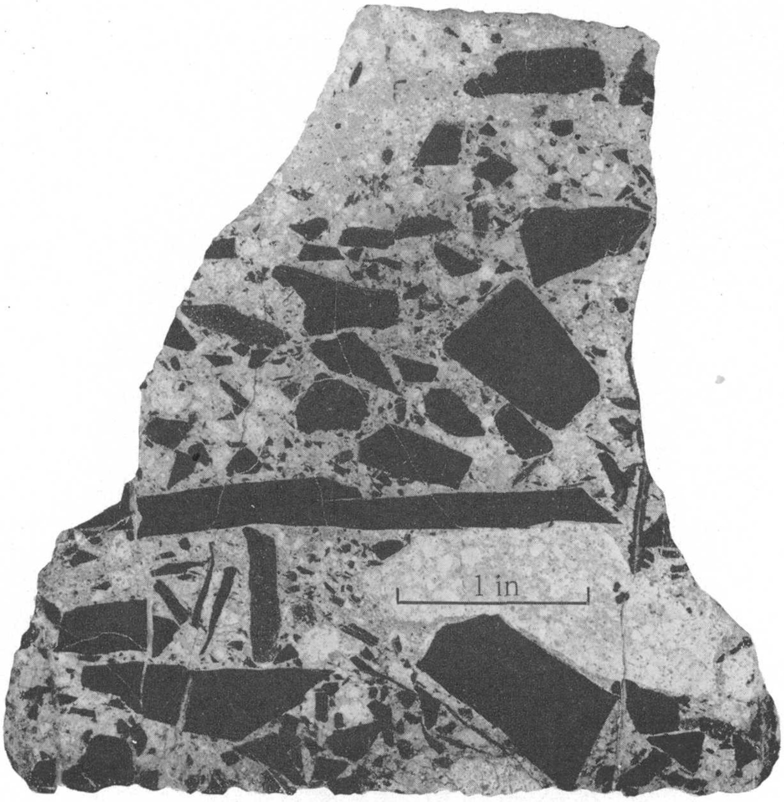
DIORITE-MONZONITE PORPHYRY

CHARACTER AND DISTRIBUTION

Intermediate in composition between the typical diorite porphyry and typical monzonite porphyry are closely related rocks that might be given many varietal

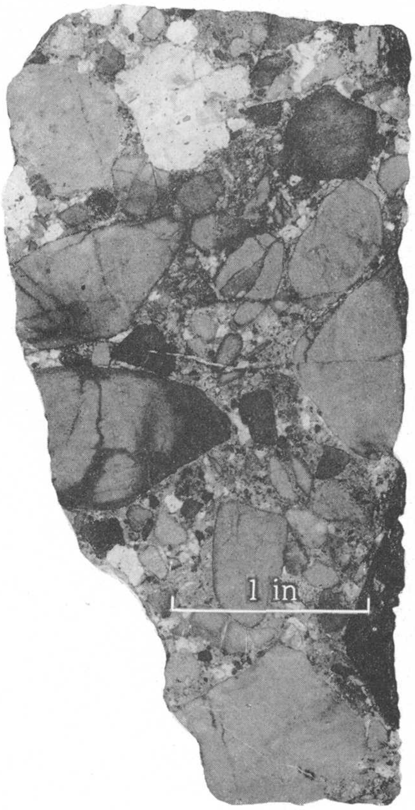
VIEW AT HEAD OF BOREN CREEK SHOWING MONZONITE STOCK.

Dashed lines show approximate boundary of stock. Spiller and Burwell Peaks are in upper left and right corners. The jagged pinnacles along the gulch in the foreground are due to erosion of strongly altered and pyritized rocks of various kinds. View looking north from the ridge east of Burwell Peak.



A. FROM MILLER TUNNEL OF INCAS MINE.

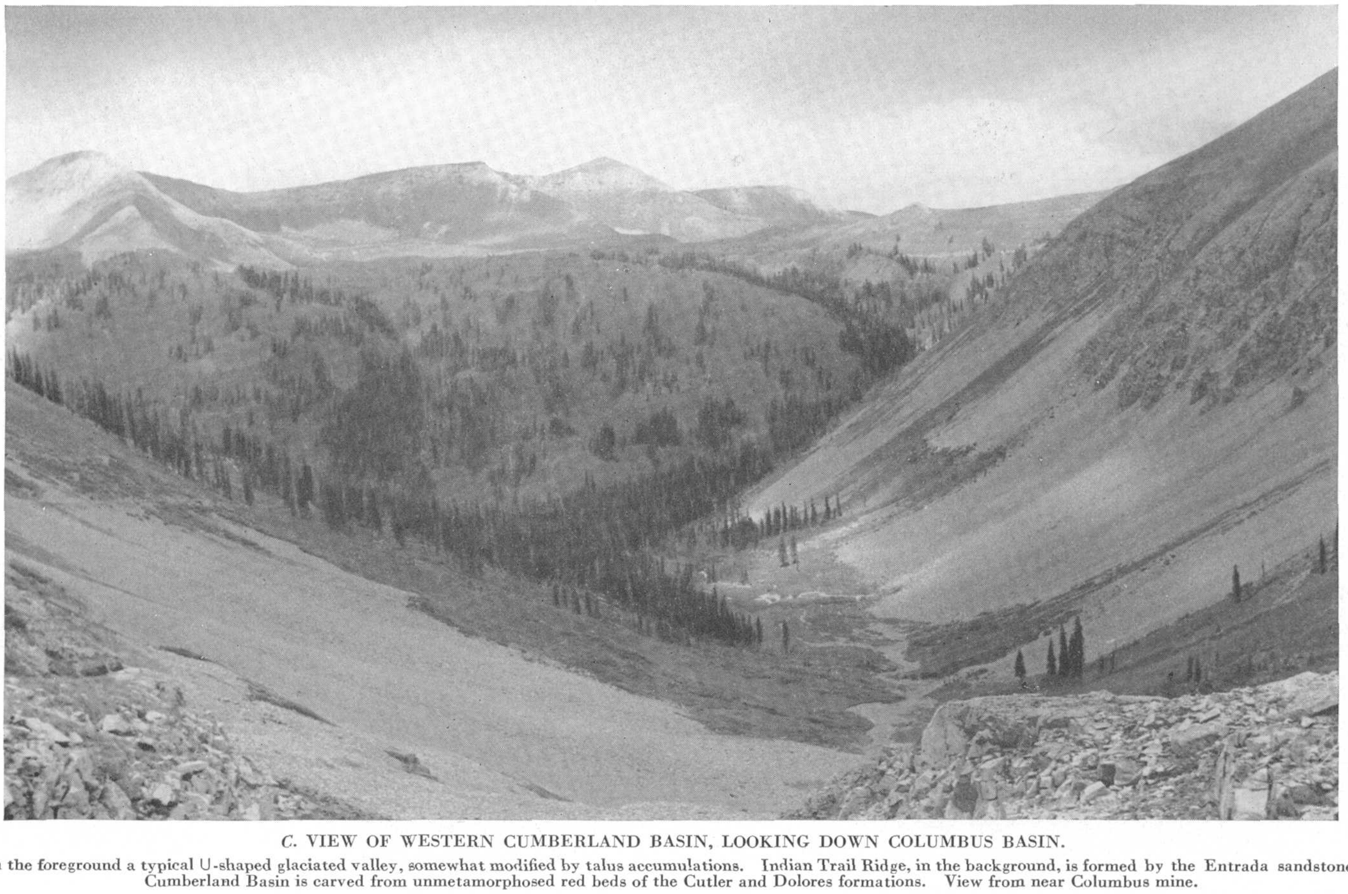
Black fragments are Pony Express limestone member of Wanakah formation; light fragments are porphyry.



B. FROM DAISY MINE.

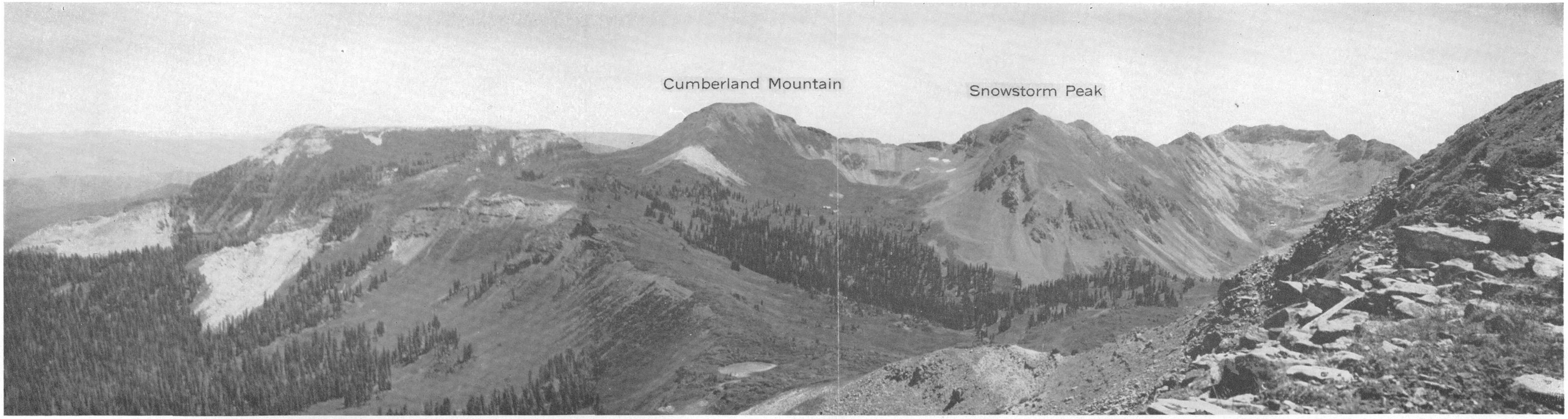
Fragments consist of mudstone, sandstone, and altered porphyry.

TEXTURES OF INTRUSIVE BRECCIAS, COMPOSED OF VARIOUS ROCK FRAGMENTS IN A MATRIX OF FINE-GRAINED ROCK.



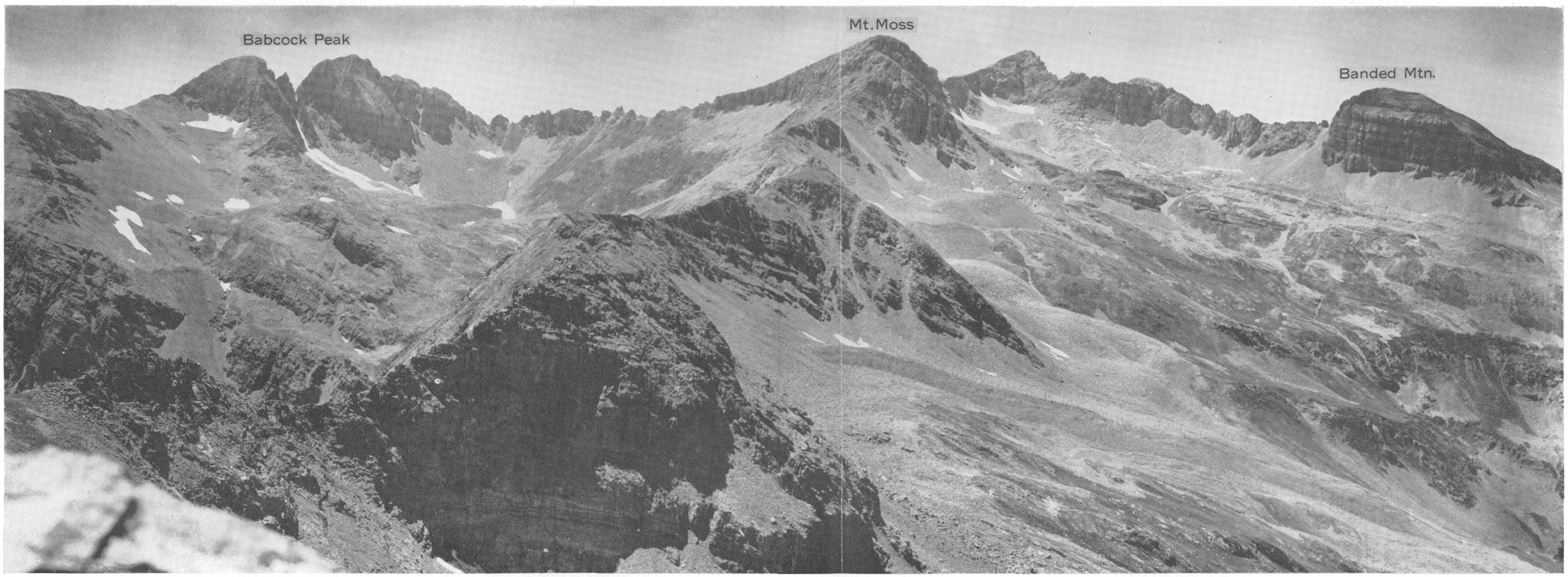
C. VIEW OF WESTERN CUMBERLAND BASIN, LOOKING DOWN COLUMBUS BASIN.

In the foreground a typical U-shaped glaciated valley, somewhat modified by talus accumulations. Indian Trail Ridge, in the background, is formed by the Entrada sandstone. Cumberland Basin is carved from unmetamorphosed red beds of the Cutler and Dolores formations. View from near Columbus mine.



A. PANORAMIC VIEW OF CUMBERLAND AND COLUMBUS BASINS.

The sharp hinge fold that characterizes the La Plata dome passes down the left side of Columbus Basin but is obscured by the large porphyry mass on Snowstorm Peak. These basins, and the one at the head of the South Fork Hermosa Creek, shown in the left foreground, have been strongly glaciated. View looking southeast from Indian Trail Ridge.



B. VIEW OF UPPER PARTS OF TOMAHAWK AND BEAR CREEK BASINS.

The rugged forms of Babcock Peak and of Mount Moss are due to erosion of monzonite. Several porphyry sills show clearly on Banded Mountain. Sedimentary rocks, all of them metamorphosed, belong to Upper Jurassic and Upper Cretaceous formations. The glaciated rock floors of the basins are exposed in a few places through the characteristically heavy accumulations of talus. View looking west from Diorite Peak with Tomahawk Basin on the left.

names; they have been grouped, however, for purposes of mapping and description, as diorite-monzonite porphyry. The rocks thus designated vary in texture, but all of them are porphyritic and contain phenocrysts of white feldspar and of dark-green to black hornblende, set in a gray to brown dense groundmass.

As shown in plate 2, the porphyry bodies are thickest and most numerous near the center of the dome, diminishing outward both in number and in individual thickness. Fully 98 percent of the porphyry related to this center lies within an oval area 12 miles wide and 17 miles long, elongate from east to west. The greater part of this area is included in plate 2, but Cross' maps [33] show that one large laccolithic body and several smaller ones crop out as much as 5 miles farther west and that several of the sills near the north edge of the area represented in plate 2 extend 1 mile to 4 miles farther north. The northwestward-trending dike on lower Bear Creek (p. 71), the dike near the Lost and Mason mines near Trimble on the Animas River, and one or two thin dikes on the east slope of Animas City Mountain, are also probably related to the La Plata center.

GEOLOGIC RELATIONS

The irregular shapes of the porphyry bodies are indicated in a general way in plate 2, but in places this map is highly generalized and represents many of the porphyry bodies in merely diagrammatic fashion. The good underground exposures afforded by the mines and the large scale of the mine maps on which these exposures are plotted serve better than surface outcrops to show the extreme complexity of the rock masses. This fact may be appreciated by comparing the mapping of the surface geology in the vicinity of some of the mines (pl. 2) with the underground maps, particularly the Gold King (pl. 22), Neglected (pl. 27), Durango Girl (fig. 24), Wheel of Fortune (fig. 50), and the Miller tunnel of the Incas mine (fig. 28). To project the irregular igneous bodies in these mines to the surface or to represent them on the scale of plate 2 would obviously be impossible.

Four stocklike masses of porphyry are exposed in the mountains. The one on Silver Mountain presents the largest uninterrupted exposure of this rock; it is roughly 1½ miles in diameter and is exposed throughout a vertical range of nearly 3,000 feet. The mass on Silver Mountain wedges out into sill-like bodies locally, as on the west side of Baker Peak, but it is obviously crosscutting on the east side of the same peak and in some other places. Cross [34] thought that this body was more nearly laccolithic than stocklike. Along its east side it conforms in places to the bedding of the sedimentary rocks, but along the ravine a few hundred feet northwest of Baker Peak the enclosing rocks are locally turned up almost on edge. There is no evidence in the surrounding rocks, however, of a steep-sided local dome such as would necessarily be formed by a laccolith with dimensions of this mass. The irregular bodies of porphyry at the head of Lightner Creek are probably offshoots of the main Silver Mountain mass. In plate 2 several bodies are represented as directly connecting the Silver Mountain stock with the igneous complex exposed in the area between Burnt Timber Creek and Baldy Peak; but as the rocks of this complex appear to be somewhat younger than most of the other porphyries of the district, there is reason to suspect that good continuous exposures might reveal a definite contact between the two types.

The relations of the diorite monzonite porphyry body to the enclosing rocks near Gibbs Peak on the divide are not clear, because the porphyry grades into syenite on its east side and because it is rather poorly exposed. The western and southern extremities of this body are certainly sill-like, but the central part is probably crosscutting.

No single large mass of porphyry is exposed in the area northeast of Lewis Mountain, but the predominance of crosscutting bodies over sills suggests that this area may contain one of the centers from which many of the sills in the northeastern part of the district were fed, and that it may be underlain by a larger stock of porphyry.

The porphyry masses that characterize the region between Burnt Timber Creek and Baldy Peak are vastly more complex than the others in the district, their representation in plate 2 being highly diagrammatic. Most of these closely related bodies cut across the sedimentary layers, but some have the form of sills or small laccoliths. They are made up of rock that is noticeably different in texture from most of the porphyry in the district, and they seem to be somewhat younger than the other bodies of porphyry.

Most of the porphyry bodies in this district are sills or sheets. They range in thickness from a few inches to more than 500 feet, and in lateral extent from a few yards to at least 5 miles. Some have a nearly uniform thickness throughout; others pinch and swell and locally assume laccolithic form and proportions. Dikes of varying thickness and extent occur throughout the district. Most of them are similar to the sill rocks in general make-up, and many can be seen to connect one sill with another. Some of them have comparatively great vertical as well as lateral extent; many reach the surface, but a few like the small one exposed in the Neglected mine (pls. 27, 28) have not yet been exposed by erosion. In one or two places dikes were seen to end abruptly at some bedding plane or other structural feature of sedimentary rocks.

Some of the porphyry bodies are unquestionably older than others, and in several places dikes can be seen to cut through sills or irregular intrusive bodies. There

[33] Cross, Whitman, and others, op. cit. (La Plata and Rico folios).

[34] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio), p. 9.

is little doubt, however, in view of the general similarity in form, texture, and composition of the various bodies, that all the masses of diorite-monzonite porphyry are closely related genetically and were intruded during a single epoch. Through what channels the sill-forming magmas rose is not fully known. Some of the sills center about the stocklike masses, but others are apparently related to channels now occupied by nonporphyritic stocks. The great thickness and number of sills in the middle of the dome suggests that many of them are related to some undiscovered center in that area. Many sills apparently are connected with one another only by narrow dikes.

The porphyries are older than the nonporphyritic rocks, but clean-cut relations between rocks of these two types are seen in only a few places. Many of the contacts are obscured by talus, and many of those exposed are gradational. There are reasons, to be presented later, for believing that this gradation is due at least in part to incomplete replacement of the porphyries by the later rocks.

Porphyry cuts all the sedimentary beds in the district from the lowest ones exposed to those at a horizon a few hundred feet above the base of the Mancos shale. Similar bodies probably once existed in the higher strata that have been removed from the center of the dome, and they probably occur also in the Hermosa and older sedimentary rocks that have not yet been exposed by erosion. The porphyry bodies are most numerous in the Cutler and Dolores beds and least so in the thick Entrada, Junction Creek, and Dakota (?) sandstones. The Cutler-Dolores contact, presumably because it is marked by an unconformity, seems to have been particularly favorable to sill intrusions, though sills have in many places been injected along other contacts between formations.

Most of the sills were intruded between the sedimentary strata and domed them upward, but some cut across the beds, and others, notably the complex sill near the mouth of Tirbircio Creek, on the La Plata River, unquestionably pushed the underlying beds downward instead of lifting the overlying beds. Local thickening of sills is marked in some places by small domes in the enclosing rocks.

Near the sides of some of the crosscutting stocklike bodies the sedimentary rocks are bent upward; the bending is particularly well shown at the head of Lightner Creek, along the northern part of the Silver Mountain stock, where the Cutler beds are locally vertical or even overturned. In most places, however, the stocks and thick dikes have not visibly disturbed the immediately adjacent rocks.

Injection of great quantities of porphyry magma was largely responsible for the forming of the La Plata structural dome. The stresses were relieved mainly by doming of the sediments, but locally, especially in brittle beds, by faulting. Some of the fault fissures were filled with dikes of porphyry; others deflected the magmas or caused them to stop abruptly, causing differences in the shapes of the intrusive bodies on opposite walls. Instructive examples of this effect may be observed in the Durango Girl and Gold King mines (fig. 24, pl. 22).

The magma in the Burnt Timber Creek-Baldy Peak area was intruded after the main period of porphyry intrusion and structural uplift. The location and shape of the bodies then formed were thus a result rather than a cause of the domal structure.

PETROLOGY

Ordinary type.—The ordinary diorite-monzonite porphyries that make up nearly all of the porphyry bodies (except those between Burnt Timber Creek and Baldy Peak) are closely similar to rocks that occur in many parts of the Rocky Mountains and that have been exhaustively studied in several Colorado mining districts. They are characteristically light gray to greenish gray or brown in color and contain abundant phenocrysts of white feldspar and of dark-green to black hornblende embedded in a dense groundmass. Folia of biotite and rounded phenocrysts of quartz occur in a few places. Augite with or without hornblende is present locally.

A great variety of texture is seen even within single masses. In some places the phenocrysts are so small that the rocks appear to be almost equigranular; in general, however, porphyritic texture is well-developed, all the feldspar phenocrysts in a given rock mass being commonly from 2 to 8 millimeters in length and the grains in the groundmass very much smaller. The phenocrysts of dark minerals are generally somewhat smaller than those of feldspar and similarly restricted in range of size.

Many of the sills and dikes contain numerous angular inclusions of foreign rocks. They range from coarse granite through hornblendic schists and gneisses to dark granular masses of amphibole. Fragments of the adjacent sedimentary formations are very rare. There is no observable relation between the size of a body of porphyry and the size or number of the inclusions it may contain. Most of the inclusions, including all types of gneiss and granite, were almost certainly derived from the pre-Cambrian basement rocks through which the porphyry magmas were forced. The hornblendic inclusions closely resemble in megascopic appearance the Irving greenstone of the Needle Mountains, but without petrographic study it is impossible to be certain whether they were derived from that rock or are genetically related to the porphyry.

The microscope reveals that although there are great differences in appearances and texture between porphyries of different bodies and wide variations even within single bodies, the mineral composition of these bodies as a group is comparatively uniform. Labradorite and orthoclase are the most abundant minerals. Labradorite is much the more abundant of the two; to the unaided eye it may appear to be the only feldspar in the rock, for it forms phenocrysts whereas the orthoclase is largely confined to the groundmass. The groundmass is actually a granular mixture of orthoclase with quartz and the accessory minerals, magnetite, sphene, and apatite. Of the ferromagnesian minerals common hornblende is the most abundant in most specimens, though a few specimens contain augite with or without hornblende. Biotite, the only other dark mineral present, is absent in many bodies and rare in all of them. A little hornblende is found in the groundmass of some specimens, but the dark minerals occur mostly as phenocrysts. In some bodies these hornblende phenocrysts are larger but less numerous than the plagioclase feldspar phenocrysts; in others the hornblende forms numerous small needles that provide a dark-gray background for the larger feldspars. Quantitatively, the rocks range in composition from those in which orthoclase and labradorite occur in nearly equal amounts to those in which labradorite is predominant. The proportion of hornblende to the feldspars varies to some extent, but most of the apparent variation is due to differences in texture rather than in composition.

In the central part of the district the porphyries are more strongly altered than elsewhere—much more so than the nonporphyritic igneous rocks. There the feldspars are partly or completely altered to sericite or to kaolin in many places, and the ferromagnesian minerals are locally altered to chlorite or to limonite. In the vicinity of some of the ore-bearing veins, the rocks are completely or partly silicified, but silicification of the porphyries is by no means as widespread as that of the sedimentary rocks. Calcite, ankerite, and pyrite are widely distributed, but in general they are abundant only near ore deposits.

Porphyry of Baldy Peak-Burnt Timber Creek area.—The chief observable difference between the ordinary porphyry and that of the Baldy Peak-Burnt Timber area is that the latter rock is characterized by sparse, comparatively large, plagioclase phenocrysts scattered here and there between smaller ones, which are far more numerous. There is little or no gradation in sizes between the large and small phenocrysts. This rock has a distinctly spotted appearance that is easily recognized in the field. It is not greatly different from the ordinary porphyry in mineral composition or in the character of its inclusions.

INTRUSIVE BRECCIA DIKES

The district contains small dikelike or veinlike bodies of intrusive breccia that are more closely related to igneous dikes than to fault breccia. Except for one small dike in the Daisy mine at the head of Lightner Creek, observations on these bodies were limited to the southern part of the district, and especially to the area between the Parrott and May Day-Idaho fault systems. These bodies are too small to show on the areal geologic map, but a few are shown on maps of the Lucky Discovery, Incas, and other mines (pl. 24, fig. 28).

The breccia bodies are very irregular. None of those seen is more than 1 foot in width, and none could be traced for more than a few feet, even with the perfect exposures afforded by the mines. They vary greatly in appearance from place to place, but all are made up of rounded to angular fragments of sedimentary rocks and of porphyry, embedded in finely comminuted rock. Two illustrative examples are shown in plate 5 *A* and *B*. Some of the breccias contain veinlets of quartz or carbonate, as well as veinlets and disseminated grains of pyrite and other sulfide minerals. The ore-bearing vein of the Daisy mine definitely cuts through the breccia.

Every breccia of this kind that was seen contains two or more kinds of rock. The breccias cannot, therefore, have been derived from adjacent wall rocks but must have been forced into the spaces they now occupy. In a few places, notably in the Lucky Discovery mine and in the Miller tunnel of the Incas mine, breccia bodies can be traced laterally to the extremities of thin porphyry sills or dikes. It therefore seems probable that the breccias are intrusive and that they were pushed along fractures or bedding planes in the country rocks ahead of porphyry magma.

SYENITE PORPHYRY

CHARACTER AND DISTRIBUTION

Cross [35] drew a distinction between the diorite-monzonite porphyries described above and a series of rocks that range from syenite-porphyry to monzonite-porphyry. He designated this series collectively as syenite-porphyry, and that term will be used here. The rocks thus classed are more feldspathic than the diorite-monzonite porphyry and contain very large phenocrysts of feldspar, which as a rule are subordinate in bulk to the groundmass. They were not studied closely by the writer, and both the representation of their boundaries in plate 2 and the following descriptions are based largely on Cross' work.

The syenite-porphyries are best exposed along the west side of the East Mancos River between Helmet Peak and Jackson Ridge. As shown by the geologic map and by section AA′ (pl. 2), the sheet exposed on Jackson Ridge is inclined to the bedding of the sedimentary rocks and cuts across most of the Morrison (McElmo) and into the Dakota (?) sandstone. The body on the ridge north of Helmet Peak is dikelike toward the southeast, but near the top of the ridge it is a sill and follows the Morrison-Dakota (?) contact. The mass on Helmet Peak itself is irregular in form

[35] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio).

but probably has the general shape of a small laccolith, as does the one that crops out near the head of Starvation Creek, southwest of Parrott Peak. The only other bodies of syenite porphyry shown on the map are the sill along the north side of the West Mancos River, 1½ miles west of Hesperus Peak, and the dike that cuts the Silver Mountain stock on its east side. Other small dikes are present on the ridge south of Spiller Peak, on Tirbircio Creek near its mouth, and on the slopes just west and southwest of La Plata.

The relations of the syenite-porphyry bodies to the other igneous rocks of the district and to one another are not fully known. The larger bodies do not come into contact with any other igneous rocks. The dike that cuts the Silver Mountain stocks is clearly younger than the diorite-monzonite porphyry but in several other dikes the two types of rock apparently grade into each other. It may well be that some of the rocks classed as syenite-porphyry represent local variants of the diorite-monzonite porphyry, that some are younger than this rock, and that some are genetically related to the nonporphyritic stock-forming rocks.

PETROLOGY

As a general rule the groundmass of the syenite-porphyries is much greater in volume than the phenocrysts, but in some places the reverse is true, the rock being made up in greater part of comparatively large phenocrysts. As a class these rocks are lighter in color than the diorite-monzonite porphyry, from which they differ also in being more thoroughly decomposed and in containing augite rather than amphibole as the chief dark mineral.

The feldspar phenocrysts consist mainly of plagioclase similar to that of the diorite-monzonite porphyries. Some of the rocks also contain tablets of pink orthoclase. Many of the plagioclase crystals, all of which are presumably rather rich in the albite molecule, are surrounded by an oriented rim of orthoclase. Pyroxene is more abundant than hornblende, and biotite is rare. The ferromagnesian minerals are almost wholly decomposed and are replaced by limonitic material in most places. Several of the bodies are characterized by honey-yellow tablets of sphene that are easily distinguished by the unaided eye.

The groundmass of these rocks is trachytic, and in the narrower dikes the microlites are nearly parallel to the walls, producing a noteworthy lamellar structure. The groundmass feldspar is commonly impregnated with pyritic dust, but it is presumably soda-rich orthoclase or possibly in part anorthoclase. Most of the pyroxene is very strongly green in color, is distinctly pleochroic, and has a large extinction angle. It is classed as aegirite-augite. The amphibole associated with the pyroxene is olive-green in transmitted light and has partly resorbed rims.

FERROMAGNESIAN INTRUSIVE ROCKS

Dark fine-grained aphanitic rocks, classed as ferromagnesian intrusive rocks in the geologic map (pl. 2), occur sparingly as dikes and sills throughout the La Plata Mountains. They have but little observable bearing on the ore deposits and were not closely studied during the present investigation. The following description is based on that of Cross,[36] to which the reader is referred for further details:

> These rocks are mostly in the form of dikes, but they form a few sill-like bodies. The largest masses seen are the dikes on the north rim of Cumberland Basin and the laccolithic sheet on Indian Trail Ridge a short distance north of the area shown in plate 2. Both of these occurrences are considered in detail by Cross. Thinner dikes, only a few of which are shown in plate 2, crop out in the north-central part of the district; they are most numerous in the general vicinity of the diorite and monzonite stocks. A thin sill of ferromagnesian rock is shown in the extreme northwest corner of plate 2, and a highly biotitic, amygdaloidal mass, which does not crop out at the surface, exists near the Barr-Menefee mine between Horse Creek and the East Mancos River.

The rocks of this class are made up of the same minerals as the lighter-colored porphyritic and nonporphyritic rocks, but here the dark silicates are characteristically predominant. For the most part the rocks are fine-grained throughout, but in places hornblende, augite, and less commonly biotite, form prominent phenocrysts. Microscopic examination and chemical analysis show that although the rocks are much less silicic than the ordinary diorite-monzonite porphyries, the feldspars are less markedly subordinate to the dark silicates than the appearance of the rocks in the field suggests. The alkali and lime-soda feldspars together are nearly as abundant as the ferromagnesian minerals and are commonly present in roughly equal amounts. Most of the rocks can be classed as vogesite, kersantite, and allied types.

NONPORPHYRITIC ROCKS

MONZONITE

Character and distribution.—The long irregular stock in the vicinity of Spiller and Babcock Peaks and Mount Moss (pl. 2) consists chiefly of monzonite. The mass is about 2 miles long and a half a mile to three-quarters of a mile wide and is exposed through a vertical range of 2,500 feet. The irregularity of its outline is inadequately expressed in plate 2, largely because of the predominance of poor or inaccessible exposures, such as those illustrated in plates 4, 7, and 6 *B*. In addition to the larger tongues and dikes shown on the map there are many smaller ones on all sides of the main stock. Some of them have been grouped with the diorite-

[36] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio), pp. 7, 11.

monzonite porphyry, but others are not shown. They are especially numerous on the ridge that connects Diorite Peak and Mount Moss and near the southern extremity of the stock at the head of Boren Creek. The main body is in general distinctly stocklike in form, but locally it spreads out in the form of sills. Examples are exposed on both sides of Banded Mountain and in the rugged peaks west of Babcock Peak, where the monzonite is underlain by metamorphosed sedimentary rocks. The relations of the monzonite to the enclosing rocks are further discussed below in the section on geologic relations of the nonporphyritic rocks.

Petrology.—The monzonite is a light-gray to pinkish-gray medium fine-grained equigranular rock. The pink tinge is due to the color of the orthoclase in partly weathered rock and is not seen in the freshest parts of the mass. Two kinds of feldspar make up the greater part of the rock as seen in hand specimen, but dark-green to black crystals of augite and a few of hornblende and biotite can also be identified. Aplitic veins and narrow dikes composed of orthoclase, microperthite, quartz, and a little hornblende or biotite cut the monzonite in places. On the east side of Banded Mountain and in Tomahawk Basin there are a few narrow, lenticular, drusy veins containing crystals of orthoclase, quartz, epidote, magnetite, specular hematite, and apatite. Some of these veins contain a little gold.

As seen under the microscope, alkali feldspar (chiefly orthoclase) and lime-soda feldspar (chiefly labradorite) are present in nearly equal quantity in the typical rock and together predominate over the dark ferromagnesian silicates. Of these, pale-green augite is the most abundant, but hornblende and biotite are present in places and are locally intergrown with the augite. The augite, fresh in most specimens, forms imperfect ragged prisms. Interstitial quartz is widespread but nowhere abundant. Of the accessory minerals, sphene is more abundant than apatite and much more so than magnetite. Except near veins the rock is very fresh; almost the only alteration being slight sericitization of the feldspars.

Most of the rock is even-grained, but locally it exhibits a poikilitic fabric, owing to the growth of large grains of orthoclase around numerous small grains of the other constituents. This fabric is more noticeable in thin sections than in specimens.

At two places observed by Cross, the monzonite grades toward diorite by an increase in the lime-soda feldspar and a decrease in orthoclase. One of these places is just south of Banded Mountain; the other is in the wedgelike arm of the stock at the head of the West Mancos River. Here the rock has a somewhat porphyritic structure. It contains more hornblende than augite and more quartz than any of the typical monzonite.

DIORITE

Character and distribution.—Two irregular stocks of diorite are exposed in the district. The typical rock is commonly finer grained and somewhat darker gray than the monzonite and contains a slightly larger quantity of ferromagnesian minerals and more lime-soda feldspar.

The larger stock, which is about 1½ miles in diameter and is exposed through a vertical range of 2,800 feet, extends southward and eastward from Diorite Peak to the valleys of the La Plata River and Basin Creek. The small body of diorite at the head of Fly by Night Gulch is almost certainly an offshoot from the main stock and is probably connected with it in depth. The smaller of the two stocks is exposed on Lewis Mountain for a total length of about 4,000 feet and a width of 500 to 1,500 feet. Many dikes and a few sills are associated with both stocks. Most of them are of typical diorite, but a few seem to grade into diorite-monzonite porphyry. Dikes are most numerous in the areas northeast of the Lewis Mountain stock and between the two main stocks—a fact suggesting that in these places diorite lies at no great depth below the surface. In some places, particularly in the Lewis Mountain stock, the diorite encloses small fragments of coarse granite and of hornblende gneiss, probably derived from the pre-Cambrian basement rocks, and a few rounded pebbles of quartz and quartzite, but these inclusions are nowhere abundant.

Petrology.—Except for the difference in color and grain size noted above, the diorite is similar megascopically to the monzonite. Augite is commonly more abundant than hornblende, but locally near the border of the Lewis Mountain stock (in the vicinity of the Columbus mine, for example) the rock grades within a few feet from an augite-bearing rock to one in which hornblende is almost the only dark mineral.

Microscopic examination reveals that the rock-forming minerals are the same as those in the monzonite but that labradorite is considerably in excess of orthoclase. The total amount of the feldspars is greater than that of the dark minerals, which are somewhat more abundant than in the monzonite. In addition to the augite and hornblende the rock contains variable quartz than any of the monzonite. As in the monzonite, apatite is unusually abundant and magnetite unusually scarce. One specimen taken from the Small Hope tunnel, which penetrates the Diorite Peak stock, is closer to monzonite than to diorite in composition. This suggests that here, and possibly elsewhere, the composition quantities of biotite and considerably more interstitial of the diorite may vary from place to place.

SYENITE

Character and distribution.—Two comparatively large stocklike bodies of augite syenite crop out in the central part of the district, south of the stocks of monzonite and diorite described above. The rock is strongly altered in many places, is characterized by gradational contacts, and is as poorly exposed as any in the district. For these reasons the relations of the syenite to other rocks are obscure, and the shapes of the stocks shown in plate 2 are highly diagrammatic. The larger, more westerly stock extends from near La Plata to Gibbs Peak, a distance of 2½ miles, and ranges from a few hundred feet to 1½ miles in width. It is exposed through a vertical distance of 3,000 feet. The smaller but similar stock on the east side of the La Plata River, between Tirbircio Creek and Bragdon Ridge, is about 1½ miles long and as much as three-quarters of a mile wide. One or more bodies connecting these two stocks may be concealed on the slopes between them, as bedrock is there exposed in but few places. Some of the rocks along the La Plata River between Boren and Tirbircio Creeks appear to be related to the syenite, but they are here mapped as porphyry. The metamorphic zone extends southward far beyond the outcrops of syenite, and much of it may be underlain by syenite at no great depth.

Petrology.—Rarely can two specimens of syenite be found that possess the same appearance or texture, but most of the rock is sufficiently different from the other igneous rocks to be readily distinguishable and mapped separately. The rock is characteristically light brown to brownish gray in color, but some of it is pinkish gray. In general, it is moderately fine-grained and nearly equigranular, although on the outcrop the altered condition of the feldspars tends to obscure the individual grains. Some of it has a marked porphyritic texture and is therefore not readily distinguished from that of the diorite-monzonite porphyries.

Except in the border facies, which is described below under the heading "Geologic relations of the nonporphyritic rocks," most of the variation in the syenite is apparently textural rather than compositional. Feldspars, of which there are several species, greatly predominate over the dark minerals. Dark-green augite, in irregular prisms, is the chief dark mineral, but a little hornblende and biotite are locally associated with it. Much of the augite of the original rock is replaced by ocherous to dark-brown limonitic material.

In the vicinity of the Allard tunnel on Bedrock Creek the syenite is traversed by innumerable veins and dikes. They trend and dip in all directions; many of the strongest trend from northeast to east and have steep to vertical dips. The most impressive of these bodies consist of coarsely bladed dark-green augite, intergrown with microcline feldspar. Coarsely crystalline calcite, white to clear crystalline quartz, and blue chalcedony form the inner parts of many of the veins. Chalcopyrite and pyrite occur in irregular masses interstitial to the nonmetallic minerals. Individual veins range from less than an inch to more than 2 feet in width. Many of them can be traced for several hundred feet; others pinch out within short distances. The largest composite vein or dike seen is 15 feet wide and consists of seven alternate sheets of medium-grained syenite and of coarsely crystalline feldspar and augite. The finer-grained sheets are 6 inches to 3 feet thick and are cut by many small quartz veins. Individual crystals of feldspar and augite in the coarse-grained layers range from half an inch to more than 6 inches in length. These layers contain much quartz, chalcedony, calcite, chalcopyrite, and some pyrite.

Microscopical examination shows that the normal syenite is made up very largely of alkalic feldspars. Orthoclase, anorthoclase, and microperthite are present in various proportions in different parts of the stocks. Anorthoclase tends to form large grains surrounded by zones of microperthite and orthoclase. The latter two minerals are commonly predominant. The augite that remains in the rock is pale green under the microscope and is locally intergrown with biotite. Quartz forms only a small proportion of the syenite on the whole, though it predominates in some of the border facies. Sphene is found in nearly every specimen examined and is even more abundant than in the diorite or monzonite rocks; some crystals of sphene are visible to the naked eye. Apatite is sparingly scattered through the rock as relatively large, clear prisms.

The porphyritic facies of the rock are similar in mineral composition to that described above. Though megascopically very similar to the ordinary porphyries, they can quickly be distinguished from these rocks under the microscope. The syenite contains less soda-lime feldspar and ferromagnesian minerals and more alkalic feldspar than the diorite-monzonite porphyry. It varies more widely, also, in grain size, and its larger phenocrysts, which are commonly of anorthoclase, are set in a distinctly granular groundmass of orthoclase and microperthite crystals. The phenocrysts are less well formed than those in the true porphyries; they exhibit highly irregular boundaries and commonly contain small inclusions of other feldspar crystals or of augite.

The syenite is almost everywhere more strongly altered than the diorite and monzonite. The feldspars are sericitized, though usually not beyond recognition, and, as noted above, the dark minerals are altered to limonitic material. Calcite is present in many places, but so far as observed it is nowhere so abundant as to be megascopically visible.

GEOLOGIC RELATIONS OF THE NONPORPHYRITIC ROCKS

MUTUAL RELATIONS

As indicated in the brief descriptions given above, the nonporphyritic rocks—syenite, monzonite, and diorite—have many features in common. Additional points of similarity are brought out in the following paragraphs. Since none of the five stocks or their associated dikes is visibly connected to any other, the mutual relations of the different kinds of nonporphyritic rocks are not apparent. It seems probable, however, that all of them were emplaced about the same time and in the same manner and that all were derived from a common source. They are all similar in appearance and in form and contain the same minerals, though in variable proportions. As already pointed out, parts of the monzonite stock grade into diorite, and at least one of the diorite bodies contains some monzonite. The variability of the syenite, both in texture and in composition, has also been commented upon. If there is any difference in age between the different types, the more highly altered condition of the syenite would suggest that it is the older rock; but this alteration may well have been due to an especially high proportion of volatile constituents in the syenite magma rather than to alteration after its emplacement.

RELATIONS TO ENCLOSING ROCKS

Most of the contacts of the stock-forming rocks with the country rocks are obscured by talus, soil, and glacial material; other contacts are well exposed but in inaccessible cliffs that defy close examination. In the few places where they can be studied, however, the contacts exhibit a variety of highly significant features. These features are summarized in the following paragraphs, and the conclusions drawn from them are stated in discussing the origin of the nonporphyritic rocks.

As now exposed, the stocks are largely in contact with the Cutler and Dolores red beds. Although these formations are made up of several different kinds of rock, individual beds in them have very little visible effect on the character or shape of the intrusive bodies.

The monzonite stock is especially notable for its large inclusions of sedimentary rock. Several of the larger ones are shown in plate 2 in the vicinity of Babcock Peak and Banded Mountain, and many smaller ones not mapped were seen in the same places. The oval mass of Dolores formation in the floor of Tomahawk Basin may possibly be an inclusion, but it may well be an island in the igneous rock mass, not underlain by monzonite. Except for this body and the small mass of Morrison formation south of Banded Mountain, all the inclusions that were seen belong to the Entrada sandstone or to the Junction Creek sandstone. This fact is significant and fits well with the observation that the monzonite stock narrows where it crosses thick beds of sandstone. This narrowing is indicated in plate 4 and figure 3, and, as may readily be seen from an examination of plate 2, the large block of these sandstones that crops out at the head of Tomahawk Basin is nearly surrounded by monzonite. Of no less significance than the siliceous character of the inclusions is the fact that every observed inclusion, whether it is only a few inches or several hundred feet in length, retains the attitude and position of the beds from which it was derived. At no place were adjacent blocks seen to differ widely in dip and strike. Similar inclusions are known to occur in the syenite and diorite stocks. It may be pointed out that on Diorite Peak, where the larger stock cuts the Entrada sandstone, the diorite contains much more quartz, and is less even-grained, than it is elsewhere. The rounded pebbles of quartz and quartzite included in the diorite afford further evidence that the granular rocks were antipathetic to highly siliceous country rocks.

Three types of contact between the stocks and the enclosing rocks have been observed; sharply defined, brecciated, and gradational.

In many places the contacts between the diorite and monzonite and the host rocks are sharply defined and of a character that is normal for crosscutting intrusive bodies. Examples can be seen on the surface in parts of Columbus Basin, on and near Diorite Peak, and near the head of Tomahawk Basin, and good underground exposures are visible in the lower tunnel of the Columbus mine and in the Brawner tunnel of the Ashland-Ten Broeck mine.

In at least two places, the Little Kate mine on Basin Creek and on the east slope of Lewis Mountain, the contact of the diorite with the enclosing rocks is marked by a coarse breccia that is unlike any other seen in the district. Similar breccia may occur in other places where it is not exposed. The distribution and areal relations of the Little Kate breccia body are shown in figure 47, and a polished specimen of the material is pictured in plate 8*C*. This irregular body is 2,200 feet long and 200 to 650 feet wide and is exposed through a vertical range of more than 600 feet. The breccia is chiefly composed of angular to slightly rounded fragments of sedimentary rocks and of porphyry, in a matrix of similar but finely comminuted rocks. Fragments of diorite are present locally but are less abundant than the other rocks. In some places the contact between breccia and country rock is sharply defined or is marked by a vein, but in most places it is gradational. Most of the breccia is made up of fragments of the immediately adjacent country rock. Several large unbroken blocks of rock occur within the breccia mass, and dikes and irregular bodies of diorite cut it in places.

Dark-green chlorite is more abundant in the breccia than it is at any other place in the district. Some of it forms flakes and veinlets in interstices between the breccia fragments, but some of it replaces the dark minerals of the diorite and porphyry. All the fragments of sedimentary rocks seen in the breccia are silicified or otherwise metamorphosed; the other fragments are not silicified except near veins.

Hematite, magnetite, chalcopyrite, and pyrite are widely disseminated throughout the breccia and are especially abundant between the breccia fragments. They occur for the most part as minute crystals or irregular masses, but the crystals of chalcopyrite and hematite are locally as much as half an inch in diameter.

In some places, calcite forms irregular lenses as much as 6 inches thick.

The breccia on Lewis Mountain is similar to that described above, but there much of the matrix consists of unbrecciated diorite.

A large body of metamorphic rock that represents a border phase of the syenite stock is exposed in and near the Copper Hill mine workings, between Boren and Bedrock Creeks. This rock contains platinum-bearing chalcopyrite and constitutes the ore of the Copper Hill mine, described on pp. 64–65. It is a dark greenish-brown to gray, massive and tough rock with a somewhat greasy luster. In places its distinct layering gives it the appearance of a stratified sedimentary rock (pl. 8 *A*). Under the microscope it is found to consist of fairly distinct alternative layers of finely to coarsely crystalline feldspar and of small bladed augite crystals. Grains and crystals of quartz, apatite, and sphene occur in subordinate amount, but all are much more abundant than in the typical syenite. Except for grain size and thickness of the individual layers this rock is similar to the augite-feldspar dikes and veins that cut the main mass of the syenite (p. 38).

The relations between a large tongue of the monzite stock and the country rocks are excellently exposed near the head of Boren Creek (pl. 4). When the almost barren exposure is viewed from a distance it seems to consist mainly of sedimentary rocks, for it shows a well-marked layering that resembles "stratification" and accords with the regional structure. Closer examination reveals, however, that at least half the mass is made up of a network of dikes, sills, and irregular bodies of monzonite, which have not disturbed the attitude of the beds. In some places the contacts are sharply defined, but in several places the country rock is cut by a network of highly irregular veins of monzonite (pl. 9). Some of the feldspar crystals that make up these veins are minute, while others are nearly as wide as the veins. Many of the veins pinch out within short distances along the projected continuation of several of the veins. Numerous microscopic feldspar crystals are scattered through the silicified sedimentary rock.

Relations similar to those just described were also observed along the south edge of the Lewis Mountain diorite stock and near the syenite body on the ridge between Bedrock and Madden Creeks, close to the La Plata River. On the upper part of this ridge, above an altitude of 10,700 feet, the rock mapped as syenite contains much fine-grained to medium-grained quartz, and locally it consists of quartzite enclosing scattered crystals of feldspar.

As seen in the field, both diorite and monzonite seem in places to grade imperceptibly into diorite-monzonite porphyry. This gradation may be observed in one large sill on the east side of Banded Mountain, and in several of the dikes and sills south of Babcock and Spiller Peaks. It is shown also in the thick sill that crops out a few hundred feet north of Diorite Peak and in the larger dikes that extend east of the Lewis Mountain stock. Similar gradations probably occur in other places. An apparently distinct gradation in texture also can be made out in the field. Thin sections, however, of a series of specimens taken from two of the larger sills that exhibit these gradations in composition and texture, all proved to be of typical diorite, typical monzonite, or typical porphyry, none of them exemplifying intermediate varieties. Such varieties might be found by studies of a more complete suite of specimens.

Both of the syenite stocks are shown in plate 2 as cutting many bodies of porphyry. So far as could be determined, however, all these contacts are gradational; no clean-cut contact of syenite and porphyry was seen anywhere. A specimen that exemplifies the usual relations between these rocks is illustrated in plate 8 *B*. The specimen was taken near the east bank of the La Plata River, opposite the town of La Plata. At this place a gradational zone, 200 feet or more in width, intervenes between porphyry on the downstream side and typical syenite on the upstream side. In most exposures it is difficult to determine whether the rock is syenite or porphyry, but in the rock shown in plate 8 *B* the porphyry obviously forms rounded residual masses that grade into the finer-grained and more even-grained syenite by which they are surrounded. Several ghosts of original phenocrysts can be seen in the syenite.

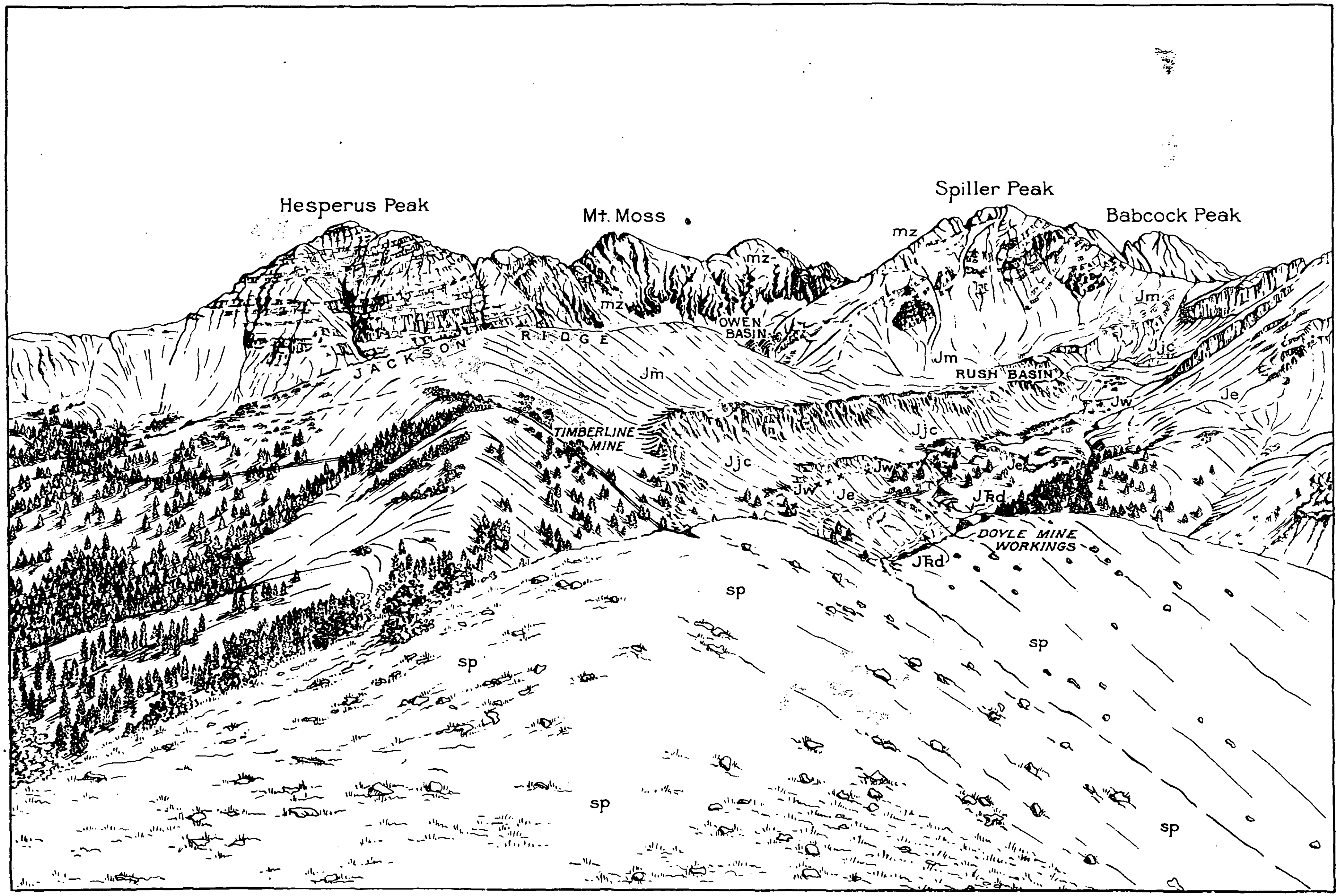
ORIGIN

Much of the evidence presented in the preceding paragraphs indicates that the nonporphyritic rocks made room for themselves in part by replacing or assimilating the country rocks, rather than wholly by mechanical intrusion. The mere presence of numerous dikes or even of veinlets of intrusive rocks in any one area is not in itself a proof of a replacement origin, as it would be perfectly reasonable to infer that the country rocks were forced apart by the intrusive magma. For stocks the size of those under discussion, however, the latter mode of origin would necessitate enormous dilation of the country rocks. The relations of the igneous rocks to the regional geologic structure are described in a later section, but it can be stated here that preexisting structures were not disturbed by the intrusion of the syenite, monzonite, and diorite stocks as they were by the intrusion of porphyries. The effects of the two types of intrusion on the structure are shown schematically in figure 3. Many of the veinlets of igneous rock contain crystals too large to have been forced in along the narrow fissures, and in many places the silicified sedimentary rocks contain scattered feldspar crystals. Neither of these facts can be explained as the result of simple physical intrusion; both imply chemical action.

Gradation between diorite-monzonite porphyry and syenite is clearly established, and there is much evidence

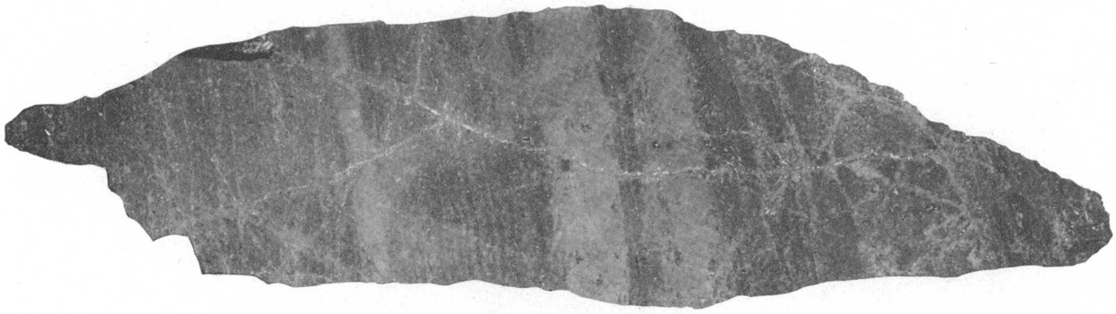
A. VIEW SHOWING A PART OF THE STEEP FOLD THAT CHARACTERIZES THE LA PLATA DOME.

At the extreme right, the beds dip steeply toward the west but on Jackson Ridge they are nearly horizontal. View looking northeast from Helmet Peak toward Spiller and Hesperus Peaks.



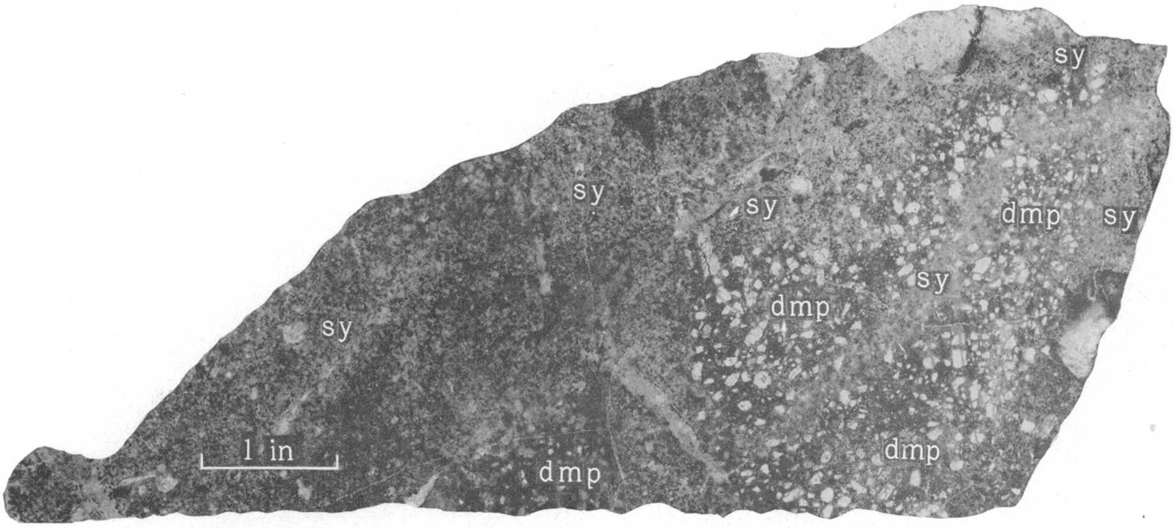
B. SKETCH OF THE VIEW SHOWN IN PLATE 7 *A*, EMPHASIZING IMPORTANT GEOLOGIC FEATURES.

JR̄d, Dolores formation; Je, Entrada sandstone; Jw, Wanakah formation; Jjc, Junction Creek sandstone; Jm, Morrison formation; mz, monzonite; sp, disintegrated syenite porphyry.



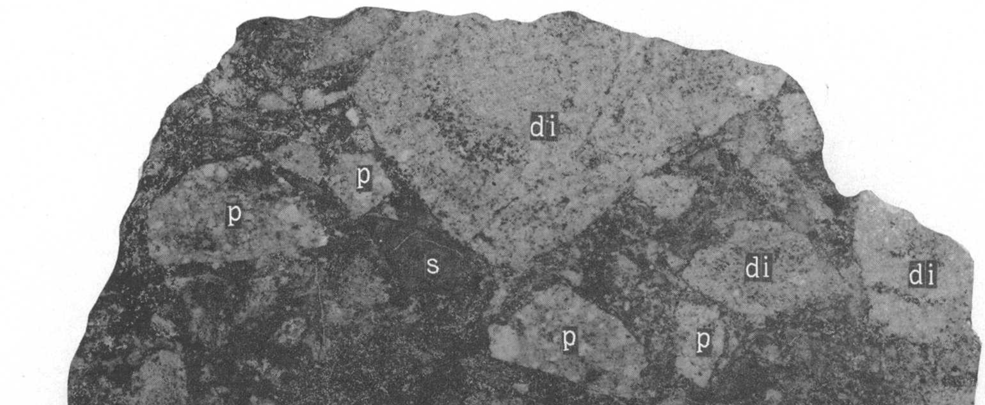
A. POLISHED SLAB OF LOW-GRADE COPPER-BEARING AND PLATINUM-BEARING METAMORPHIC ROCK FROM COPPER HILL GLORY HOLE.

The light-colored layers consist of feldspar, the dark ones of fine crystalline augite. The veinlets and the disseminated grains are largely chalcopyrite. Two-thirds natural size.



B. PHOTOGRAPH OF SPECIMEN OF DIORITE-MONZONITE PORPHYRY PARTLY REPLACED BY SYENITE.

dmp, Diorite-monzonite porphyry; *sy*, syenite. Ghosts of original feldspar phenocrysts can be seen in several places, especially in the indistinct "vein" of syenite that appears in large porphyry remnant at right. Specimen from near La Plata River, opposite La Plata.



C. POLISHED SLAB FROM BRECCIA BODY NEAR LITTLE KATE MINE ON BASIN CREEK.

Fragments of diorite (*di*), porphyry (*p*), and sedimentary rock (*s*), in a matrix of fine-grained rock. The dark grains are largely chlorite, magnetite, and specular hematite.

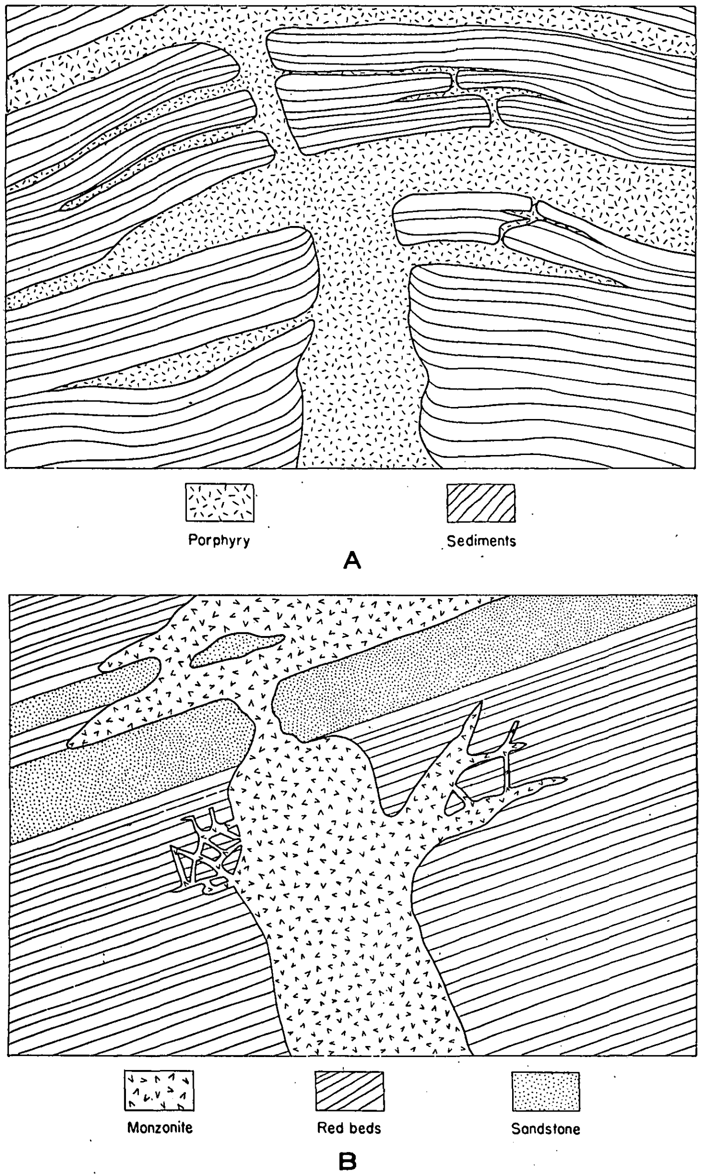


FIGURE 3.—Schematic sections showing relations of igneous rocks to structure and to country rocks.

A. Section through porphyry stock and associated sills. Beds have been dragged upward in walls of stocks and domed by sills. The sill in lower left depressed the beds beneath it.

B. Section through monzonite stock. Existing structures are not disturbed and stock narrows where it passes through thick bed of sandstone.

of similar gradation between porphyry and monzonite or diorite. These relations, too, can best be explained by chemical replacement; especially as in all observed rocks the porphyry is more strongly altered, and hence presumably older, than the nonporphyritic rocks.

As most of the inclusions are of sandstone, and as the stocks narrow where they cut sandstone beds, it is clear that siliceous rock was not easily digested by the stock-forming magmas. The rounded pebbles of quartz and quartzite that are found in parts of the stocks could only have been derived from conglomerates such as those that characterize the Cutler formation; the fine-grained matrix has been removed, having evidently been attacked more freely by the magmatic emanations than were the siliceous pebbles. This difficulty in digesting silica might be expected in view of thorough silicification of the country rocks that accompanied the formation of the igneous stocks.

Fragments of granite and hornblende gneiss of pre-Cambrian origin are less abundant in the diorite stocks than in several of the porphyry bodies, although many of the latter contain no inclusions. No genetic significance, therefore, can be attached to these inclusions on the basis of available data.

In places the monzonite stock enclosed large inclusions of sandstone that retain the position and attitude of the beds from which they were derived. In these places, at least, it seems evident that the country rock was not pushed aside or upward by the invading magma. This relation also indicates that the monzonite was not emplaced by stoping, for if stoping had taken place on a large scale there surely should be some inclusions that do not accord in attitude with the immediately adjacent country rock.

The chief evidence against the suggested replacement origin is found in the breccia that borders the diorite stock near the Little Kate mine. The rounded shape of most of the breccia fragments and the presence of fragments of porphyry, diorite, and sedimentary rock indicate clearly that the breccia was formed by mechanical means. The fact that the breccia is cut by diorite dikes shows it to have been formed at the same time as the diorite stock. Perhaps this brecciation is evidence of structural conditions that controlled and guided the replacing solutions; recurrent brecciation of the country rocks, caused by pressure from the underlying magma, may have played an important if not vital part in allowing access of the magmatic solutions.

Further field and laboratory studies would doubtless add much information regarding the origin of the nonporphyritic rocks, but the facts now at his disposal lead the writer to the belief that these rocks were formed in large part by reactions between the country rocks and liquid magmatic emanations. Mechanical disruption of the preexisting rocks, though subordinate in importance to the chemical processes, was probably a highly necessary adjunct to them.

METAMORPHISM OF COUNTRY ROCKS

Widespread metamorphism of the country rocks accompanied the emplacement of the nonporphyritic rocks and even affected the syenite itself. Except near veins, the diorite and monzonite are very fresh, alteration being essentially confined to slight kaolinization and sericitization of the feldspars. The syenite, on the other hand, is strongly altered in many places. As noted above, the feldspars are nearly everywhere cloudy, and locally they are almost completely altered to sericite or to calcite. The augite and other dark minerals are frequently represented only by spots of limonitic material. Whether this alteration is due to endometamorphism during formation of the syenite or indicates that the syenite is somewhat older than the diorite and monzonite, and so has been weathered longer, is not known.

The area within which most of the country rock is metamorphosed is indicated on plate 2. The northern part of this irregular area is obviously closely related to the diorite and monzonite stocks. Southward it encloses the syenite stocks and extends down the La Plata River nearly 2 miles below the most southerly exposure of syenite. The only pronounced reentrant in the metamorphic area includes the greater part of the Lewis Creek drainage basin. Outside of this area the rocks are bleached and slightly altered in places, but otherwise they are generally unaltered.

Within the metamorphic area the porphyries are more strongly sericitized than elsewhere, though locally the sericite is displaced by chlorite or calcite. Fine-grained quartz, pyrite, and clay minerals have been developed in many places, but they are almost without exception related to the ore deposits rather than to the metamorphism.

Nearly all the sedimentary rocks in the central part of the district have been strongly metamorphosed. The prevailing red colors have been lightened to pale pink, or brown gray, the rocks have been rendered hard and erosion-resistant, and many of the distinguishing features of the formations have been almost obliterated. Silicification has been the dominant process, and the sandstones have been changed to dense, hard, light-colored quartzite. Shales and mudstones have been altered to hornfels made up chiefly of fine-grained quartz, intergrown with varying porportions of sericite, epidote, pyroxene, and other silicates. The carbonaceous shales of the Mancos and the coaly beds of the Dakota (?) have locally become graphitic. Limestone beds and limy nodules in the redbeds are characteristically represented by intergrowths of coarse calcite with typical "contact-metamorphic" minerals. In some places these minerals are chiefly dark reddish-brown garnet and green augite, hornblende, and epidote; elsewhere magnetite and specular hematite predominate, almost to the exclusion of silicates. A little pyrite and less chalcopyrite are locally associated with the iron oxides. Tremolite, apatite, wollastonite, and probably vesuvianite are present in places. Widespread introduction of pyrite followed the metamorphism whose results have just been described. The places at which pyrite is most abundant are on Jackson Ridge, near the heads of Boren and Bedrock Creeks, and on the westward slopes of Deadwood Mountain. As gold is associated with most of the pyrite, discussion of these occurrences is reserved for the section on ore deposits.

A close relation between metamorphism and the emplacement of the granular stocks is indicated by several lines of evidence. That the metamorphism took place after the intrusion of the porphyries is proved by the facts that the porphyries themselves are altered, whereas, except in the central part of the district, the sedimentary rocks in contact with the porphyries are unaltered. Furthermore, the extensive silicification of the sedimentary rocks, attended by greatly increased competence, must have taken place after the formation of the La Plata dome, for otherwise the stresses occasioned by the dome-forming intrusions of porphyry would have resulted in faults instead of in folds. If, as the writer believes, the later stocks were formed by replacement of the country rocks, it seems hardly possible that the silicification could have preceded the intrusion of the stocks, for there would then have been little opportunity for replacement by the magmatic emanations. Some of the metamorphism of the enclosing rocks may have been accomplished merely by heat, rangement of the chemical constituents of the country rocks. Thus it seems possible that much of the iron in the magnetite and specularite was derived from the redbeds themselves and that the silica in the metamorbut the process of replacement must have been attended by much transfer of material, either in liquid or in gaseous form. There was probably also much rearphic rocks may have been released from the sedimentary rocks that were replaced by syenite, monzonite, and diorite. The pyrite deposits probably represent a late, low-temperature phase of the general metamorphic process, which was closed by the introduction of the telluride ore deposits. The platinum-bearing chalcopyrite deposit of Copper Hill may have been formed contemporaneously with the pyrite deposits.

AGE OF IGNEOUS ROCKS

There are no means of dating the La Plata intrusive activity more closely than by saying that it took place during late Cretaceous or Tertiary time. The similarity in form and composition of the rocks in both the La Plata and the Rico domes with the late Cretaceous or early Tertiary rocks at Ouray [37] strongly suggests that all three groups are of the same age. It is almost as likely, however, that the several intrusive groups are of greatly different ages, and that the intrusions of the La Plata Mountains took place in Miocene time, during the main period of volcanism in the San Juan region. It certainly preceded the formation of the San Juan peneplain, which took place at the end of the Tertiary period, for pebbles of porphyry that must have come from the La Plata Mountains occur in the gravel on remnants of this peneplain far to the southwest.[38]

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[37] Burbank, W. S., Revision of geologic structure and stratigraphy in the Ouray district of Colorado and its bearing on ore deposits: Colorado Sci. Soc. Proc., vol. 12, pp. 193–206, 1930.

[38] Atwood, W. W., and Mather, K. F., Physiography and Quaternary geology of the San Juan Mountains, Colo.: U. S. Geol. Survey Prof. Paper 166, p. 67, 1932.

STRUCTURE

GENERAL FEATURES

The most pronounced structural feature of the La Plata Mountains (pl. 2) is a domal uplift of the sedimentary beds, about 15 miles in diameter, which blends somewhat into the southwestern flank of the much broader San Juan uplift. This dome is partly bounded by a steep, horseshoe-shaped hinge fold, open at the south, which nearly encircles the central part of the mountains. On the south side of the hinge, and along the northern and northwestern margins of the dome, there are several strong faults along which the rocks in the central part of the dome were uplifted. The formation of these major structural elements was contemporaneous with and resulted from the porphyry intrusions, and it preceded the emplacement of the granular stocks and the metamorphism. Numerous short, discontinuous faults of small displacement were formed during the doming process. Many of them trend east, but some radiate from the center of the dome. After the emplacement of the nonporphyritic stocks, some of these faults were reopened and other similar faults were formed, which became the loci for many ore deposits.

FOLDS

The domal structure of the La Plata Mountains is apparent from the areal distribution of the sedimentary rocks (pl. 2) and is clearly shown in the cross sections. Beyond the limits of the dome, which is roughly 15 miles in diameter, the beds dip about 5° toward the south and southwest. This regional dip is a part of the main San Juan uplift, which centers far to the northeast.

In plan, the La Plata dome is somewhat elongate toward the northeast. It appears also to be unsymmetrical in section, as the beds are higher in the northern and eastern parts of the district than they are in the southern and western parts. This asymmetry is due to the fact that the dome is superimposed on the gentle southwestward regional dip just mentioned. If the sections are rotated through this small angle, they are more nearly symmetrical with respect to the horizon.

As can be seen in the cross sections (pl. 2), the base of the Dolores formation has been elevated in the center of the dome nearly 6,000 feet above its normal position. The lower formations have been domed less than the upper ones because each of the porphyry sills has raised all the beds above it.

Although the dome is nearly symmetrical in section when viewed broadly, it is not so in detail. From the outskirts of the dome, the rocks rise gradually toward the center, with dips of 5° to 20°, until they reach the steep hinge fold that is the most striking feature of the structure. The position and shape of this fold can be made out on the geologic map (pl. 2) by noting the relations of the sedimentary rocks to the topography and to the distribution of symbols that show steep dips. Views of parts of it are shown in plates 6 *A* and 7. The zone involved in this hinge fold is 1,000 to 3,000 feet in width, is irregular in plan but has the general shape of a horseshoe, with the open end toward the south. It follows the east bank of the East Mancos River from the vicinity of Madden Peak to Rush Basin, passes through Babcock Peak, and crosses the divide between Basin and Bear Creeks a short distance east of Mount Moss. There it swings eastward, crossing Indian Trail Ridge at the head of Fly by Night Gulch, and it can be traced through the central part of Columbus Basin. Just northeast of the Columbus mine it turns abruptly south along the east slope of Lewis Mountain and crosses the head of Walls Gulch. It is well-marked on the ridge between this gulch and Lightner Creek but dies out between that ridge and the Silver Mountain stock.

Along this hinge zone the beds generally dip outward at angles of 25° to 60°. Individual beds are thus elevated as much as 1,000 feet in horizontal distances of 2,000 feet or less. Both inside and outside of the hinge the beds flatten abruptly, and locally there is a minor syncline along the outer edge. In places the rocks are sheared and brecciated along the fold and, as shown on the geologic map, many of the ore-bearing fractures are concentrated within or near it. The hinge fold is most strikingly exposed on the ridge between Spiller and Burwell Peaks (pl. 7) and on the east side of Lewis Mountain, but it can be made out rather clearly throughout its extent. It shows clearly in some cross sections, such as AA′ and CC′, plate 2, but it does not show in some others, such as BB, plate 2. This difference in expression is partly due to the fact that the steepness of the fold varies from place to place, and partly to inaccuracies in the topographic base map, which preclude accurate plotting of the geologic features.

The hinge does not continue as a structural unit along the south edge of the dome. There, the upward rise of the rocks toward the center is distributed between moderately steep dips and several strong east-west fault systems, and the structural relations are further complicated and obscured by numerous highly irregular bodies of porphyry.

In general, the rocks inside the hinge fold rise gradually toward the center of the dome, which lies near the junction of Lewis Creek with the La Plata River. Within the dome, however, there are many local folds of varying degrees of magnitude. Most of them, if not all, can be attributed directly to the influence of porphyry bodies.

FAULTS

GENERAL RELATIONS

Most of the ore deposits are closely associated with faults, which are thus of the greatest economic importance. Compared with folding, however, faulting played a minor part in the growth of the La Plata dome. In general, nearly all of the faults fall into two groups: one is classed here as "barren" and the other as "ore-bearing." Members of the first group, though mineralized in places, are not known to contain workable bodies of ore, whereas the second group contains most of the district's ore deposits. The essentially barren faults are older than the ore-bearing faults and are characterized in general by much larger displacements. They are almost entirely confined to the northwestern and southern outskirts of the dome, while the ore-bearing fractures are widely distributed.

All the known faults are shown in plate 2 or on the various mine maps. The mapped faults are believed to include nearly all of those in the district, but some faults, even of large displacement, may have been overlooked because they failed to displace any prominent horizon marker. With two exceptions, all the "barren" faults shown in plate 2 are in places where the Pony Express limestone member of the Wanakah or some other easily recognized rock unit is exposed.

BARREN FAULTS

Central part of district.—Of the two so-called barren faults in the central part of the district that are shown in plate 2, only one (the one on the ridge southwest of Diorite Peak) is definitely known to be barren. As this fault is unimportant except for its effect on the ore deposits of the Black Diamond mine, it will be described in connection with that mine. The other of these two faults is on the ridge between the La Plata River and Lewis Creek. As it is poorly exposed and has never been explored by prospectors, nothing is known of it except that its downthrow is on its northwest side.

Northwestern part of district.—A group of strong faults extends along the northwest and north sides of the dome (pl. 2). The most prominent of them strike northeast to due east; some of them can be traced for several miles. Along most of them the downthrow is on the north side away from the center of the dome. Vertical displacements on them range from several tons to several hundreds of feet. These main faults are connected by a few cross faults. Little is known as to the character of the faults of this group except that they are nearly vertical and that the curving courses they show on the map are due to actual changes in direction rather than to the influence of topography. Most of them are probably similar to the fault explored by the Euclid mine near Sharkstooth (No. 25, pl. 1). That fault is marked by a 1-foot to 3-foot zone of gouge and breccia, and its wall rocks are sheared and fractured over a width of at least 50 feet. As noted in the description of the Euclid mine, some ore occurs along and near this fault zone. The other faults of this system show no evidence of mineralization so far as known, but they have received scant attention from prospectors.

Southern part of district.—A series of strong faults trending nearly due east crosses the southern part of the dome and closes the open end of the horseshoe-shaped hinge fold described above. The most prominent members of the series fall into two parallel systems, known as the May Day-Idaho and the Parrott faults. A strong tendency toward parallel alinement here characterizes all the structural features; most of the porphyry dikes trend east and west, probably along faults of comparatively small displacement. There may be many other small faults here that were overlooked in mapping because they are not marked by porphyry or ore deposits. As a group, these faults raise the beds toward the center of the dome, thus having the same general effect as the hinge fold.

The Parrott fault system is strongest and best exposed on the ridge between Parrott and Madden Peaks, where it has a downthrow on the south of about 1,000 feet and brings the Dakota (?) against the upper beds of the Dolores formation. Two main splits can be traced westward to the divide between the East Mancos River and Starvation Creek, but the displacement diminishes rapidly in this direction, and no fault of any considerable displacement can be found along the East Mancos. West of the mapped area, however, the Menefee fault, as mapped by Cross,[39] is almost directly in line with the Parrott system. In the interval between the Menefee and Parrott are a few small step-faults, such as the one followed by the Red Arrow vein, but their aggregate displacement probably amounts to only a small percentage of the displacement near Parrott Peak.

The two main splits of the Parrott fault can be traced eastward for several thousand feet from the type locality, but in this direction also the displacement diminishes greatly within a short distance. The most extensive branch can be traced eastward to the lower part of Bragdon Ridge, east of the La Plata River, where it clearly dies out for it cannot be traced any farther east despite the relatively good exposures in many parts of the Burnt Timber Creek drainage basin. A strong shear zone that cuts the large porphyry mass along Burnt Timber Creek is probably a continuation of the Parrott system, though the displacement along it is certainly less than 200 feet (section BB′, pl. 2).

Much of the ore produced by the Lucky Discovery mine was taken from a split of the Parrott system known as the Nettie fault. The showings of gold ore in the Kiabab and Billings properties farther west are closely related to this fault; and so, probably, is the Comstock deposit, though it occurs in a northward-trending vein. No other ore deposits are known to be associated with the Parrott system, unless the Red Arrow and nearby veins also be considered parts of it.

The actual fault contacts are poorly exposed in most places, and little is known of their character. Their

[39] Cross, Whitman, Spencer, A. C., and Purington, C. W., op. cit. (La Plata folio).

dips are certainly steep if not vertical. By analogy with the May Day-Idaho system it may be supposed that they are marked in most places by abundant gouge and breccia. This supposition is confirmed in part by observations of the Nettie fault in the Lucky Discovery mine and of the heavy ground in and near some of the Kiabab openings. As noted in the section on igneous rocks, intrusive breccias are present in at least two places along the fault system, but their origin and significance are not entirely clear.

The reason for the abrupt termination of the major faults is not fully known. Some of the displacement was doubtless absorbed by compression of soft beds, and some of it by folding. An unknown proportion of the total displacement was almost certainly distributed along bedding-plane slips. None of them were seen along the Parrott system, but they are definitely associated with the similar May Day system. It seems possible, too, that preexisting eastward extensions of the Parrott fault were sealed or obliterated by later intrusions of porphyry. If that is true the shear zone is porphyry noted along Burnt Timber Creek must represent a fault that was reopened after the porphyry was emplaced.

The May Day-Idaho fault system, named for the mines in which it is most strongly developed and has been most thoroughly explored, trends nearly due east along the south side of the La Plata dome. Most of the faults of this system are barren of ore deposits, but for reasons that will be discussed in the description of the May Day and Idaho mines (pp. 143–149) they are believed to have played an important part in the localization of ore.

The block diagram of plate 26 *A* gives a generalized representation of the major aspects of the system as exposed in the mine workings. Many details of the structure are also shown on the structure sections (pl. 26 *B*) and on the geologic maps of the mine levels (pl. 25). In its type locality the system comprises two strong eastward-trending faults, the Idaho and the May Day. Their dips vary widely but are generally steep and toward the north. Both are reverse faults displacing the rocks downward to the south; a strong horizontal displacement, the south wall having moved east, is also indicated by the relations shown on the mine maps. The rocks have been dropped 50 to 100 feet along the Idaho fault and 300 to 375 feet along the May Day.

The system can be traced for a total distance of 10 miles or more, but nowhere is it as strongly developed as in the immediate vicinity of the May Day and Idaho mines. So far as can be determined, the two named faults die out completely a few hundred feet east of the May Day workings, but the movement is transferred to a parallel fault a short distance to the north. This fault, which dies out to the west of Ohlwiler Ridge, can be traced as far east as Deadwood Creek and locally contains a little ore and much carbonate. Between Deadwood and Lightner Creeks it is represented by an apparently discontinuous series of porphyry dikes, which clearly follow a single definite fracture zone, along which the displacement is almost certainly small. The several veins and faults in the Lady Maurine prospect on Lightner Creek are on the eastward extensions of the same fault zone.

West of the La Plata River the faulting appears to die out rapidly; in that direction, however, exposures are poor and there are no recognizable marker horizons except the base of the Dakota (?) sandstone. In and near the Jumbo-Morovoratz mine, several segments of the faults have been found, but all of them have small displacement. On the southeast slope of Parrott Peak, segments were identified and mapped with certainty and several probable faults were mapped on the basis of physiographic evidence (pl. 2). The land surface is characterized by a series of eastward-trending ledges, separated by horizontal steps or by swampy depressions. It seems likely that this topography expresses a series of step faults, each of which has dropped the beds a few feet to the south. Subsequent erosion has carved the ledges from the basal Dakota (?) and from sandstone beds in the upper part of the Morrison formation.

On the ridge east of Starvation Creek, only one fault, with a displacement of 30 feet, cuts the Dakota (?) sandstone. Between Starvation Creek and the East Mancos River, west of the area shown in plate 2, several prospect pits expose eastward-trending shear zones in the Dakota (?) and Mancos beds. These zones line up with the projection of the May Day-Idaho fault system, but no actual displacement of the beds could be discovered.

Several irregular dikes and sills of porphyry are exposed in the May Day and Idaho mine workings and on the surface. They are shown on plate 25 but not in plate 26. The most continuous of these bodies follows the Idaho fault for at least half its length and is known as the Idaho dike. It consists of typical diorite-monzonite porphyry, which is nearly everywhere sheared and strongly altered. It is highly irregular in form, and most of its exposed contacts are faults marked by more or less abundant gouge.

In places the displacement along the May Day-Idaho faults, as seen in the mines, follows single fracture planes; elsewhere it is distributed along several splits. Near the junction of the fault with the May Day vein, where the faults are only a few feet apart, the rocks between them are much broken and jumbled. In other places the fault planes are more distinct and are marked by zones of gouge or breccia from an inch to more than 10 feet in width. As would be expected, brecciation is most extensive where the wall rocks are brittle sandstone or limestone and least so where they are soft shale. There is considerable evidence that the structure is locally complicated by bedding-plane slips, but their distribution and relative importance has not been determined. A good example of such a slip is exposed near the portal of the Idaho No. 1 tunnel (pl. 25, insert sketch).

Nearly all the slickensides seen on the fault planes indicate that the last movement was horizontal, with the south walls moved east, but there are many reasons for believing that the main movement was vertical or inclined steeply to the east on the south walls of the faults. Since the evidence for this belief rests largely in the relations of the ore deposits to the faults, further discussion is reserved for the description of the mines.

The structural relations are not completely understood. Nearly all the slickensides seen on the fault planes indicate that the last movement was horizontal and that the south walls moved relatively eastward, but there are reasons for suspecting that the main movement may have been vertical or inclined steeply to the east. Further discussion is reserved for the description of the mines.

Evidence presented in the mine descriptions indicates clearly that the May Day-Idaho faults are older than the ore deposits and nearly contemporaneous with the porphyry intrusions that formed the La Plata dome. The Idaho dike is mineralized in places and certainly was intrenched before the last period of movement along the Idaho fault. It may have been intruded during the main period of east-west faulting and its irregular shape may be due in part to movements that took place while the magma was still semimolten.

ORE-BEARING FAULTS AND BRECCIA ZONES

Many faults and fractures along which the rocks are displaced from a few inches to 75 or 100 feet occur throughout the district, and two broad breccia zones occur in the central part. The effect of these features on the structural pattern is relatively slight as compared to that of the folds and the strong barren faults described above. They are, however, of much greater economic importance than the other structural features, for, though relatively few of them contain workable deposits of ore, most of them are mineralized to some extent.

These faults and mineralized fractures, which are designated in plate 2, are comparatively few and far between in the central and outer parts of the district, but they are numerous and closely spaced along and near the hinge fold that encircles the central part. They show a slight tendency toward radial arrangement with respect to the La Plata dome. The majority trend northeast to east, though several of them, particularly in the southern part of the district, trend nearly due north, and a few on Jackson Ridge and elsewhere trend northwest.

Most of the faults of this class are considerably less than a mile long, and many of them extend only a few hundred feet. A few individual veins, such as the Black Diamond vein and several of those in the upper part of the Bear Creek Basin, can be traced for more than a mile. More commonly, however, the longer fault zones are made up of a series of overlapping fractures. This kind is best exemplified by the Cumberland vein system, characterized by the presence of ruby silver ores, which extends from the head of the La Plata River as far east as Fassbinder Gulch. The same tendency toward overlapping arrangement can be seen in the groups of fractures explored by the Ashland-Ten Broeck, Gold King, and Durango Girl mines along Lewis Creek and in Walls Gulch, by the May Day, Idaho, Lady Eleanora, and other mines in the southern part of the district, and by the Daisy-Hibernia group at the head of Lightner Creek. Some individual faults in these and other groups die out completely along their strike, or fray out in a series of minor fractures, or pass into local folds. The displacement on others is transferred, along cross faults, to parallel members of the system.

So far as can be determined, displacements of more than 30 feet are rare along any of the ore-bearing faults, and no displacements of more than 100 feet are known. Most of the faults are normal, but there are a few reverse faults. There is some reason to believe that the fault followed by the Columbus vein is a hinge fault, having displacements in opposite directions at the two ends, but it is possible, as shown in the description of the Columbus mine, that the ore deposit follows segments of two separate faults that cross each other at a small angle.

Like the barren faults, the ore-bearing faults cut every kind of rock that occurs in the district, but they are more numerous, and are characterized by stronger shear zones, in the harder and more brittle sandstones and igneous rocks than they are in the less competent shaly beds. The difference is due largely to the fact that the shaly rocks yielded to stresses by folding rather than by faulting. The Century vein offers an extreme example in this regard. This vein, which follows a strong breccia zone, cuts the massive Entrada and Junction Creek sandstones but stops abruptly at the contact of the overlying shale members of the Morrison (McElmo). This example is particularly illuminating because all the rocks near the Century are now thoroughly silicified and hence almost equally brittle. Clearly, therefore, the Century fault was formed before the period of silicification. The age relations of the faults to other structural features are further discussed below.

Because of the generally small displacements along these faults it is difficult or impossible to recognize them in places where they are not mineralized or where good marker beds are lacking. Many faults may therefore have been overlooked, but plate 2 probably gives a fairly true picture of their general distribution.

There are many differences in character between one fault and another, and even between parts of the same fault. The characteristics of many faults are described and illustrated somewhat fully in the mine descriptions in the latter part of this report. All the known faults range in dip from 35° to 90°, and most of them dip at angles of 65° or more. Abrupt changes of dip and of strike are characteristic of many of them. Some of them split in places, and in the Gold King and Neglected mine and elsewhere the splits reunite within short distances, enclosing blocks or "horses" of country rock. Other splits diverge from the main faults and die out in the walls.

Although a few faults are marked by clean-cut fracture surfaces, most of them consist of zones of sheared or brecciated country rock from a few inches to more than 15 feet in width. Gouge is present along one or both walls of many of them and is especially abundant along some of the strong barren faults described above. It is a somewhat remarkable fact that throughout the district most of the slickensided surfaces seen on fault planes indicate nearly horizontal movement. This is so even where there is direct evidence that the main displacement was nearly or quite vertical. Well-exposed slickensided surfaces are indeed so few and so widely scattered that no reliable conclusions can be drawn, but it seems likely that the last disturbance in the La Plata Mountain area took the form of slight horizontal quivers, principally in an east-west direction.

Two extensive breccia zones have been observed in the central part of the district, and a smaller one is exposed in the Gold King mine. The two larger ones are ill-defined and are not shown on plate 2, although many of the stronger fractures within them have been mapped. One of the zones extends northeastward along the ridge between Gibbs Peak and Spiller Peak and includes the upper parts of the Bedrock Creek and Boren Creek drainage basins. The other extends from Burnt Timber Creek to Baker Peak, crossing Bragdon Ridge a short distance below the top of Deadwood Mountain. Within these zones the rocks are weakly sheared and brecciated along numerous fractures and minor faults, a few of which are very extensive. Most of them trend northeastward. Pyrite and chalcopyrite are widely distributed throughout the breccia zones, being particularly abundant in and near the fractures. Some of the fractures contain sufficient gold to be workable, at least in their oxidized parts.

Some of the most productive deposits in the district, including the Gold King, Incas, May Day, and Idaho, lie along the continuations of the Baker Peak-Burnt Timber Creek breccia zone. It seems likely, therefore, that this zone, and perhaps the Gibbs Peak-Spiller Peak zone, are upward extensions of major rifts in the basement rocks through which the ore solutions gained access to the higher rocks.

Little is known about the shape of the breccia body in the Gold King mine. Evidence is presented in the description of the mine that the formation of the breccia preceded the emplacement of the porphyry sills and of the ore deposits.

ORIGIN OF STRUCTURAL FEATURES

The greater part of the structural doming in the La Plata Mountains was caused directly by the intrusion of sills and other bodies of porphyry. Local evidences of this relation can be seen in innumerable places throughout the district. Nearly everywhere the sedimentary layers are domed above individual sills (fig. 3). Locally the sills swell downward rather than upward, and the underlying rocks are depressed, but this type of displacement occurred on a smaller scale than the doming. Some crosscutting bodies turned the surrounding beds upward very steeply before breaking through them. The cumulative effect of the intrusion of all the porphyry masses resulted in the formation of the La Plata dome.

As shown in section BB′, plate 2, the sills exposed in the central part of the dome have a total thickness of about 2,500 feet. Nearly half of the 6,000-foot uplift of the base of the Dolores is thus accounted for by sills that are actually exposed. Presumably the Hermosa and lower sedimentary beds that have not yet been exposed by erosion also contain intercalated sills. If the proportion of sills to sedimentary rocks is constant throughout the stratigraphic section, the aggregate thickness of porphyry is ample to account for the entire uplift. If, on the other hand, less porphyry is associated with the Hermosa beds than with the Cutler and younger ones, it is necessary to suppose that before or during the porphyry intrusions the basement rocks were pushed upward by some localized force. The latter supposition gains some weight from the fact that an upthrust of this sort might readily produce the steep hinge fold, whereas it is more difficult to understand how the simple intrusion of porphyry bodies could achieve such an effect.

In places the rocks yielded to the uplifting forces by faulting rather than by folding. This faulting resulted in the strong barren faults in the northwestern and southern parts of the district. Many minor faults were formed at or about the same time as a result of the tensional stresses set up by the doming. These faults, some of which were later filled with ore in places, are most numerous along the horseshoe-shaped hinge fold, where the stresses were greatest. Some of them displaced all the rocks that they crossed, but others broke only the brittle rocks and produced folds or died out altogether in the softer, less competent rocks. The minor faults must have been formed about the same time as the major, barren faults. Had they been later, some of them should have crossed and displaced the barren faults.

Although most of the faults and fractures were formed contemporaneously with the folding and are thus of the same general age as the ordinary diorite-mozonite porphyry, faulting certainly preceded the emplacement of some of the porphyry bodies. As was pointed out in the description of the porphyry, the shapes of the porphyry bodies fail to match along the walls of many veins. The discrepancy may be large even where the displacement along the faults amounts to only a few feet. It is hardly necessary to add that all the dikes must have followed fractures of some kind. There is nothing to indicate that any considerable time elapsed between faulting and intrusion.

The spotted porphyry of the Burnt Timber Creek-Baldy Peak area is believed to be somewhat younger than the ordinary porphyry that occurs elsewhere in the district. The chief evidence in support of this view is that the largest and most numerous bodies of spotted porphyry occur along the southward continuation of the steep hinge fold, which dies out in this direction. They must therefore be younger in the main than the domal uplift caused by the ordinary porphyries. Further evidence that the spotted porphyry of the Burnt Timber Creek area is younger than the major structural features is afforded by the fact that many dikes of this trend eastward, parallel to the major faults in this part of the dome and that many bodies of the same rock appear to have obliterated traces of other fault zones.

The nonporphyritic rocks are unquestionably younger than the folds and faults that produced the La Plata dome. The attitudes of the country rock near the stocks were not disturbed by the intrusion, and moreover, the positions of the monzonite and diorite stocks and the west edge of the larger syenite body were obviously controlled in part by the steep preexisting hinge fold. The relations of minor, "mineralized" faults to the porphyry bodies and to the strong "barren" faults proves that many, if not most, of the minor faults also must have been formed before the emplacement of the nonporphyritic rocks. In places where the country rocks are thoroughly silicified, as in the Century mine, some faults affect only rocks that were originally brittle. If all these rocks had been silicified before the faulting occurred, the faulting would have affected them all in the same way; and as the regional silicification certainly accompanied and followed the formation of the nonporphyritic stocks, it follows that the faults are older than the stocks.

Renewed movement must have taken place along many faults and fractures after the formation of the stocks, probably because of slight settling and other crustal readjustment at the close of igneous activity. Many old fractures were reopened and new ones were formed, both within the stocks and elsewhere, and openings were thus provided for access of ore-bearing solutions.

Apart from very slight shearing, which locally resulted in slickensided surfaces along which ore minerals have been smeared, there is no known evidence of post-ore faulting. Several ore bodies stop abruptly where the veins that contain them intersect faults, but in nearly all such cases it can be shown that the faults were in existence before the ores were deposited, and that this guided and controlled the ore-bearing solutions.

PHYSIOGRAPHIC HISTORY

The carving of the present La Plata Mountains from the La Plata structural dome occurred in large part during Quaternary times. The form of the mountain mass has been determined by several factors, the most important of which were probably the domal structure of the rocks, the erosion-resistant nature of the central core and glaciation. By the beginning of the Quaternary, late Tertiary erosion had obliterated the greater part of whatever topographic expression the structural dome may have had. Erosion had cut deeply enough to expose some of the porphyry masses and to contribute pebbles and boulders thereof to the gravels that were spread far to the south on the gently sloping surface of the San Juan peneplain. Masses of resistant rock may have stood as monadnocks on the plain. A radiate stream system, consequent on the structural dome, had probably been initiated, and the La Plata River may already have become the dominant stream.

Early in Quaternary time a broad uplift of the entire San Juan region rejuvenated the streams and caused them to begin active downcutting, which they have continued, with interruptions, to the present day. The general form of the La Plata Mountains was probably blocked out rather early in Quaternary time, and the three glaciations only reinforced the work of the streams without producing a new drainage pattern.

The first, or Cerro, glacial stage was the most widespread, but it left little record in the La Plata area. Atwood and Mather[40] say of it:

> The record of Cerro glaciation on the southwestern front of the mountains is very meager. It is possible that no large bodies of ice were present there, although it is more likely that the apparent absence of glaciation is only apparent, being due to gaps in the record. On the west slope of the La Plata Mountains a piedmont glacier must have moved westward in the valley of the Middle Mancos River to a point at least 4 miles west of Helmet Peak.

The second, or Durango stage, is described by Atwood and Mather[41] as follows:

> The glaciers that formed in the La Plata Mountains during the Durango stage were in general somewhat more extensive than those of the Wisconsin stage, although in certain valleys, such as that at the head of the East Mancos River, no record of Durango ice was recognized by us. The glacier in the La Plata Valley was large enough to spread widely south of Parrott during Durango time; during the Wisconsin stage the glacier was a narrow tongue reaching less than a mile beyond Parrott. Again, the great basin southwest of Jackson Ridge and north of Helmet Peak [Echo Creek basin, pl. 2] was occupied by Durango ice, although it was not affected by glaciation during the Wisconsin stage.

[40] Atwood, W. W., and Mather, K. F., op. cit. (Prof. Paper 166), p. 83.
[41] Atwood, W. W., and Mather, K. F., idem., p. 81.

The largest Wisconsin glacier was that in the La Plata valley. It filled the whole central part of the mountain mass except for the highest peaks and ridges, and it carved all the cirques at the heads of the tributary streams. Ice also filled the valley of the East Mancos River at least as far downstream as Gold Run. Both forks of the West Mancos valley were glaciated at the same time, and so was the valley of Bear Creek, down which the ice extended several miles past the edge of the mapped area. The cirques at the head of the South Fork Hermosa Creek were partly excavated by ice. The basins at the heads of the Lightner Creek forks were carved by ice, and there is some reason to believe that the valleys of Junction Creek and its tributaries were glaciated. The drainage system of the Middle Mancos was not glaciated during the Wisconsin epoch, and the same is probably true of the headwaters of Starvation Creek.

To some extent, glacial sculpture has been modified by post-Wisconsin erosion, but it still dominates the topography in most of the district. The steep-walled cirques at the heads of many of the streams, the typical U-shaped cross sections of the main valleys, and the faceted spurs and hanging valleys along these valleys are all typical results of glaciation. Examples of these features are shown in plates 5, 6, 7, and 23. Glacial striae appear on many bare rock surfaces, particularly in the northern part of the district. The principal results of erosion since the retreat of the glaciers are the extensive accumulations of talus, the gorges cut in the glaciated floors of several of the main valleys, and deposits of stream gravels.

Relatively smooth surfaces cap the peaks and ridges in several parts of the La Plata Mountains. They were mapped by Atwood and Mather [42] as remnants of the warped San Juan peneplain. It seems more probable, however, that these surfaces resulted from ordinary processes of differential erosion, for almost all of them are dip slopes of resistant rocks, and the La Plata dome, formed before the peneplain, has since only moved as a part of the general San Juan uplift. The age relations of these surfaces to the glacial epoch are not known.

LATE GEOLOGIC HISTORY

SAN JUAN REGION AS A WHOLE

In order to understand the late geologic history of the La Plata Mountains, it is necessary to have some idea of the sequence of events that took place in the San Juan region as a whole. The following summary is based on the reports of Cross and Larsen [43] and of Atwood and Mather.[44]

[42] Atwood, W .W., and Mather, K. F., idem, pl. 2.

[43] Cross, Whitman, and Larsen, E. S., A brief review of the geology of the San Juan region of southwestern Colorado: U. S. Geol. Survey Bull. 843, 1935.

[44] Atwood, W. W., and Mather, K. F., Physiography and Quaternary geology of the San Juan Mountains, Colo.: U. S. Geol. Survey Prof. Paper 166, 1932.

Regional uplift that took place near the close of the Cretaceous period resulted in the formation of a broad dome, which was soon incised by erosion that cut deeply enough to reach the Paleozoic rocks and perhaps even to cut through them in places. Volcanoes first became active in very late Cretaceous or early Tertiary time. The intrusive quartz monzonite and associated ore deposits near Ouray [45] are the only known direct evidence of this volcanism, but volcanic rocks make up much of the fragmental matter in the McDermott formation (upper Cretaceous) and in the Animas formation (Cretaceous and Paleocene). The gradual decrease in the proportion of volcanic material in the formations observed as they are followed southward away from the mountains indicates that the main volcanic area was near the center of the San Juans. The overlying Wasatch formation contains few or no volcanic fragments, which indicates that the volcanic rocks were almost entirely destroyed by erosion after renewed uplift early in the Paleocene. Glaciers were present in parts of the area during the latter part of this erosion cycle, which was closed during the Paleocene by deposition of the Torrejon beds.

The region was again elevated and locally folded, and was then eroded to a surface of low relief, which in places cut across the beveled edges of the Cretaceous rocks. Along the southern slopes erosion reached at least as low as the Jurassic rocks and probably exposed the pre-Cambrian in places. The sands and gravels of the Blanco Basin formation and Telluride conglomerate were laid down on this surface, most probably during the Oligocene.

Volcanism again became active in Miocene time and continued, with many interruptions, into the Pleistocene or possibly even into Recent time. This later activity, which in many places was accompanied by ore deposition, built up a great complex volcanic pile, more than 100 miles across and many miles high, composed mainly of rhyolitic and andesitic lava flows. These rocks have been faulted, tilted gently to the east and north, domed, and deeply incised by erosion, to form the present San Juan Mountains.

The Miocene and post-Miocene volcanic activity was broken by several long intervals without eruptions, during which the lavas were actively eroded and canyons were cut. The longest of these intervals permitted formation of the San Juan peneplain, above whose gently rolling surface rose a few mountains or monadnocks 1,000 feet or more in height. The main uplift of the San Juan region, which followed the development of this peneplain, marked the beginning of Pleistocene (Quaternary) time. It took place in two main stages and a third minor stage and may not yet be complete.

[45] Burbank, W. S., Revision of geologic structure and stratigraphy in the Ouray district of Colorado and its bearing on ore deposition: Colorado Sci. Soc. Proc. vol. 12, No. 6, pp. 151–232, 1930; Structural control of ore deposition in the Uncompahgre district, Ouray County, Colo.: U. S. Geol. Survey, Bull. 906–E, pp. 189–244, 1940.

The first stage, called the Florida cycle of erosion, raised the central part of the region about 3,000 feet. Uplift was relatively slow so that the main streams were able to maintain their courses. They were rejuvenated and began to cut deep canyons and later to broaden their valleys, depositing their loads near the margins of the dome. A mature topography with broad valleys and low hills was gradually developed. Normal stream erosion was then interrupted by the Cerro glacial stage. The main valleys were filled with ice, and large glaciers moved outward from the central part of the region. These glaciers deposited moraines which have been much modified and for the most part removed by later erosion. Their outwash contributed to the Florida gravel, which now caps mesas and terraces lying halfway between the higher summits and the present streams. The Cerro stage was followed by the Canyon cycle of erosion, during which the range was again elevated and many great canyons were cut. The canyons were again filled with ice during the Durango glacial stage, and again moraines and outwash were deposited. The Durango stage was followed by slight uplift or doming, in consequence of which these Durango deposits now appear on terraces that are 100 to 300 feet above the streams. A third glacial stage, the Wisconsin, closely followed the Durango. The moraines that represent it are commonly upstream from those of the Durango glaciers and are well-preserved. Since the last glaciation, erosion has been active, but its results have been slight except for the local cutting of deep canyons.

LA PLATA DISTRICT

Many details of the complex Tertiary and Quaternary history of the La Plata district are now known, but it is difficult to correlate them exactly with the history of the San Juan region as a whole. At the close of the Cretaceous period the area was covered by 11,000 to 14,000 feet of horizontally bedded sedimentary rocks. When the ancestral San Juan dome was formed these beds were tilted upward toward the northeast. The tilting was followed by the deposition of several thousand feet of Paleocene and Eocene sediments in nearby areas; no record is preserved to show whether they ever covered the La Plata area.

Volcanism began either very early in the Tertiary or during the Miocene. For some reason not now apparent the crust was weaker, or the load of sedimentary rocks lighter here than elsewhere, which led to the localization of activity in this particular place. Before and probably during this stage, the basement was almost certainly pushed upward by deep-seated, highly localized forces. Great quantities of diorite-monzonite porphyry magma were intruded into the basement rocks, along one or more comparatively small conduits. Upon reaching the sedimentary layers, the magma gradually spread out and pushed the sediments upward. As the magma followed paths of least resistance, much of it followed bedding planes, forcing the overlying rocks upward, thus forming sheets or small laccoliths. Fractures in the beds were filled by dikes of porphyry, and where the rate of injection became too rapid to allow development of sheets stocks of porphyry were formed and the country rocks were turned up around their margins. Some magma worked out laterally from these stocks and formed additional sheets. The magma may possibly have approached the surface or even spread out on it as lava flows, but it seems more probable that very little of it rose above the lower parts of the Mancos shale.

The intrusion of the porphyries went on very slowly and in a gentle, but forceful manner. The magma was relatively low in temperature and poor in content of volatile materials. The country rocks were soft and they yielded to the intrusive forces largely by bending. On the outskirts of the dome, however, the stresses were partly relieved by faulting. Some of these faults transected soft and hard beds alike; others, like those in and near the Century mine on Bear Creek, broke only the brittle beds and passed into local folds in the softer strata.

The aggregate effect of the porphyry intrusions, of the upward thrust of the basement, and of the faults was the formation of the structural dome that characterizes the La Plata Mountains. Apart from the effects of erosion, this dome had essentially the same shape and size at the close of the period of porphyry intrusion that it has at present. The doming must have been reflected in the surface topography, although the surface slopes were probably much less steep than the dips of the underlying rocks. The dome was welded into a unit, supported, and strengthened by a complex framework of solidified porphyry bodies, and was destined to move as a unit throughout its later history.

Soon after the intrusion of porphyry had ceased, or possibly even a little before it had ceased entirely, stocks of diorite, monzonite, and syenite began to form. The magmas of which they were made possibly followed some of the same channels as the preceding porphyry magmas, but they were guided in large part to weak places that had developed along the sharp hinge line of the dome. These magmas were in a liquid condition, and, though they may have opened parts of their paths by pushing the country rocks aside and upward with explosive violence, a large part of the space they were to occupy was provided by replacement of the country rocks. Some sills of nonporphyritic rock were formed by processes similar to those by which the porphyry was emplaced, but some sills that consist partly or wholly of nonporphyritic rock were formed by partial or complete replacement of older porphyry. Possibly, as with the porphyries, some of the magma that formed nonporphyritic intrusive bodies broke through to the surface, but no vestiges of volcanoes thus formed are preserved.

The emplacement of the holocrystalline stocks was accompanied by silicification, baking, and metamorphism of the surrounding country rocks. The shape and size of the metamorphic aureoles were largely controlled by the stocks themselves, but in most places the hinge line of the dome limited its area. The pyritic-gold deposits of Jackson Ridge and elsewhere and the disseminated platinum-bearing copper deposits of Copper Hill appear to have been formed during the general metamorphism of the rocks in the central part of the district.

The silicification of the country rocks, together with the additional support of the newly emplaced stocks, made the central part of the dome a coherent, brittle mass, which could yield to further stresses only by faulting. Toward the close of the igneous cycle, a certain amount of subsidence probably took place, owing to crustal readjustment incident to the removal of large quantities of magma from the underlying rocks. Subsidence thus caused would account for the minor syncline noted along the outer edge of the hinge fold, and for slight sags in the central part of the dome. Movement was renewed along the faults that had formed during the rise of the dome, and many new faults were formed. Hydrothermal solutions rose along many of the fractures, and quartz deposited early in this process was sheared and brecciated by renewed fault movements, thus leaving open channelways for the ore-bearing solutions. Slight movement took place along some of the veins after the ores had been deposited, and a few new minor faults were formed.

There are some reasons for believing that the series of events which have been described above as occurring in definite chronologic sequence followed one another in rapid succession, and even overlapped to some extent. The most definite break in the sequence seems to have occurred between the intrusion of the porphyritic rocks and that of the nonporphyritic rocks.

Erosion must have attacked the La Plata dome as soon as it rose above the surface of the surrounding plains, but subsequent erosion has been intermittent in character, having been governed by alternating changes in base level of the region. By the close of the Tertiary the La Plata dome had already been eroded deeply enough to supply pebbles of porphyry to the gravels that were being strewn on the peneplain surface to the south. The Quaternary history of the La Plata Mountains was essentially the same as that of the San Juan Mountains, since both ranges were affected by the same series of uplifts. Many of the ore deposits in the La Plata district may have been enriched by downward-circulating waters during late Tertiary and early Quaternary time, but the glaciers which carved many of the present features removed nearly all of the weathered ore and even cut deeply into the primary deposits. Weathering has been going on ever since the retreat of the ice, but post-glacial time has been too short and erosion too vigorous to permit the formation of new zones of enrichment.

ECONOMIC GEOLOGY

HISTORY AND PRODUCTION

Spanish explorers visited the La Plata Mountains in the 18th century and reportedly found mines already in operation. Bancroft,[46] in telling of Escalante's expedition of 1776, says:

> The eastern section of the La Plata range was called by Escalante Sierra de la Grulla. The La Plata River he called the San Joaquin, and in the canyon, says his narrative, were the mines sought for by Cachupin's explorers (circa 1750–60. E. B. E.) and which gave the name to the mountains, supposed to contain silver. . . . At the Rio Mancos, or San Lazaro, he again heard reports of mines.

There is no other record of the early history but placer gold was found on the Animas River in 1861, near the present site of Durango. Mining in the La Plata district itself began in 1873. In that year, placer gold was discovered along the La Plata River by men from California and eastern Colorado. The miners immediately began construction of a large ditch to provide water for sluicing gravels near the mouth of the La Plata canyon.[47] They recovered enough gold to maintain their interest for several years, but the outcome of their operations is not known. The Comstock vein also was discovered in 1873. According to Toll,[48] A. K. Fleming, one of the discoverers, exhibited some of the ore during the following winter in Del Norte, where Capt. John Moss, an old California miner, was so impressed by it that he went with Fleming to the La Plata Mountains the following spring. On June 22, 1874, Captain Moss and Harry Lightner located the South Comstock lode, and A. K. Fleming, Almarion Root, and Robert James located the North Comstock lode and millsite. In 1875, Moss bought Fleming's interest for $5,000 and then sold both claims to Tibircio Parrott for $10,000. The names of several of these pioneers were later given to prominent geographic features in the district.

La Plata County was organized in 1874, and Parrott City, whose site is now occupied by Mayday, was founded in the same year. Chittenden[49] describes it thus:

> In 1874 the only settlement in the whole district (San Juan Basin) was on the La Plata at its head. It was at that time a very embryotic mining town, containing two log houses and a third in process of erection. It is called Parrott City, and

[46] Bancroft, H. H., History of Nevada, Colorado, and Wyoming, 1540–1888, p. 340, San Francisco, The History Co., 1890.

[47] Lee, H. A., Report of the Colorado State Bur. Mines (for 1897), p. 71, 1898.

[48] Toll, R. H., personal communication.

[49] Chittenden, G. B., in Hayden, F. W., U. S. Geol. and Geog. Survey Terr., 9th Ann. Rept. (for 1875), p. 359, 1877.

since that time has grown quite considerably, having been made the county seat of La Plata County and supplied with a regular mail. Its support comes from the mines at the head of the stream, which consists of both quartz lodes and placer diggings, and have been pronounced quite valuable.

The nearest supply point was Del Norte, 100 miles east of the district, and separated from it by rugged mountains. In addition to this small settlement of miners on the La Plata River, there were a few ranches along the Animas River and in other parts of the San Juan Basin. Most of the ranchers, however, had been driven off by the Ute Indians about the same time that gold was discovered in the La Plata Mountains. Captain Moss, leader of the mining operations, must have been a competent diplomat as well as a miner, to judge from the following comment by Jackson [50] on his meeting with Moss in September 1874, during the unrest among the Indians:

Moss explained his own security in this threatening situation by saying that when he had brought in his party of miners a year earlier, he had made his own treaty with the head chiefs of this region. By this treaty he had acquired mining rights over 25 square miles along the La Plata, through the payment of a liberal annuity in sheep, horses, and some other things. This purchase had placed him and his companions on friendly terms with all the Indians of the region.

In spite of all difficulties, the prospectors persisted in their efforts. Holmes,[51] in 1875, notes that "a great number of veins, many of which carry silver and gold," have been discovered, and mentions the placer operations at the mouth of the La Plata valley. He says:

Until the summer of 1875 but little was done toward the exploration of the localities from which the ore-bearing gravel came. During that summer many hundreds of claims were located on lodes both of gold and silver. . . . But little is known . . . of the value of more than a very few of the lodes. The Comstock . . . shows some very fine silver ore.

By 1880 Mancos had been established, Parrott City had grown to a town of 40 to 50 houses, and a weekly newspaper, the La Plata Miner, was being published. The general character of the ore deposits had become fairly well known. In addition to the Comstock several other mines, including the Ashland, the Century, the Cumberland, and the Morovoratz had already produced some ore. In 1880 Durango was founded also, just south of the older town of Animas City, its growth being stimulated by the completion of the Denver & Rio Grande Western Railroad in 1881. It grew rapidly and soon replaced Animas City and Parrott City as the commercial center of southwestern Colorado.

In 1884 the county wagon road was extended to the head of the La Plata River. The town of La Plata, or La Plata City as it is called locally, was probably founded about the same time. For some years it had a population of more than 200 and possessed several stores and saloons, a livery stable, and a hotel. A small Catholic convent occupied log buildings about a mile south of the La Plata at some period during the early history of the camp. La Plata gradually declined in importance, and in 1937 it contained only about a dozen families.

By 1885 two unsuccessful attempts at milling the ores had been made. Freeman [52] mentions the original 5-stamp Cumberland mill and an arrastre mill, the location of which is not known. The Cumberland mill was designed for extraction of free gold, although the Cumberland ore yielded only ruby silver.

Montezuma County, formed from the western part of La Plata County, was organized in 1889. The completion of the Rio Grande Southern Railroad branch line between Durango and Rico in 1891 may possibly have had something to do with the increased production from the district during the next decade. In 1897 the following mills were in existence, although some of them had already been abandoned.

Mills in La Plata district, 1897 [1]

Name	Kind	Capacity (tons)
Little Kate	Amalgamation, 20 stamps	60
Cumberland	Amalgamation and concentration, 25 stamps.	60
Pret (Small Hope)	Bromination	10
Baker	Amalgamation, 10 stamps	20
Fairfield	do	20
Columbus	Amalgamation and concentration.	40
Lewis	Amalgamation and concentration, 20 stamps.	50
Oro Fino	Amalgamation and concentration, 10 stamps.	25
Snowstorm	do	25

[1] Lee, H. A., Report of Colorado State Bureau of Mines (for 1897), pp. 70–72, 1898.

Between 1897 and 1901 attention was temporarily diverted from the high-grade telluride deposits to the low-grade pyritic-gold deposits on Jackson Ridge and at the heads of Bedrock and Boren Creeks. At the turn of the century, hundreds of locations had been recorded and more than 200 claims had been patented. Many of the mines had produced some ore, but the total production of the district up to 1900 was comparatively small. Some of the mines discovered during the early years of the district had produced, intermittently, up to 1937, but not one of the mines opened before 1900 had then produced as much as $100,000.

The failure of the district to live up to expectations was variously attributed to high mining and transportation costs, poor judgment as to milling methods, litigation, and excessive royalties. Undoubtedly several of these were and still are, contributing factors, but

[50] Jackson, W. H., The pioneer photographer; p. 231, Yonkers-on-Hudson, N. Y., World Book Co., 1929.

[51] Holmes, W. H., in Hayden, E. W., U. S. Geol. and Geog. Survey Terr., 9th Ann. Rept. (for 1875), pp. 271–272, 1877.

[52] Freeman, H. C., The La Plata Mountains: Am. Inst. Min. Met. Eng. Trans., vol. 13, pp. 681–684, 1885.

then as now the chief factor was the character of the ore deposits.

With the coming into production of the Neglected mine in 1901, the district entered upon a new era of real discoveries. The Valley View or Idaho vein was located in 1902 and the May Day deposits in 1903. These mines began production in 1904, reached a peak about 1907, and, in spite of many legal and other difficulties, remained the leading mines for many years. The Incas deposit was discovered in 1909 and yielded $260,000 within 3 years. No other large deposit was found until about 1923, when the Gold King vein, an extension of the old Eureka-Bulldozer vein, was uncovered. It did not begin large-scale production, however, for several years. In 1933 the sensational Red Arrow discovery was reported.

The latter half of the history of the camp has thus been characterized by discovery and exploitation of a few relatively large deposits. Each discovery stimulated exploration in other parts of the district for a few years, but few of the many efforts were rewarded. All the deposits that were to become largely productive were discovered at irregular intervals after the district had been combed by prospectors for more than 30 years. This fact tends to justify a hopeful view of the future of the district; its bearing is discussed in a later section. More than half of the nearly $6,000,000 total production of the camp was taken from two mines, the May Day and the Idaho, and four others, the Neglected, Gold King, Incas, and Red Arrow, have together yielded more than $1,000,000 worth of ore. More than two-thirds of the district's production has thus come from six mines.

Mining activity was at a low ebb in 1937 except for work at the Idaho, Red Arrow, and Gold King, which was shut down in June. Some work was being done by lessees and prospectors in various places, and several small exploratory programs were being carried on. At the close of the year only two mills were in operation. These were the Pioneer, which was treating ore from the Idaho mine and dump, and a small amalgamation mill treating high-grade ore from the Red Arrow. The Gold King mill, which ran for several months on ore previously broken at the mine, was shut down indefinitely on October 15, 1937. The May Day and the smaller Monarch and Lady Eleanora mills were in good condition but were not being operated. The Cumberland, Euclid, Doyle, Neglected, Oro Fino, Texas Chief, and Tomahawk mills were either in ruins or in bad repair.

The production of the district for 1878–1937 is summarized in the table on page 54. Some ore is now known to have been produced during the years 1874–77, but there are no authentic records for this period. An estimate of $15,000 total value for metals produced during these years is probably very liberal. No explanation can be found for the tremendous increase in silver production in 1894, and it would seem that the figures are in error.[53] As 1892–94 were years of very large production in the neighboring camp of Rico,[54] it seems reasonable to suggest that much of the ore represented by these figures originated in that camp.

MINERALOGY

By F. W. Galbraith

MINERALS OF THE ORE DEPOSITS

The following descriptions of the minerals closely associated with the ore deposits are grouped according to Dana's system. In the alphabetical list which precedes the descriptions a question mark indicates that presence of the mineral in the district has not been definitely established. In addition to the listed minerals, a few that occurred in particles too small for positive identification are described under the general group headings to which they belong. The methods used in identifying the telluride minerals have been described elsewhere.[55]

Aikinite (?)	Copper (native)	Orthoclase
Amalgam (?)	Cosalite (?)	Palladium (native?)
Andradite	Covellite	Pearceite (?)
Anglesite	Dickite	Petzite
Ankerite	Enargite	Platinum (native?)
Argentite	Epidote	Polybasite (?)
Arsenopyrite	Fluorite	Pyrargyrite
Augite	Galena	Pyrolusite
Azurite	Gold (native)	Pyrite
Barite	Gypsum	Realgar
Benjaminite (?)	Halloysite	Quartz
Bornite	Hematite	Roscoelite
Calaverite	Hessite	Siderite
Calcite	Krennerite	Silver (native)
Cerargyrite (?)	Limonite	Stephanite
Cerussite	Magnetite	Sylvanite
Chalcanthite	Malachite	Tellurium (native)
Chalcocite	Marcasite	Tetrahedrite
Chalcopyrite	Mercury (native)	Tourmaline
Chlorite	Miargyrite	Tremolite
Cinnabar	Muscovite, var. sericite	Troilite (?)
Coloradoite		

NATIVE ELEMENTS

Gold, Au.—Native gold is an important ore mineral throughout the district and is the only valuable product of some of the mines. Finely divided free gold is associated with pyrite in the Doyle "blanket" and in many veins, such as those worked by the Century, the Timberline mine of the Doyle group, and the various mines and prospects along Boren and Burnt Timber Creeks, notably the Boren Gulch, May Rose, and Monarch properties. It is also associated with pyrite and chalcopyrite in contact-metamorphic deposits worked at the Bay

[53] Henderson, C. W., Mining in Colorado, a history of discovery, development, and production: U. S. Geol. Survey Prof. Paper 138, pp. 52, 177, 1926.

[54] Henderson, C. W., idem., p. 117.

[55] Galbraith, F. W., Identification of the commoner tellurides: Am. Mineralogist, vol. 25, pp. 368–371, 1940.

Production of gold, silver, lead, and copper from La Plata district, 1878–1937, in terms of recovered metals [1]

Year	Ore treated (short tons)	Lode gold [2]	Silver			Copper			Lead			Total value
			Fine ounces	Average price per ounce	Value	Pounds	Average price per pound	Value	Pounds	Average price per pound	Value	
1878		[3] $1,000	[3] 1,934	$1.15	$2,224							$3,224
1879		[3] 2,500	[3] 3,867	1.12	4,331							6,831
1880		[3] 5,000	[3] 7,734	1.15	8,894							13,894
1881		5,000	7,734	1.13	8,739							13,739
1882		10,000	23,203	1.14	26,451							36,451
1883		13,000	3,867	1.11	4,292							17,292
1884		500	4,641	1.11	5,152							5,652
1885		[4] 5,000	[4] 5,000	1.07	5,350							10,350
1886		10,225	4,671	.99	4,625				100,000	$0.046	$4,600	19,449
1887		12,473	7,126	.98	6,983				42,210	.045	1,899	21,355
1888		3,574	2,294	.94	2,156							5,730
1889		4,465	1,118	.94	1,051							5,516
1890		3,729	2,011	1.05	2,112							5,841
1891		23,054	3,207	.99	3,175							26,229
1892		34,881	3,335	.87	2,901							37,782
1893		37,872	4,928	.78	3,844							41,716
1894		114,264	417,465	.63	263,003							377,267
1895		3,682	99	.65	64							3,746
1896		10,741	41	.68	28							10,769
1897		36,944	1,514	.60	908	420	$0.12	$50	857	.036	31	37,933
1898		38,653	5,219	.59	3,079	2,568	.124	318	8,407	.038	319	42,369
1899		41,092	3,389	.60	2,033	211	.171	36	3,176	.045	143	43,304
1900		24,927	7,187	.62	4,456	350	.166	58	14,500	.044	638	30,079
1901		30,819	5,588	.60	3,353	132	.167	22	6,197	.043	266	34,460
1902		127,182	7,416	.53	3,930	3,143	.122	383	2,156	.041	88	131,583
1903		145,331	7,716	.54	4,167	810	.137	111	3,017	.042	127	149,736
1904	3,792	130,200	31,086	.58	18,030	1,473	.128	189	2,177	.043	94	148,513
1905	5,662	254,007	93,258	.61	56,887	2,923	.156	456	610	.047	29	311,379
1906	7,757	304,633	121,721	.68	82,770	445	.193	86	2,228	.057	127	387,616
1907	7,812	413,034	217,579	.66	143,602	708	.20	142	340	.053	18	556,796
1908	2,416	101,584	71,592	.53	37,944	458	.132	60	748	.042	31	139,619
1909	4,135	127,205	74,160	.52	38,563	484	.132	63	2,980	.043	128	165,959
1910	6,798	399,608	141,752	.54	76,546	362	.127	46	273	.044	12	476,212
1911	10,059	286,953	69,444	.53	36,805	73,911	.125	9,239	1,511	.045	68	333,065
1912	2,761	135,391	47,948	.615	29,488	918	.165	151	6,756	.045	304	165,334
1913	7,403	312,891	121,122	.604	73,158	113,897	.155	17,654	4,455	.044	196	403,899
1914	5,083	126,498	60,244	.553	33,315	26,038	.133	3,463	11,410	.039	445	163,721
1915	2,966	72,024	46,472	.507	23,561	4,114	.175	720	23,532	.047	1,106	97,411
1916	1,688	33,055	29,380	.658	19,332	15,142	.246	3,725	6,667	.069	460	56,572
1917	1,772	27,952	15,512	.824	12,782	28,333	.273	7,735	3,745	.086	322	48,791
1918	300	7,378	6,415	1.00	6,415	668	.247	165	3,000	.071	213	14,171
1919	405	5,966	6,075	1.12	6,804	167	.186	31	2,283	.053	121	12,922
1920	717	11,020	10,578	1.09	11,530				937	.08	75	22,625
1921	1,279	45,181	20,327	1.00	20,327				3,734	.045	168	65,676
1922	791	32,261	10,656	1.00	10,656							42,917
1923	838	15,905	17,138	.82	14,053	816	.147	120	1,800	.07	126	30,204
1924	1,295	23,502	11,597	.67	7,770	488	.13	64	387	.08	32	31,367
1925	905	24,074	22,831	.694	15,845				2,000	.087	174	40,093
1926	119	6,472	2,681	.624	1,673							8,145
1927	613	23,103	8,912	.567	5,053							28,156
1928	8,120	47,433	24,193	.585	14,153	97	.144	14	63,000	.058	3,654	65,254
1929	19,970	116,511	83,107	.533	44,296				71,000	.063	4,473	165,280
1930	272	8,482	2,969	.385	1,143				600	.050	30	9,655
1931	404	12,752	2,317	.290	672				190	.041	7	13,431
1932	3,041	[5] 30,397	6,968	.282	1,965				7,000	.030	210	32,571
1933	7,822	[6] 43,958	14,889	.350	5,211	200	.064	13	9,700	.037	359	49,541
1934	14,430	[7] 116,344	17,523	.646	11,328	600	.080	48	7,900	.037	292	128,012
1935	11,666	[8] 85,876	17,490	.718	12,571				23,400	.040	936	99,383
1936	13,331	[9] 97,923	14,465	.774	11,203	2,000	.092	186	13,300	.046	612	109,922
1937	18,161	143,311	34,242	.773	26,486	2,000	.121	242	257,000	.059	15,163	185,202
Total		4,362,792	2,003,497		1,289,238	283,876		45,590	715,183		38,095	5,741,711

[1] Figures for 1878–1923 are from C. W. Henderson, Mining in Colorado: U. S. Geol. Survey Prof. Paper 138, p. 178, 1926. Figures for 1924–37 were compiled by C. W. Henderson, Supervising Engineer, Bureau of Mines, Denver.
[2] Gold valued at $20.67+ per ounce 1873–1932, at $25.56 for 1933, at $34.95 for 1934, and at $35 for 1935–37.
[3] Estimated by C. W. Henderson, by subtracting from figures for San Juan region. Production for 1874–77 unknown but probably small.
[4] Interpolated by C. W. Henderson to correspond with total production of the State.
[5] Includes $86 placer gold.
[6] Includes $111 placer gold.
[7] Includes $367 placer gold.
[8] Includes $460 placer gold.
[9] Includes $646 from 7 tons of ore from Vallecito district.

City, Lady Eleanora, Silver Falls, and other mines. These deposits are characterized by sulfides and by garnet, augite, epidote, magnetite, and other silicates and oxides. Elsewhere, as in Tomahawk Basin and on Baker Peak ridge above the Bonnie Girl mine, sulfide-free garnet or magnetite bodies that have replaced limy beds and lenses are reported to contain small quantities of gold. In most of the deposits mentioned above the primary ore is too low grade to be workable, but in some of them weathering and oxidation have concentrated the gold near the surface, largely by removal of other constituents, and have resulted in the formation of workable deposits, some of them rich.

The most notable occurrence of free gold is at the recently discovered Red Arrow mine, which has produced much coarse gold in crystals, wires, and irregular masses. The largest "nugget" found weighed more than 5 pounds. This gold is associated with quartz, coarsely crystalline barite, ankerite, chalcopyrite, tetrahedrite, and pyrite. Some of it is intergrown with tetrahedrite, minute crystals of which are perched on gold crystals in one specimen. Telluride minerals are extremely rare in the deposit; only one small mass of hessite, replacing tetrahedrite, was seen in the specimens examined. The observed relations between gold and tetrahedrite show the gold to be primary, but some of the "nuggets" may have been enlarged by supergene agencies.

Native gold was seen in polished sections of ores from the Bessie G., Durango Girl, Neglected, Lucky Discovery, and Eagle Pass mines. It is relatively abundant in several parts of the Gold King vein and is probably present in the telluride ores at many other places. In nearly every section the gold is intimately associated with the tellurides of gold, silver, and mercury; it selectively replaces tetrahedrite, coloradoite, and hessite (pl. 10 *A*) and is of hypogene origin. In one section from the Bessie G. mine, native gold occurs with cinnabar deposited in vugs lined with very late quartz. This occurrence probably represents the final stage of hypogene mineralization.

In a section of ore from the Eagle Pass vein much of the gold fills tiny fractures and follows minute capillary cracks along the cleavage of hessite (pl. 12 *D*). This is the only occurrence of native gold believed to be of supergene origin that was observed in the polished sections. Several occurrences of gold in association with native mercury and amalgam have been reliably reported, however, and free gold is said to have been abundant in the near-surface workings of the Neglected, May Day-Idaho, Comstock, and other mines. Most of this gold probably represents residual concentration of metal originally intergrown with the telluride and other hypogene minerals. Some of it may have been dissolved, transported, and reprecipitated during the weathering process, but the apparent absence of "rusty" and "mustard" gold, which are the usual weathering products of gold tellurides, argues against this mode of origin.

Free gold is said to be associated in small quantity with the ruby silver ores of the Cumberland and other mines, but as none of it was seen in the specimens examined the relation of gold to the silver minerals is not known.

Tellurium, Te.—Native tellurium is possibly associated with the tellurides in several deposits but has been identified only in one polished section of ore from the Gold King mine (pl. 11 *A*). It therefore occurs in contemporaneous intergrowth with krennerite, hessite, and coloradoite and is of hypogene origin. According to R. M. Wheeler, native tellurium is fairly abundant in the Mountain Lily mine, where much of the ore that appears to be rich in tellurides fails to yield commercial quantities of gold or silver.

Silver, Ag.—Native silver has been reported only as an oxidation product in some of the copper mines on Bear Creek (see p. 71), but it may have been present in the oxidized parts of other deposits; it is scarce throughout the district.

Copper, Cu.—Native copper has been reported from the Copper Age and Bonnie Girl mines and from several of the mines along Bear Creek. A little may be present in the oxidized zones of other deposits, but it is not abundant anywhere, and, in view of the general scarcity of primary copper minerals, it is probably absent in most places. The Copper Age vein is said by Wallace [56] to have been 8 feet wide and rich in red copper oxide (cuprite ?) and native copper. Both minerals were doubtless derived from original chalcopyrite by weathering processes. Local reports credit the old Bonnie Girl mill with recovering a fairly large quantity of copper amalgam by milling the oxidized ores from the Bonnie Girl mine. No copper was seen in these deposits, but as the rocks contain partly oxidized pyrite and chalcopyrite they may well contain native copper.

The most interesting occurrence of native copper is in a recent swamp deposit on the west side of the La Plata River, just below the town of La Plata. Here the soil in a depression half an acre or so in extent is kept moist in part by surface waters from Boren Creek and in part by small seep springs in the immediate vicinity of the swamp. All of this water drains through or over rocks that contain appreciable quantities of disseminated chalcopyrite. The black muck of the swamp, which is 5 feet thick or more in places, contains many irregular nodules and grains of native copper, the smallest of which are less than a millimeter and the largest more than a centimeter in diameter. With them are associated similar nodules of fine-grained ferrous sulfide, described below as troilite (?). Both copper and troilite (?) are doubtless precipitated by reactions between organic matter and copper and iron sulfates in the swamp waters.

Mercury, Hg.—Native mercury was not seen during the present investigation, but it has been reliably reported from several mines. It may have been widespread in many of the early, near-surface workings. It was formed by supergene processes, most of it probably by the breaking down of the mercury telluride, coloradoite, though some may have come from cinnabar. According to Wallace,[57] mercury and gold amalgam were relatively common in the Iridos mine and mercury was associated with the telluride minerals in the old Ashland vein. W. H. Emmon's field notes of 1903 remark that mercury was associated in considerable quantity with free gold, silver, and amalgam in the Ruby mine. It is said to have been associated with gold and copper in the Gold King-Swamp Angel workings and to have been found in some of the wall rocks of the Neglected vein. Lakes [58] reports the association of free mercury with amalgam, gold, and tellurides in the Mason mine.

Amalgam, Au, Ag, Hg.—Native amalgam is said to occur in nearly all the deposits that are mentioned above

[56] Wallace, J. P., La Plata County, in Burchard, H. C., Report of Director of the Mint, 1883, pp. 368–376, 1884.

[57] Wallace, J. P., op. cit.

[58] Lakes, Arthur, A peculiar occurrence of native mercury, free gold, and telluride minerals near Trimble Springs, Durango: Mining Reporter, vol. 54, pp. 389–390, 1906.

as containing native mercury. It is certainly a supergene mineral. The relative proportions of gold and silver in the amalgams are not recorded, but as free silver is relatively scarce in the district gold is probably the more abundant.

Platinum, Pt. and palladium, Pd.—As noted below in the description of the ore deposits (pp. 63–64), small quantities of platinum and palladium are associated with chalcopyrite-bearing rock on Copper Hill, between Boren and Bedrock Creeks. The platinum metals were discovered and proved by chemical methods. Microscopic examination of a few sections by Horace Fraser, of the California Institute of Technology, and by the writer have failed to disclose how these metals occur. They may be in solid solution in the chalcopyrite, or they may form discrete particles intergrown with the chalcopyrite or with the iron-oxide minerals. A report that platinum occurs in the Barr-Menefee prospect has not been confirmed.

SULFIDES

Realgar, AsS.—C. W. Purington's field notes of 1896 refer to small crystals of supposed realgar in the Greenhorn prospect, on the upper part of the La Plata River. They were enclosed in calcite that was associated with quartz and barite in a silver-bearing vein. The field identification does not appear to have been confirmed, and no other occurrences of realgar in the district have been reported.

Galena, PbS.—Galena is widely distributed through the La Plata district, both in the telluride and the sulfide ores, but it is abundant in only a few of the deposits studied, the Gold King, Jumbo-Morovoratz, and Puzzle being almost the only mines that have produced it in commercial quantity.

The galena commonly occurs as small grains associated with sphalerite, tetrahedrite, and the tellurides. In some of the ores it fills open vugs and fissures in a gangue of quartz or barite, but more commonly it replaces sphalerite, tetrahedrite, and chalcopyrite. In ore from the Gold King and Daisy properties sphalerite replaces galena (pl. 12 *A*), and in the Iron King prospect relatively large masses of pale yellowish-green sphalerite are surrounded by narrow aureoles of galena, but such relations are unusual. Galena is earlier than the tellurides but is not extensively replaced by them.

Galena is replaced to a limited extent by supergene anglesite and cerussite (pl. 12 *B*).

Galena with perfect octahedral cleavage was found by Hills [59] on the north side of Bedrock Creek, possibly in the vicinity of the Copper Hill mine but more probably in the vicinity of the Allard tunnel, farther up the creek. According to Hills, the galena did not occur in a vein but in bunches irregularly distributed through a metamorphosed sedimentary rock. The gangue was siliceous in some places and calcareous in others, but all of it contained a mineral that Hills called chlorite; it seems possible, however, that this mineral was really augite, which is found in the metamorphic rocks and the syenite along Bedrock Creek. The galena was heated to 325° C. for 45 minutes but did not develop cubic cleavage. Hills suggests that the octahedral cleavage may have been due to the relatively large amount of antimony and bismuth sulfide shown in his analysis, given below. Similar galena has been noted by McCausland at [60] several places in the vicinity of the Allard tunnel, but none was seen by the writer.

Analysis of galena with octahedral cleavage, Bedrock Creek

R. C. Hills, analyst

	Percent
Lead (Pb)	82. 06
Bismuth (Bi)[1]	1. 78
Antimony (Sb)[2]	. 65
Iron (Fe)	. 58
Zinc (Zn)	. 36
Sulfur (S)	13. 65
Calcium carbonate ($CaCO_3$)	. 41
Silver (Ag)	. 02
Gold (Au)	Tr.
Water (H_2O) at 105° C	. 05
Total	99. 56

[1] The 1.78 percent of bismuth corresponds to 2.19 percent of Bi_2S_3.
[2] The 0.65 percent of antimony corresponds to 0.91 percent of Sb_2S_3.

Argentite, Ag_2S.—Small quantities of argentite are associated with sphalerite, tetrahedrite, pyrite, and ruby silver minerals in the coarse-grained galena of the Daisy mine. Argentite has also been reported from the Hidden Treasure mine near the Daisy, and a few very small grains of supposed argentite were seen in a polished section of table concentrates from the Neglected mine. It is not known to occur elsewhere in the district and is almost certainly rare.

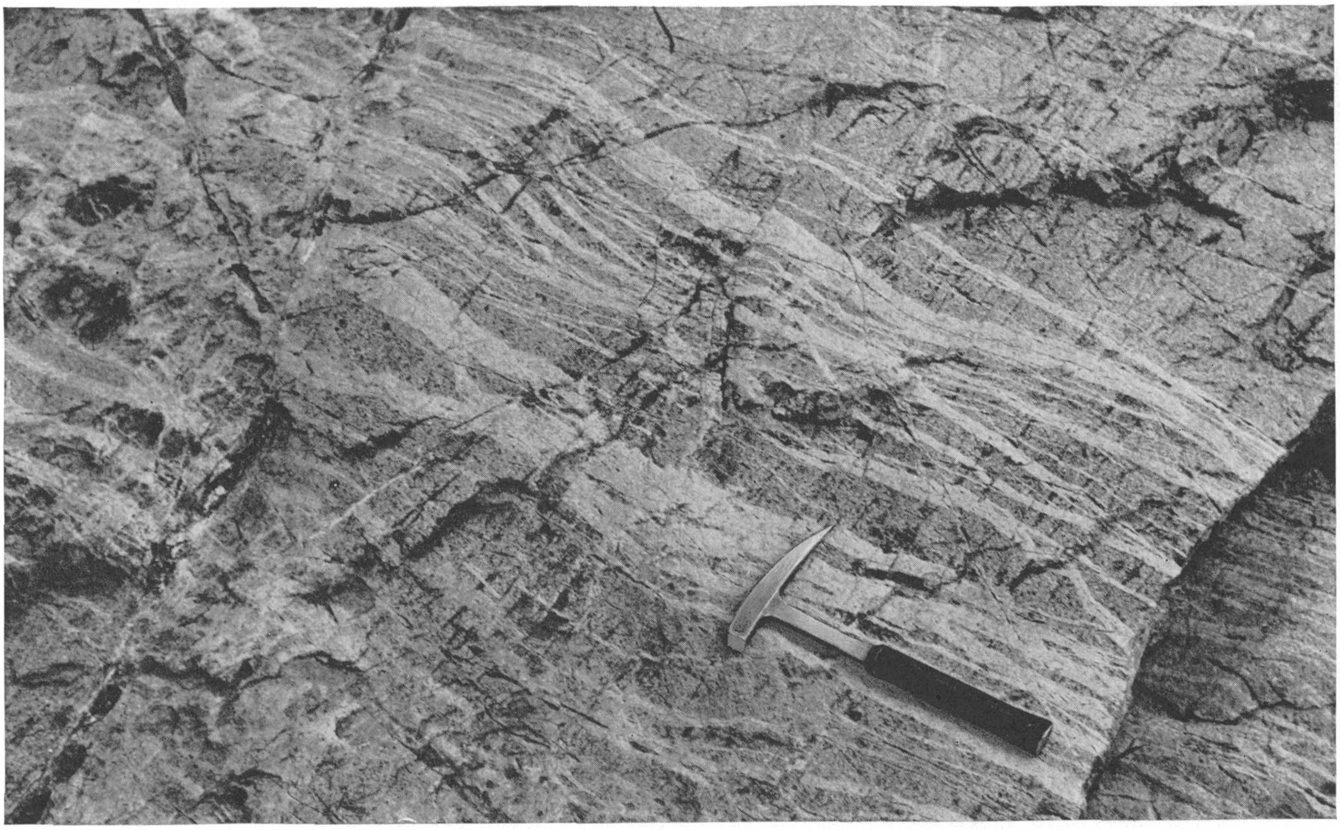
Chalcocite, Cu_2S.—Aside from the copper deposits along Bear Creek (p. 70), the only known occurrence of chalcocite in the district is in the Red Arrow Extension prospect, where small rounded grains of the mineral, partly altered to copper carbonate, are associated with calcite and a little quartz in shattered sandstone and shale.

Sphalerite, ZnS.—With the exception of pyrite, the most abundant sulfide mineral in the La Plata district is sphalerite.

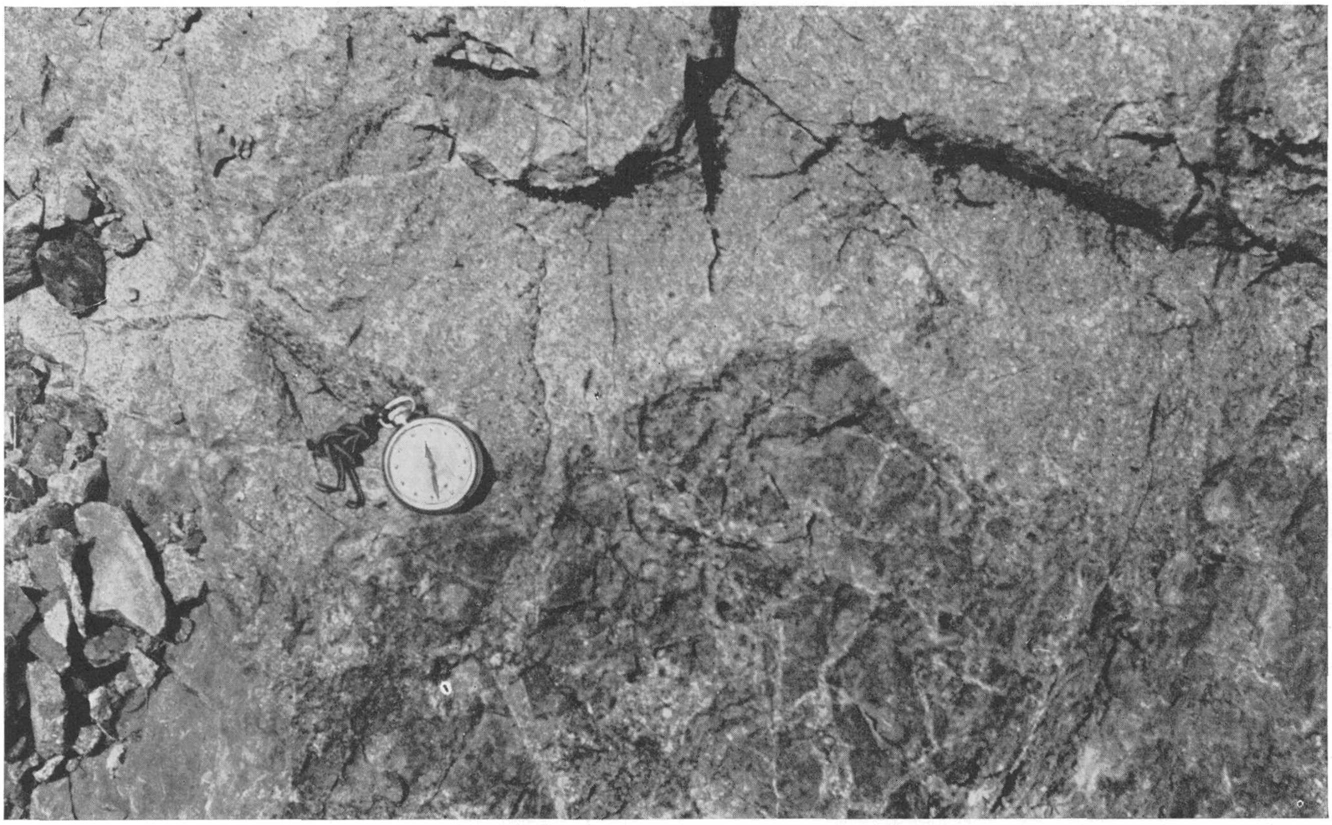
Sphalerite has been deposited in open vugs and fissures in quartz, and it also has replaced quartz, pyrite, and carbonate gangue. Sphalerite and chalcopyrite are essentially contemporaneous, tiny blebs of chalcopyrite being contained in much of the sphalerite. Sphalerite is replaced by tetrahedrite and galena, appearing in some sections only as small residual areas within the replacing minerals. As already noted, irregular masses of light yellowish-green sphalerite are surrounded by aureoles of galena in the Iron King prospect. In ores

[59] Hills, R. C., Notes on rare mineral occurrences: Colorado Sci. Soc. Proc., vol. 11, pp. 203–205, 1916.

[60] McCausland, R. D., personal communication.



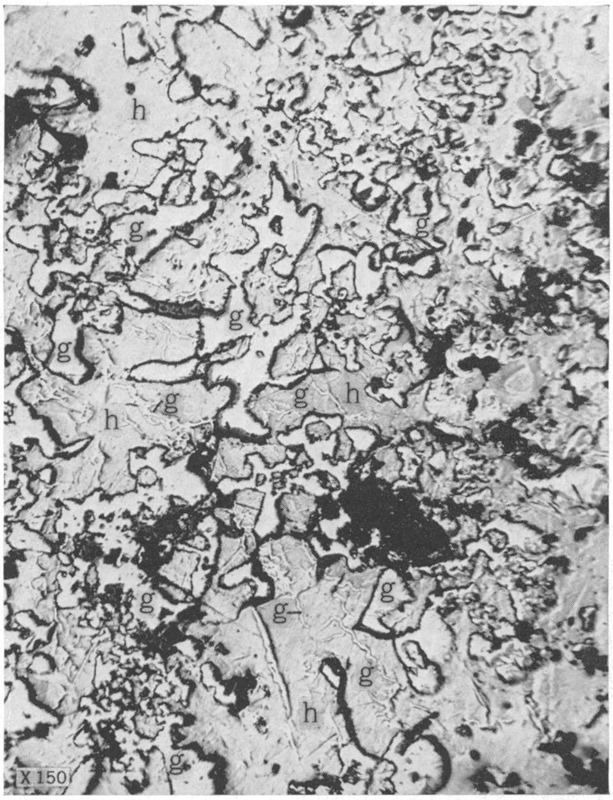
A. SYENITE IN BED OF BOREN CREEK CUT BY SEAMS OF APLITE.



B. SEDIMENTARY ROCK PARTLY REPLACED BY MONZONITE.

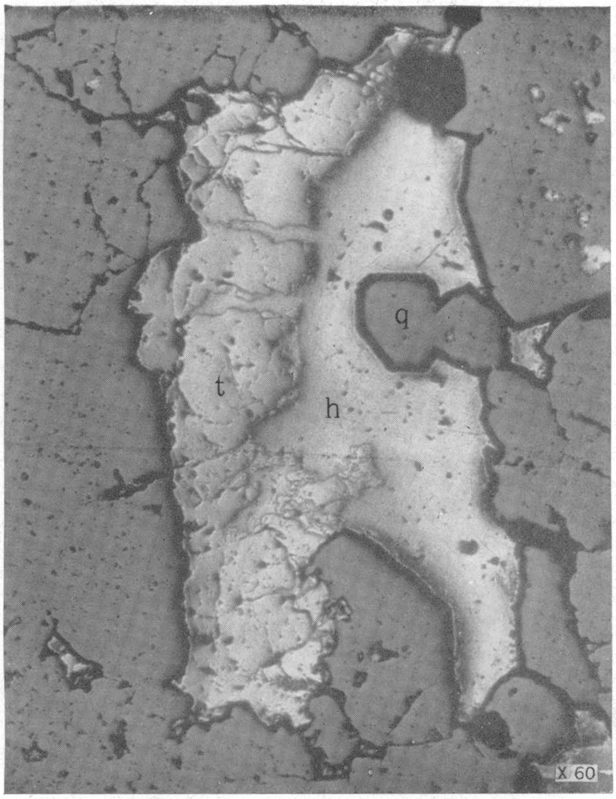
The sedimentary rock (dark gray), probably a shale originally, contains numerous veinlets of monzonite (light gray). From exposure near head of Boren Creek.

CLOSE-UP PHOTOGRAPHS OF IGNEOUS ROCKS AND PARTLY REPLACED SEDIMENTARY ROCK, BOREN CREEK AREA.



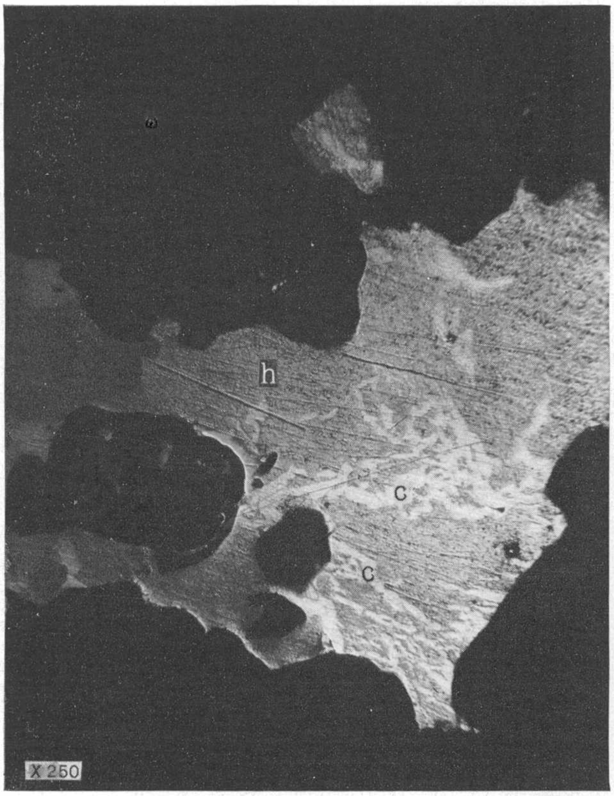
A. IRREGULAR MASSES AND VEINLETS OF NATIVE GOLD IN HESSITE.

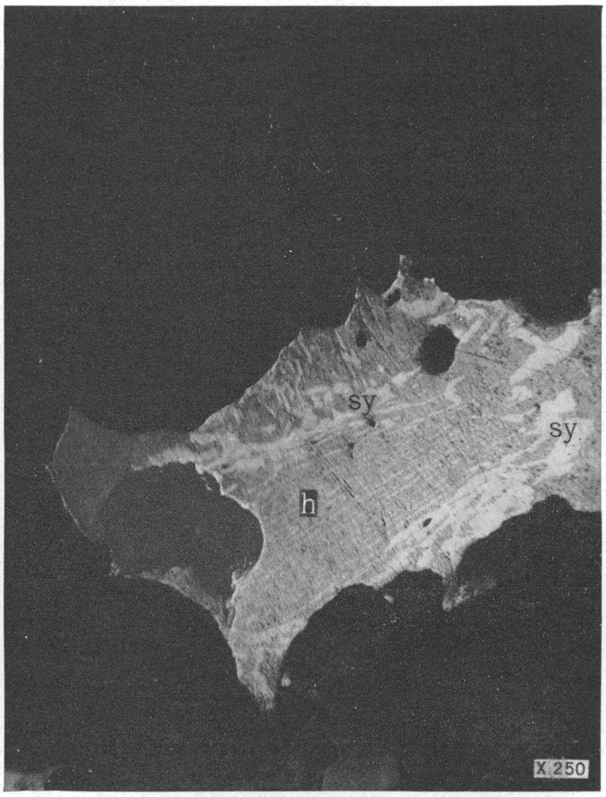
g, Native gold; *h*, hessite. Lucky Discovery mine. Reflected light, × 150.



B. TETRAHEDRITE REPLACED BY HESSITE.

t. Tetrahedrite; *h*, hessite; gangue is quartz (*q*). Durango Girl mine. Reflected light, × 60.



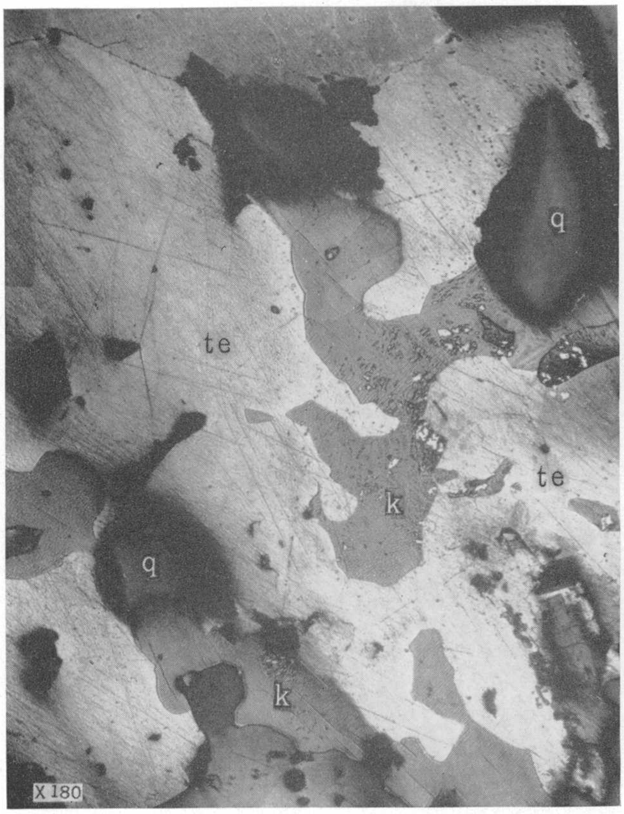


C, D. SUBGRAPHIC PATTERNS OF CALAVERITE AND SYLVANITE IN HESSITE.

c, Calaverite; *sy*, sylvanite; *h*, hessite. These textures may indicate replacement of hessite by the gold tellurides, but owing to its rarity, such replacement is not believed to be important in La Plata ores. Gold King mine. Reflected light, × 250.

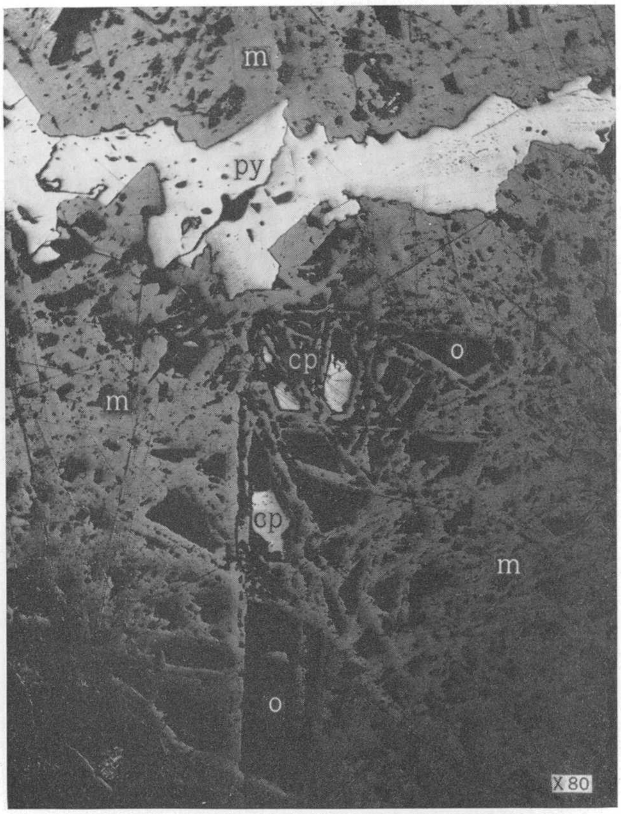
PHOTOMICROGRAPHS OF POLISHED SECTIONS OF ORE.

All photographs by F. W. Galbraith.



A. INTERGROWTH OF KRENNERITE (*k*) AND NATIVE TELLURIUM (*te*).

Specimen etched with concentrated HNO_3. Cleavage pattern produced by etching is characteristic of krennerite. Gangue is quartz (*q*). Gold King mine. Reflected light, × 180.

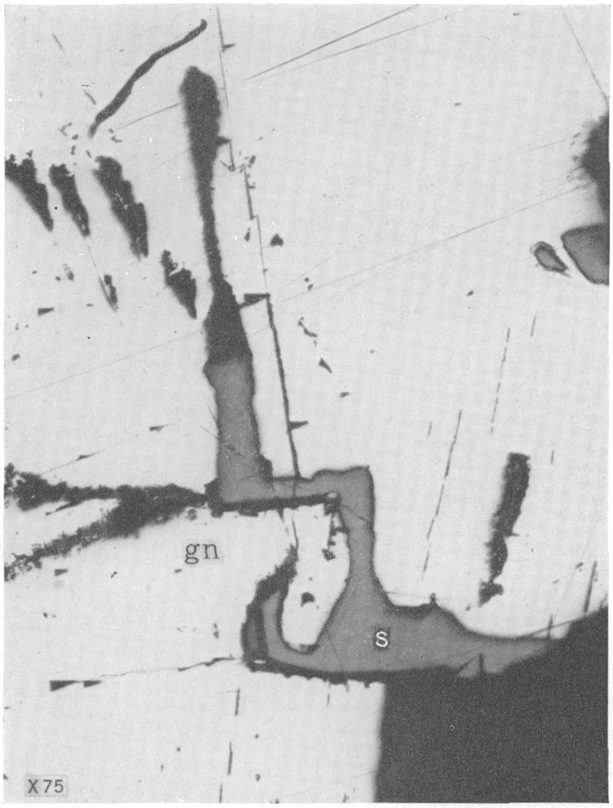


B. BOXWORK STRUCTURE OF MAGNETITE.

Chalcopyrite (*cp*) has filled spaces (*o*) in boxwork and veinlet of pyrite (*py*) cuts magnetite (*m*). Bay City mine. Reflected light, × 80.

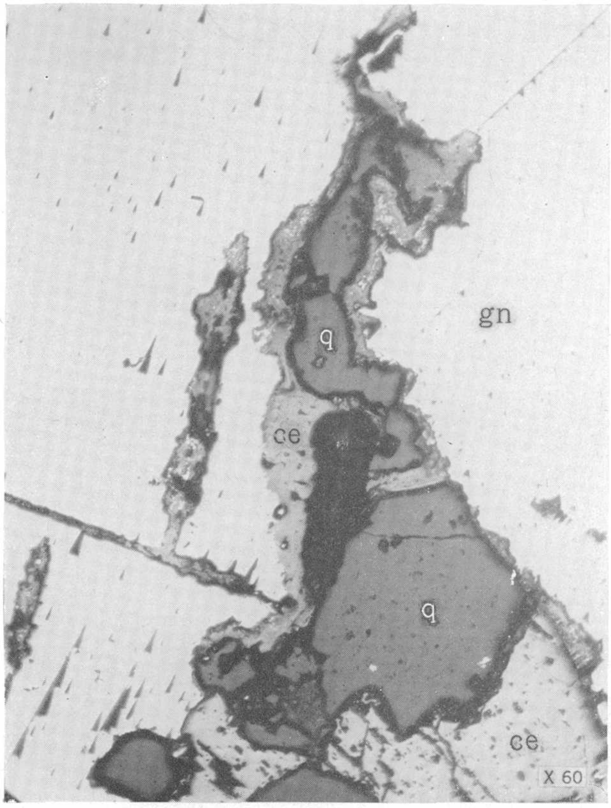
PHOTOMICROGRAPHS OF POLISHED SECTIONS OF ORE.

Photographs by F. W. Galbraith.



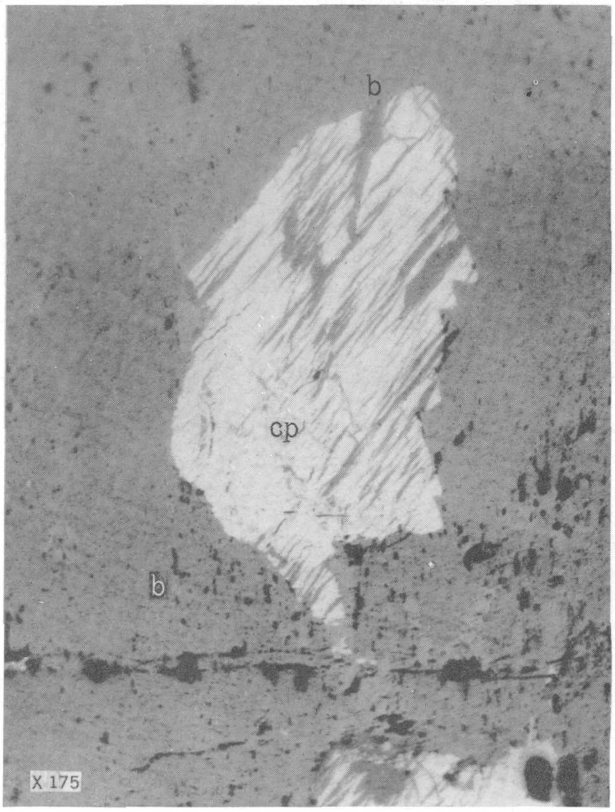
A. GALENA REPLACED BY SPHALERITE ALONG CLEAVAGE TRACES.

gn, Galena; *s*, sphalerite. Gold King mine. Reflected light, × 75.



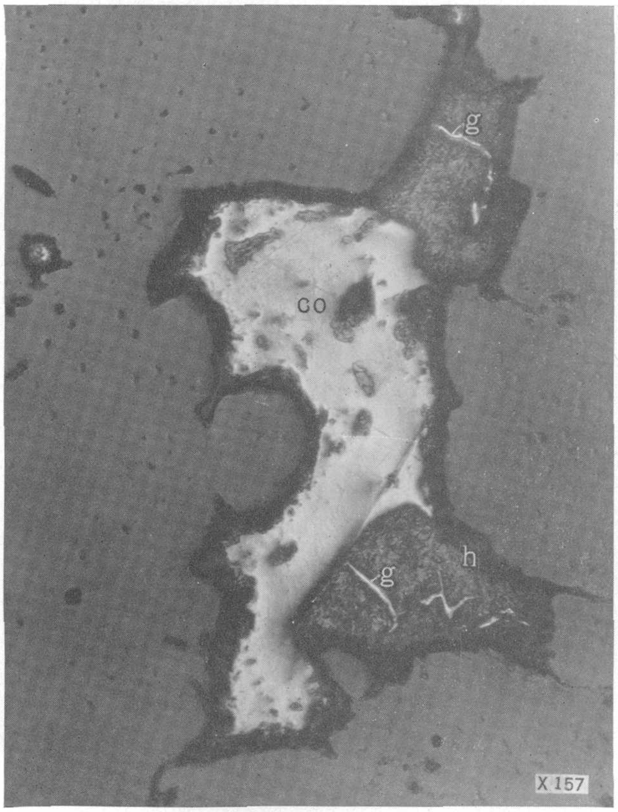
B. GALENA REPLACED BY SUPERGENE CERUSSITE.

Replacement by supergene cerussite (*ce*) along boundaries between grains of galena (*gn*) and quartz (*q*), and along cleavage traces of galena. Gold King mine. Reflected light, × 60.



C. HYPOGENE CHALCOPYRITE REPLACED BY SUPERGENE BORNITE.

cp, Chalcopyrite; *b*, bornite. Neglected mine. Reflected light, × 175.



D. SUPERGENE GOLD VEINLETS (*g*) DEPOSITED IN FRACTURES IN HESSITE (*h*).

Surface etched with 1:1 HNO_3. Large area of white mineral unaffected by acid is coloradoite (*co*). Gangue is quartz. Eagle Pass mine. Reflected light, × 157.

PHOTOMICROGRAPHS OF POLISHED SECTIONS OF ORE.

Photographs by F. W. Galbraith.

from the Gold King and Daisy mines, sphalerite is clearly later than galena, which it replaces along grain boundaries and cleavage planes (pl. 12 *A*).

Cinnabar, *HgS*.—Cinnabar was observed in a single specimen of ore from the Bessie G. mine, where it forms globular incrustations in a vug lined with very late quartz. It is believed to be hypogene, but it probably represents the last stages of hypogene mineralization. Associated with the cinnabar is a small amount of native gold believed to have been deposited contemporaneously with the cinnabar. Mercury sulfide, probably cinnabar, was noted by Emmons [61] in the Durango Girl mine associated with tetrahedrite and the telluride minerals. Cinnabar has also been reported from the Mason mine.

Troilite (?), *FeS*.—Small irregular grains and nodules of a dark-grey to black ferrous sulfide are associated with native copper in a swamp at La Plata. The nodules are very fine-grained aggregates of a mineral doubtfully identified as troilite, an end member of the pyrrhotite series. The occurrence has no bearing on the ore deposits of the district.

Covellite, *CuS*.—The very small quantity of covellite in the district is all of supergene origin. The mineral replaces hypogene bornite, chalcopyrite, and tetrahedrite along minute fractures and grain boundaries.

Bornite, Cu_5FeS_4.—A little bornite, partly of hypogene and partly of supergene origin, has been found in several mines of the district. Hypogene bornite occurs in contemporaneous intergrowth with chalcopyrite, tetrahedrite, and enargite. Supergene bornite replaces chalcopyrite along minute capillary cracks (pl. 12 *C*).

Chalcopyrite, $CuFeS_2$.—Chalcopyrite is recognizable in about half the ores studied. In most of them it is scarce, very little being present in the ores that contain telluride minerals. It is the most abundant sulfide, however, in the vicinity of Copper Hill and Bedrock Creek.

In most polished sections of the ores the chalcopyrite is associated with either sphalerite or tetrahedrite. Where chalcopyrite occurs in tiny blebs in sphalerite, the two minerals are believed to be essentially contemporaneous. In general the chalcopyrite is earlier than the tetrahedrite. Some of its fills open spaces in the gangue, and in one or two polished sections it was seen to have replaced pyrite. The chalcopyrite is replaced to a slight extent by supergene bornite and covellite (pl. 12 *C*).

Pyrite, *FeS*.—Pyrite is the most abundant sulfide mineral in the district and is present in most of the ores. Scattered euhedral to subhedral grains of it are enclosed in quartz gangue, where crystal outlines of the cube and pyritohedron can be recognized under the microscope. Pyrite occurring in this way is the earliest of the sulfides and is believed to have been deposited at the same time as the early vein quartz. A second generation of fine granular to massive pyrite fills open spaces and veinlets in vein quartz and is intimately intergrown with arsenopyrite in some places. Even this later pyrite is in general earlier than the other sulfides, and, although in one or two polished sections of ore it has replaced sphalerite, it has been extensively replaced by sphalerite and to a limited extent by chalcopyrite. Some supergene alteration of pyrite to "limonite" has taken place.

Pyrite is the chief constituent of some massive ores of the replacement type, such as are found at the Doyle and Bay City mines. It is the chief metallic mineral in the pyritic-gold deposits of the Century and Little Kate mines and of the gulches along Burnt Timber and Boren Creeks. It is widely disseminated in the wall rocks of many deposits.

Marcasite, FeS_2.—Marcasite, accompanying chalcedony in striking concentric structures, was observed in a polished section of ore from a prospect near Boren Creek, where it probably was formed in connection with the colloidal deposition of the silica. Its relation to other sulfides is not known.

Arsenopyrite, *FeAsS*.—Arsenopyrite is rather widely distributed in the La Plata ores, though nowhere abundant. The mineral is a component of the complex sulfide ores of the Lady Eleanora and other properties and is intergrown with pyrite and chlorite in the Peerless deposit on the West Mancos River. It occurs in nearly all ores that contain abundant telluride minerals.

The arsenopyrite is not closely associated with the tellurides, however, but occurs with pyrite, with which it is believed to be virtually contemporaneous. In one polished section from the Lucky Discovery mine both pyrite and arsenopyrite appear to be earlier than or contemporaneous with the early vein quartz; both exhibit euhedral to subhedral outlines. In most of the other sections the two minerals form granular intergrowths and are later than the early vein quartz.

In a section from the May Day mine a tiny veinlet of arsenopyrite in fine-grained sandstone contains several small masses of hessite, which have replaced arsenopyrite.

TELLURIDES

Sylvanite, (*Au*, *Ag*) Te_2.—According to local report and to most of the published descriptions of the district sylvanite is by far the most widespread telluride mineral in the La Plata deposits and is commoner there than any other telluride. Speaking absolutely, however, it is actually very rare in the many polished sections of representative ores that have been studied.

A little hypogene sylvanite occurs in the ore of the Lucky Discovery mine, where it forms a contemporaneous intergrowth with hessite, coloradoite, and petzite. The mineral has filled open spaces in the quartz gangue

[61] Emmons, W. H., The Neglected mine and near-by properties, Durango quadrangle, Colorado: U. S. Geol. Survey Bull. 260, pp. 121-127, 1905.

and has replaced sphalerite and tetrahedrite. It is in turn replaced to a small extent by hypogene native gold. Sylvanite is present also in ore from the Gold King mine (pl. 10 *D*).

Calaverite, $(Au, Ag) Te_2$.—Calaverite is a minor constituent of ores from the Gold King and Bessie G. mines. In the Gold King ore it forms a subgraphic pattern of tiny wormlike inclusions in hessite (pl. 10 *C*); in the Bessie G. ore small masses of calaverite are intergrown with krennerite, petzite, hessite, and coloradoite.

Krennerite, $(Au, Ag) Te_2$.—Krennerite occurs sparsely in ore from the Gold King, Bessie G., Neglected, and Idaho mines, where it forms contemporaneous intergrowths with the other telluride minerals and, in the Gold King ore, with native tellurium (pl. 11 *A*).

Hessite, $Ag_2 Te$.—Hessite is by far the most abundant telluride of the La Plata district and occurs in considerable quantity in the ore of the Bessie G., Durango Girl, Gold King, Idaho, Lucky Discovery, and May Day mines. It is intimately associated with the other tellurides in contemporaneous hypogene intergrowths. Hessite and the associated tellurides fill open spaces in the gangue, and they extensively replace tetrahedrite (pl. 10 *B*), which in many polished sections is found only as corroded residual grains in the tellurides. Sphalerite, pyrite, galena, and chalcopyrite are also replaced by the tellurides but to a much smaller extent. In ore from the Gold King mine, calaverite forms a subgraphic pattern of tiny wormlike inclusions in hessite (pl. 10 *C*), and in ore from the Durango Girl a similar pattern is formed by hessite and petzite. Hessite is replaced by hypogene native gold in the Lucky Discovery and Durango Girl ores (pl. 10 *A*) and by supergene gold in one polished section from the Eagle Pass vein (pl. 12 *D*).

Petzite, $(Ag, Au)_2 Te$.—Petzite is a minor constituent of ores from the Bessie G., Durango Girl, Idaho, Neglected, and Lucky Discovery mines. It is much less abundant than hessite, krennerite, and coloradoite but more abundant than sylvanite or calaverite.

Petzite is intimately associated with the other hypogene tellurides in a contemporaneous intergrowth and forms a subgraphic pattern of tiny wormlike inclusions in hessite, in ore from the Durango Girl and Lucky Discovery mines.

Coloradoite, $HgTe$.—Coloradoite, heretofore unreported from the district, is more abundant there than any telluride except hessite, and is probably a constituent of all ores that contain tellurides. It forms contemporaneous intergrowths with the other tellurides and is of hypogene origin. In some polished sections it is extensively replaced by hypogene native gold. It is doubtless the source of most of the supergene native mercury that is reported from several mines.

SULFOSALTS

Aikinite, $2Pb.Cu_2S.Bi_2S_3$.—See cosalite.

Miargyrite, $Ag_2S.Sb_2S_3$, *and Pyrargyrite*, $3Ag_2S.Sb_2S_3$.—Pyrargyrite was identified only in ores from the Gold King and Texas Chief mines, and miargyrite only in ore from the Gold King mine. These minerals, however, with proustite ($3Ag_2S.As_2S_3$), are doubtless among the principal ore minerals in the Cumberland, Muldoon, Kennebec, and other mines of the belt that crosses the northern part of the district, since that is known as the "ruby silver" belt. Ruby silver minerals have also been reported from the Shoo Fly on Tirbircio Creek, and from the Euclid mine west of the Sharkstooth, and they may be present, though scarce, in ores of other mines.

A contemporaneous intergrowth of miargyrite and pyrargyrite, believed to be of hypogene origin, is revealed in a polished section of ore obtained between the main and 100-foot levels of the Gold King mine. These minerals have filled open spaces and to a small extent have replaced the quartz and pyrite in their quartz gangue, which contains abundant euhedral crystals of pyrite. A very small amount of chalcopyrite and sphalerite occur with the ruby silvers, but their relations to one another are not clear. A little pyrargyrite is associated with galena and chalcopyrite in ore from the Texas Chief mine, and a few grains, too small for positive identification, of ruby silver mineral are intergrown with stephanite in ore from the Muldoon.

Benjaminite $(Cu,Ag)_2S.2PbS.2Bi_2S_3$.—See cosalite.

Cosalite, $2PbS.Bi_2S_3$.—Hillebrand[62] has described cosalite from the Comstock mine. He found it in irregular masses, rarely as much as an inch long, with no cleavage or recognizable crystallization but with a suggestion of fibrous structure. It was associated with pyrite, sphalerite, sylvanite (?), and native gold. Calculating the iron found in this analysis as pyrite, Hillebrand deduced the general formula $2RS.Bi_2S_3$, with $R = Pb$, Ag_2, and Cu_2. Since theoretically pure cosalite contains neither silver nor copper, the mineral analyzed either is a mixture or was incorrectly classified. As shown in the table below, the chemical composition as

Analyses of "cosalite" from Comstock mine and of benjaminite [1]

	Cosalite [2]	Benjaminite [3]	
		Found	*Theory*
Bismuth	42. 93	48–53	49. 18
Silver	8. 43	3–4	4. 25
Copper	7. 50	3–7	5. 01
Lead	22. 49	23–27	24. 50
Iron	. 70		
Zinc	Tr.		
Sulfur	17. 11	15–16	17. 06
Total	99. 16		100. 00

[1] Shannon, E. V., Proc. U. S. Nat. Mus. (1925), vol. 65, art. 24; No. 2537 (June 17, 1924.)
[2] W. F. Hillebrand, analyst.
[3] E. V. Shannon, analyst.

[62] Hillebrand, W. F., Miscellaneous mineral notes: U. S. Geol. Survey Bull. 20, pt. 6, p. 95, 1895. Also in Colorado Sci. Soc. Proc., vol. 1, p. 52, 1884.

given by Hillebrand corresponds well with that of benjaminite, and it may well be that the Comstock material consisted largely of that mineral.

George [63] says "some of the ore from the La Plata Mountains, called cosalite, is clearly aikinite." But analytical data given above fit aikinite little better than they fit cosalite, and unless new material can be found and studied microscopically the identity of the mineral or minerals in the material analyzed by Hillebrand must remain in doubt.

Tetrahedrite, $5Cu_2S.2(Cu,Fe)S.2Sb_2S_3$. — Tetrahedrite is one of the most widely distributed sulfide minerals in the district and is abundant in most of the telluride ores. In composition the mineral is closer to tetrahedrite than to tennantite, though all the specimens tested by microchemical methods contain an appreciable quantity of arsenic. Few of the specimens gave a reaction for silver by the ammonium bichromate method.[64]

The tetrahedrite is of hypogene origin. It was deposited soon after sphalerite and chalcopyrite, and in most sections it is clearly earlier than galena. The periods of deposition of the four minerals overlapped, however, so that in some places two or more of them were deposited contemporaneously.

Tetrahedrite has been more extensively replaced by the tellurides than any other mineral (pl. 10 *B*), and in many sections it is seen only as embayed remnants in the tellurides. It has also been selectively replaced by native gold. In some specimens from the Red Arrow vein, gold is intergrown with tetrahedrite; in a few, minute crystals of tetrahedrite are perched on the surface of gold crystals. Supergene alteration of tetrahedrite along minute fractures has produced a little covellite in a few places.

Polybasite, $8Ag_2S.Sb_2S_3$, *and pearceite*, $8Ag_2S.As_2S_3$.—Polybasite was not found during this investigation, but C. W. Purington, in his field notes for 1896, stated that the ores of the Daisy-Hibernia workings contained polybasite and possibly other silver minerals. They were associated with galena, chalcopyrite, pyrite, and free gold in a gangue of quartz.

Pearceite was found only in ore from the Cumberland mine. A polished surface of this ore reveals an intergrowth of a pinkish isotropic mineral with a white anistropic mineral. Both minerals yielded nearly identical etch tests and are shown by microchemical tests to be silver sulfarsenides. The white mineral is believed to be pearceite, although the etch tests do not exactly conform to those given by Short.[65] The results of etch tests and chemical analysis suggest that the pinkish mineral is a variety of pearceite, but as the mineral is isotropic, this determination is questionable. Its relations to the other ore minerals are not known.

Enargite, $Cu_2S.4CuS.As_2S_3$.—The ores of the Neglected and Tomahawk mines contain very small quantities of enargite, intergrown with chalcopyrite and tetrahedrite. The enargite in the Tomahawk ore is of the pink variety known as luzonite.

Stephanite, $5Ag_2S.Sb_2S_3$.—Stephanite, or "brittle silver," was observed only in polished surfaces of ore from the Muldoon mine but is reported from the May Day mine by several mining engineers. That in the Muldoon ore is of hypogene origin and was deposited in open spaces in the quartz gangue. Intergrown with the stephanite is a little ruby silver in masses too small for specific identification. Supergene anglesite replaces the stephanite along minute fractures.

HALOIDS

Cerargyrite, $AgCl$.—Cerargyrite has not been positively identified in any of the ores, but the rich oxidized silver ores of the Little Nona and Jumbo-Morovoratz mines probably contain this mineral, and so possibly, do the weathered portions of other silver-bearing deposits. "Chlorides and bromides of silver" (cerargyrite, embolite, and bromyrite) are said by miners to occur in the May Day-Idaho ores, but they have not been identified with certainty.

Fluorite, CaF_2.—Fluorite has been observed in the Copper Hill-Bedrock Creek area and in the Gold King mine, and it also has been reported from the Mason mine near Trimble. Small quantities of fluorite are associated with the platinum-bearing chalcopyrite ores of Copper Hill, but there the mineral is seldom visible megascopically. Comparatively large lenses and veins of very siliceous lavender to dark-purple fluorite occur in many places along the upper part of Bedrock Creek, especially in the vicinity of the Allard tunnel. Many of these bodies contain disseminated crystals of pyrite and chalcopyrite.

Clear cubical crystals of pale-violet fluorite line vugs at many places of the Gold King vein. The largest ones observed are about half an inch in diameter, but most of them are much smaller. Fluorite was one of the last minerals to form in this vein.

OXIDES

Quartz, SiO_2.—Quartz is by far the most abundant gangue mineral in the veins of the district and at many places the only one.

Most of the quartz in the veins is of a rather coarsely crystalline, clear, colorless variety and contains abundant vugs, which are lined wholly or in part with projecting crystals or crystal faces. Fine-grained translucent quartz was found in some veins and chalcedony in a few. In places the quartz is rendered dark gray to black by finely disseminated pyrite, and in much of the high-grade telluride ore it is tinted green by roscoelite.

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[63] George, R. D., Common minerals and rocks, their occurrences and uses: Colorado Geol. Survey Bull. 12, 463 pp., 1917.

[64] Short, M. N., Microscopic determination of the ore minerals, 2d. ed.: U. S. Geol. Survey, Bull. 914, pp. 200, 201, 1940.

[65] Short, M. N., idem., p. 135.

Quartz was being formed throughout the period of ore deposition. The clear, coarsely crystalline variety was deposited during the early stages of vein formation with some of the pyrite. Quartz of several later generations, most of it fine grained, cuts all the hypogene ore minerals in tiny veinlets and replaces them along grain boundaries and cleavage traces.

Cuprite, Cu_2O.—The red copper oxide cuprite has been found only along Bedrock Creek, where it forms veins and veinlets that cut the metamorphic rocks in the border zone of the syenite stock. The only one of these veins that has been worked is the Copper Age, which according to Wallace[66] was very rich in red copper oxide and native copper. The mineral is doubtless a weathering product of the chalcopyrite, which is disseminated in most of the rocks in this area.

Hematite Fe_2O_3.—Specular hematite is a prominent constituent of many of the "contact-metamorphic" bodies that have been formed by replacement of limestone beds and nodules. It is commonly associated with magnetite, garnet, augite, hornblende, and epidote. The only places where these bodies have been worked as ore are in the Bay City, Gold Farm, Lady Eleanora, and Silver Falls mines. Polished surfaces of ore from the Bay City mine reveal radiating plates of hematite that penetrate boxwork intergrowths of magnetite and quartz. In this ore all three minerals were probably deposited contemporaneously, or nearly so. In some ore from Copper Hill, however, magnetite is pseudomorphic after hematite and magnetite and is associated with platinum-bearing chalcopyrite.

Magnetite, $FeO.Fe_2O_3$.—Magnetite has the same general distribution as hematite, some of it being pseudomorphic after hematite, but it is more abundant than that mineral in many places. On the northeast slope of Diorite Peak the "La Plata" limestone has been entirely replaced by massive granular magnetite over a comparatively large area. In a few places the magnetite is weakly magnetic.

The abundant magnetite in the ore of the Bay City mine (pl. 11 *B*) forms a striking boxwork structure and appears to be contemporaneous with the clear, glassy quartz of the early stage. It is earlier than pyrite, veinlets of which cut both quartz and magnetite. Radiating plates of hematite penetrate the magnetite and quartz.

Pyrolusite, MnO_2.—Pyrolusite and possibly psilomelane are widespread but nowhere abundant. They form stains, films, and veinlets in and on weathered rocks and were doubtless formed by oxidation of manganese-bearing carbonate minerals, here grouped under the term ankerite.

Limonite.—A mixture of unidentified hydrated ferric oxides, commonly referred to as limonite but probably consisting largely of goethite ($Fe_2O_3.H_2O$), is present in small amount in the outcrops of many of the veins, though observed in only a few of the polished sections. It is of supergene origin and replaces pyrite and siderite.

Limonite that has been derived from gold-bearing pyrite is comparatively rich in gold in places, and it forms most of the ore in the Monarch, Bay City, and some other mines. Limonite containing a little gold is even now being deposited in a bog in Rush Basin, near the Doyle mine, but it is not rich enough to constitute ore.

CARBONATES

Calcite, $CaO.CO_2$.—Calcite is fairly widespread in the district but is generally not abundant as a gangue mineral. By far the greatest concentration of calcite seen occurs along the eastward extension of the May Day-Idaho fault system, in the general vicinity of the Oro Negro prospects, where there are solid bodies of white calcite 10 to 20 feet in width. In the few polished sections in which calcite has been found, it fills open spaces in the quartz gangue and is clearly later than both the early quartz and the associated pyrite. Its relation to the later minerals is not clear, but it probably was being formed throughout a long period. It appears to have been deposited contemporaneously with the sulfides of copper, lead, and zinc, and in places it has been replaced by them. A little late crystalline calcite lines vugs in several veins.

Ankerite, $CaO.(Mg.Fe)O.2CO_2$.—Carbonate minerals are present in many ores throughout the district and are relatively abundant in some of them. Most of the carbonate approaches ankerite in composition, but some of it is probably closely allied to rhodochrosite; much ore contains so much manganese that it is stained black when weathered.

Ankerite is abundant in polished sections from the Neglected, Florence W., and Red Arrow properties. It has filled open spaces in the quartz and extensively replaced the pyrite, and it has in turn been replaced by chalcopyrite, bornite, and tetrahedrite. Ankerite probably was being formed, however, throughout the period of deposition of the copper sulfides, for in one polished section of ore from the Neglected mine a carbonate deposited at a later stage forms a network of tiny veinlets in the sulfide areas.

Siderite, $FeO.CO_2$.—Siderite appears to be rare in the district, having been seen in only two polished sections. It is the chief gangue mineral in the Texas Chief ore, where it has replaced pyrite extensively and has in turn been replaced by sphalerite, chalcopyrite, and galena. In ore from the Lady Eleanora mine, chalcopyrite, tetrahedrite, and galena are intimately associated with siderite. It was not possible to determine whether these minerals were all contemporaneous or whether the sulfides replaced older siderite.

[66] Wallace J. P., La Plata County, in Burchard, H. C., Report of Director of the Mint, 1883.

Cerussite, $PbO.CO_2$.—Small quantities of cerussite are found in most of the ores that contain abundant galena. The mineral is of supergene origin and has replaced galena along minute fractures and grain boundaries (pl. 12 *B*). It apparently was formed only near the surface.

Malachite, $2CuO.CO_2.H_2O$ *and azurite*, $3CuO.2CO_2.H_2O$.—Green and blue films of malachite and azurite stain the oxidized parts of many deposits that contain copper, but neither mineral is anywhere abundant.

SILICATES

Orthoclase, $K_2O.Al_2O_3.6SiO_2$.—Except the disseminated chalcopyrite deposits of Copper Hill and Bedrock Creek, orthoclase is rare as a gangue mineral. Coarsely crystalline orthoclase is intergrown with vein quartz in base-metal ore from the Honeydew mine, although the sulfides are in general younger than the quartz and feldspar. Several small veins that cut monzonite in the upper part of Tomahawk Basin contain orthoclase and quartz, together with a little gold, but none of them is of any economic importance.

The host rock on Copper Hill is a massive metamorphic rock formed by partial replacement of sedimentary rocks by syenite. It is composed of rather distinct layers of fine-grained to coarsely crystalline orthoclase alternating with layers of augite in small bladed crystals. Platinum-bearing chalcopyrite, magnetite, and hematite are disseminated through the rock and fill numerous veinlets. Similar but much more coarsely crystalline rock of the same type crops out along Bedrock Creek (see pp. 65–66).

Augite, silicate of calcium, magnesium, iron, and aluminum.—The most important occurrence of augite as a gangue mineral is the one on Copper Hill noted above in the paragraph on orthoclase. Augite is widespread in the contact-metamorphic bodies in the central part of the district, where it is associated with andradite, epidote, magnetite, hematite, and other minerals. It has not been identified, however in any of the deposits of this type that have been worked for ore.

Tremolite, $5MgO.2CaO.8SiO_2.H_2O$.—Tremolite was seen only in ore from the Camp Bird prospect, near Diorite Peak, where it forms small, clear to white, rodlike crystals intimately intergrown with pyrite and chalcopyrite in a quartz gangue. It is here accompanied by ankerite, calcite, and barite.

Garnet, var. andradite, $3CaO.Fe_2O_3.3SiO_2$.—Yellow to brown andradite is abundant in many of the contact-metamorphic bodies formed by replacement of limestone. It makes up a large proportion of the primary gangue material in the Bay City and Silver Falls deposits and in several others that have been worked. Most of the andradite is massive and is intergrown with other silicates and with iron oxides, but well-formed crystals occur in many places.

Epidote, $H_2O.4CaO.3(Al,Fe)_2O.6SiO_2$.—Yellowish-green to bright-green epidote is a widespread constituent of the contact-metamorphic deposits, but it is not very abundant except in the Bay City mine, where it is closely associated with garnet. It is present in the altered wall rocks of a few veins.

Tourmaline, complex borosilicate of aluminum and other elements.—Tourmaline has been observed only as a product of wall-rock alteration in the Neglected mine, but it may occur in other deposits and have been overlooked. In the Neglected mine, the hornblende phenocrysts in the most thoroughly altered porphyry, close to the vein, have been replaced by intergrowths of tourmaline, sericite, and chlorite, named in order of abundance. At greater distances from the vein these minerals give way to chlorite with a little epidote and carbonate. Other products of wall-rock alteration in this mine are silica, pyrite, and halloysite.

Muscovite, var. sericite, $2H_2O.K_2O.3Al_2O_3.6SiO_2$.—Sericite, the fine-grained variety of muscovite, is widespread as an alteration product of feldspars in the porphyritic rocks. It is also a constituent of altered wall rocks near many of the ore deposits, particularly where these rocks are igneous, and of some fault gouges, which are largely made up of very finely comminuted rock.

Roscoelite, $2H_2O.K_2O.3(Al,V)_2O.6SiO_2$.—The green vanadium-bearing mica, roscoelite, is a widespread associate of the telluride minerals. It commonly occurs in small quantities in microscopic intergrowth with fine-grained quartz, to which it imparts a dull-green color. This green quartz is an almost certain indication of high-grade ore, even where no telluride minerals are visible to the naked eye. In a few deposits roscoelite forms easily visible felted aggregates of small platy crystals. It is much more abundant in the Durango Girl mine than anywhere else. It was not seen underground there, but the dump contains several tons of material extremely rich in roscoelite. One relatively pure sample, analyzed qualitatively by J. J. Fahey in the Geological Survey laboratory, was estimated to contain 4 to 8 percent vanadium.

Chlorite, hydrous silicate of aluminum, ferrous iron, and magnesium.—Chlorite is widespread as a product of wall-rock alteration. It is most abundant in the general vicinity of Diorite Peak and Tomahawk Basin, but even there it does not occur in large quantities. In the Silver Falls mine a little chlorite is intergrown with the garnet and sulfide minerals, and in the Peerless mine chlorite is closely associated with pyrite and arsenopyrite.

Dickite, $2H_2O.Al_2O.2SiO_2$.—Dickite, one of the clay minerals, is widespread in the veins of the district. It commonly forms white pulverulent masses of microscopic platy crystals, many of them stained yellow or brown with limonitic material, but in a few places it is dense and relatively hard and somewhat resembles massive alunite. So far as known it was the last mineral to form in the telluride-bearing veins, and it fills vugs and other openings in the vein matter. It is probably most abundant in the Neglected and Wheel of Fortune deposits, but it is rather prominent in many others. Purington, in his field notes of 1896, notes the discovery in the Cumberland mine of a large vug filled with white clay (probably dickite) that was rich in free gold.

Halloysite, $Al_2O_3.2SiO_2$ *with water*.—Halloysite, one of the clay minerals, has been identified in the altered wall rocks of several deposits and is probably rather widespread, though it is nowhere very abundant. Other minerals of the kaolin and hydrous aluminum silicate groups may be present in places, but have not been identified.

SULFATES

Barite, $BaO.SO_3$.—Barite is rather widely distributed as a gangue mineral in the veins of the district but is everywhere subordinate to quartz in abundance. Deposition of barite followed that of quartz and early pyrite and preceded the main period of sulfide mineralization. On some polished surfaces of ore from the Gold King and Bessie G. mines, small veinlets of barite appear to cut the sulfides and tellurides, which suggests a late stage of barite deposition; it seems likely, however, that these veinlets consist of early barite originally having walls of quartz, and that solutions depositing the metallic minerals replaced the quartz but did not affect the relatively nonreactive barite. A little late barite in clear or light-blue crystals lines vugs in some deposits. Coarsely crystalline barite characterizes the coarse-gold ore of the Red Arrow mine and is also present in the Kiabab property.

Anglesite, $PbO.SO_3$.—Anglesite in small amount replaces galena in a few of the sections studied. It is of supergene origin.

Gypsum, $CaO.SO_3.2H_2O$.—A little gypsum is present in highly oxidized ore from the Bay City mine. It accompanies porous limonite and is clearly supergene.

Melanterite $FeO.SO_3.7H_2O$ and *chalcanthite*, $CuO.SO_3.5H_2O$.—Melanterite, chalcanthite, and other soluble sulfate minerals occur in many mines as postmining oxidation products, but they are nowhere abundant or economically important.

SEQUENCE OF HYPOGENE ORE MINERALS

The ores of the La Plata district are of several different types which differ in age. Although the character of these types varies in detail from place to place, the general sequence of vein mineral formation shown in figure 4 is characteristic of the district as a whole.

The main stages in the history of ore formation are deposition of (1) quartz and pyrite, (2) barite and ankerite, (3) vein sulfides in the order pyrite and arsenopyrite, sphalerite and chalcopyrite, tetrahedrite and galena, (4) tellurides, all believed to be of contemporaneous origin, (5) native gold, and (6) cinnabar and native gold.

There are many exceptions, however, to this order. Although most of the vein quartz was found early, quartz continued to be formed throughout the period of ore deposition, some veinlets of fine-grained quartz being clearly later that the tellurides. Euhedral to subhedral grains of pyrite are contemporaneous with quartz and accompany it in nearly every specimen stud-

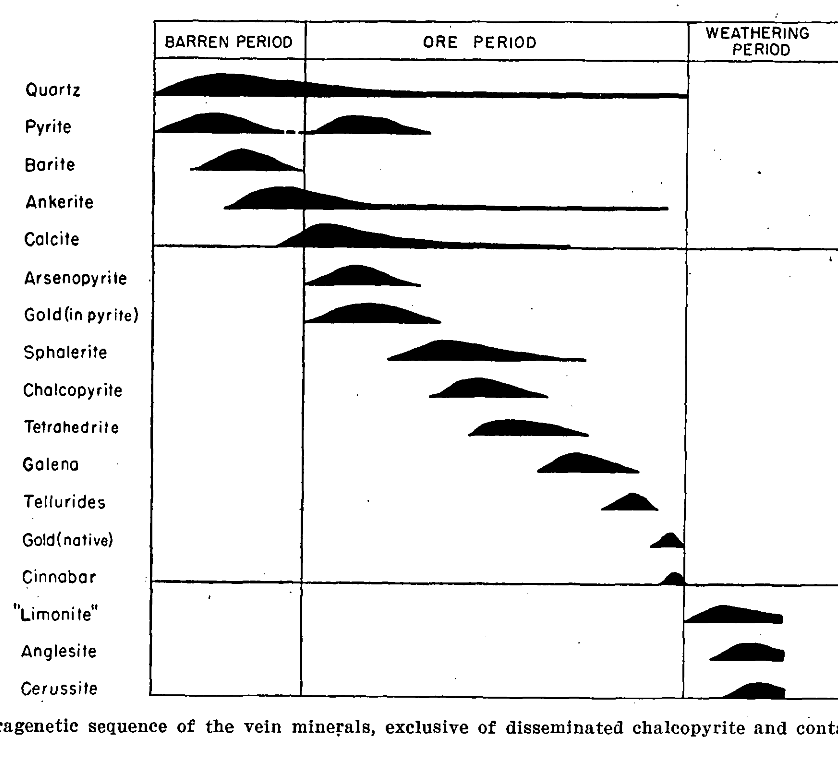

FIGURE 4.—General paragenetic sequence of the vein minerals, exclusive of disseminated chalcopyrite and contact-metamorphic deposits.

ied. Barite is later than the early quartz and was formed before the sulfides. Ankerite is closely associated with barite in several specimens, and most of the ankerite is believed to be later than the barite, but the relations of the two minerals are not entirely clear. Ankerite is extensively replaced by sulfides, yet in some places the carbonate is later than the sulfides. The most variable relations are exhibited by the sulfides. The relations most commonly observed indicate the order of deposition given above, but the occasional replacement of sphalerite by pyrite, of tetrahedrite by chalcopyrite and sphalerite, and of galena by sphalerite suggests an overlapping sequence of deposition. The rarer sulfosalts, such as the ruby silvers and stephanite, were also deposited during the sulfide stage of mineralization, but their place in the sequence could not be clearly determined from the small quantity of these minerals present in available specimens. Calcite probably was being formed throughout the sulfide stage.

The tellurides are clearly later than the sulfides. Tetrahedrite is the mineral most extensively replaced by them, although pyrite, sphalerite, chalcopyrite, and galena are all replaced in lesser degree. No evidence of the replacement of one telluride by another was observed in any of the polished sections studied, so that the tellurides are believed to have been formed contemporaneously.

With the exception of cinnabar, which was observed in only one section, the latest hypogene mineral is native gold. The minerals most extensively replaced by it are tetrahedrite, hessite, and coloradoite.

SUPERGENE ALTERATION

Little alteration of the primary ores by surface waters has taken place. Limonite is the most abundant supergene product, especially in ores containing much pyrite. Anglesite and cerussite in small amount were formed from the alteration of galena, a little covellite replaced chalcopyrite and tetrahedrite, and supergene bornite filled capillary cracks in chalcopyrite. Native gold is believed to have replaced a little of the hessite. A little gypsum accompanies the limonite in the oxidized zone of the Bay City mine.

ORE DEPOSITS

GENERAL FEATURES

As indicated by the production figures given above, more than 98 percent of the production of this district has been of gold and silver. The district is best known for its veins and replacement deposits of gold-bearing and silver-bearing telluride ores, from which the greater part of the production has come. In addition to them, however, it contains a surprising variety of types of ore deposit within a small area. They include deposits of disseminated platinum-bearing chalcopyrite, gold contact-metamorphic deposits, deposits in which base-metal sulfides or pyrite and native gold predominate, and deposits characterized by the ruby silver minerals. They include disseminations and bed replacement bodies as well as veins. Some of these various classes of deposits are relatively unimportant commercially, and none of them probably will ever approach the telluride veins in total production. From the scientist's viewpoint, however, they form an interesting group, and some of them bear promise of having greater economic value in the future than they have had in the past.

CLASSIFICATION

Because of their diversity the ore deposits of this district do not lend themselves to simple classification. The classification given below is based primarily on mineral content and secondarily on form. This treatment seems best suited to an objective discussion of the economic geology, though it leaves much to be desired from the scientific standpoint. Discussion of the mutual relations of the several types is reserved for a separate section, where it will be seen that this classification corresponds in general to a genetic one; that is, the deposits high in the list were formed closer to their source and at higher temperatures and pressures than those farther down in the list.

Classification of ore deposits of La Plata district is as follows:

1. Disseminated chalcopyrite with platinum and palladium.
2. Gold with sulfides:
   - a. Contact-metamorphic replacement bodies.
   - b. Gold-bearing pyrite:
     - Veins.
     - Replacement bodies.
     - Breccia bodies.
   - c. Mixed sulfides with silver and free gold.
3. Chalcocite veins.
4. Ruby silver veins.
5. Telluride deposits:
   - a. Veins.
   - b. Replacement bodies.
6. Gold placers.

DISSEMINATED CHALCOPYRITE WITH PLATINUM AND PALLADIUM

By G. M. Schwartz, D. J. Varnes, and E. B. Eckel

INTRODUCTION

Disseminated deposits of chalcopyrite, rich enough in a few places to constitute copper ore, are associated with both of the syenite stocks in the central part of the district. As a result of Eckel's study [67] small amounts of palladium and platinum were found to be associated with the chalcopyrite in one of these deposits on Copper Hill, and the general similarity of all the deposits of this type in the district made it seem possible that these precious metals are present in other places. In 1943 the Bureau of Mines sampled the entire workings of the

[67] Eckel, E. B., Copper ores of the La Plata district, Colorado, and their platinum content: Colorado Sci. Soc. Proc., vol. 13, No. 12, pp. 657–664, 1938.

Copper Hill mine and the Allard tunnel for the purpose of determining the commercial importance of the deposits, and in the summer of 1944 B. S. Butler, G. M. Schwartz, and D. J. Varnes of the Geological Survey spent several days in the area. The descriptions of the deposits at the Copper Hill mine and the Allard tunnel are based on the results of all this work.

DEPOSIT ON COPPER HILL

The Copper Hill mine is situated on the ridge between Boren and Bedrock Creeks, at an altitude of 10,250 feet. It has yielded 2,336 tons of ore that contained 223,865 pounds of copper, over 4,000 ounces of silver, and a very small amount of gold. Most if not all of the ore produced was taken from a single small glory hole.

The deposit is situated within the larger syenite stock and near its northeast border. The geologic features are in large part obscured by moderately heavy timber and by soil, talus, and glacial debris, which cover most of the hill. As seen in the excellent exposures afforded by the glory hole, the country rock is a dark, greenish-brown to gray massive metamorphic rock that resulted from partial replacement of sedimentary rocks and porphyry by a syenitic mineral aggregate. The rock is hard and tough, has a somewhat greasy luster, and in some places shows distinct layering (pl. 8 *A*). The layered rock, which probably is a metamorphosed sediment, is associated with rock having a relict porphyritic texture and with rock having a simple granitoid texture. The later doubtless represents the result of rather complete replacement of the porphyry or sediment by the syenitic mineral aggregate. All these types of rock have gradational contacts and show very complex relations in space with each other. Their general distribution in the workings around the glory hole is shown in figure 20.

Thin sections of the rocks around the mines show the various types to be somewhat similar in mineral composition. The most abundant constituent is feldspar, mainly orthoclase. Perthitic intergrowths with albite are common. Residual cores of the original feldspar form cores of many of the present grains. Generally the original plagioclase is clouded with sericite, kaolinite, zoisite, and carbonates. Augite and its alteration products, hornblende and chlorite, are important in all the rocks. Inclusions of metamorphosed sedimentary rocks have a hornfels texture in which hornblende is an essential mineral instead of augite. Some of the augite in the metasediment is clearly along veinlets and is accompanied by sulfides. Apatite is a common constituent in most of the thin sections. Its irregular distribution in clusters, and as veinlets in one specimen, suggests that much of the apatite was introduced during the replacement and mineralization of the original rocks. Magnetite and titanite are common, some as accessory minerals in the host rock and some as introduced material.

Small irregular grains and masses of chalcopyrite are disseminated abundantly through the rock and are accompanied by minor quantities of specular hematite, and magnetite. The rock is cut by innumerable closely spaced veinlets, the thinnest of which are mere irregular films and the thickest are gash veins more than 2 inches in maximum thickness. These veinlets trend in all directions, but the dominant trend seems to lie between north and northeast. They are composed in large part of chalcopyrite, which is intimately intergrown in places with hematite, magnetite, and pyrite. In the few polished sections of the veins that have been made, the iron oxides were found to be the oldest of the metallic minerals, pyrite second in age, and chalcopyrite latest. Nonmetallic minerals are much less abundant in the veins than the metallic minerals. Garnet, ankerite, and quartz are the chief gangue minerals; a little fluorite occurs in places.

These deposits have undergone only slight oxidation, the chief products of which are green and blue films of malachite and azurite and veinlets of limonite.

The better ore zone in the vicinity of the glory hole appears to be the result of intense fracturing at a late stage in the alteration of the rock. Solutions circulating along the fractures rather completely replaced the adjoining rock with orthoclase and deposited the ore minerals. The original porphyry is generally highly sericitized and contains much pyrite, whereas the feldspathized rock is now largely orthoclase. Vein quartz occurs in some places in the upper workings, but it is not common. In the lower tunnel, and particularly on the dump, vein quartz is more abundant, but it appears to have no relation to the sulfides.

Efforts to work out a system of fracturing which may have controlled the mineralization were not successful. A well-marked series of joints in the glory hole strike N. 65° W. and dip 20° to the northeast. There are also strong joints that have a strike of N. 65° W. and dip 75° to the northeast, and a great many other fractures of irregular strike and dip. However, the intense local fracturing in the ore zone does not seem to be related to any of the larger systems of joints. The lower tunnel, which was driven directly under the glory hole and 180 feet lower, did not encounter ore (fig. 20).

A sample of relatively high-grade chalcopyrite ore from the Copper Hill dump was submitted by the writer to E. T. Erickson, of the Geological Survey, to be assayed for gold and silver. Cupellation yielded a metallic button whose character indicated that it contained metals of the platinum group; that is, the button had a peculiar frosted appearance and showed a tendency to flatten out toward the close of cupellation. Determination of gold and silver in this button by special methods left a remainder that was at first thought to represent platinum metals. Platinum was identified, but the content of platinum indicated by difference was later found to be too high, owing to the fact that cupellation had failed to remove all the lead from the button. This difficulty in completely removing lead is commonly met with in treating buttons that contain relatively high proportions of the platinum group of metals. Spectographic examination of this sample by George Steiger, of the Survey Laboratory not only confirmed the presence of platinum but also showed the presence of palladium.

Although samples representative of the dump as a whole had not been collected, the material discovered above and a second large sample from the same dump were studied further. The second sample, which consisted of many small pieces and chips of ore that contained a comparatively large proportion of chalcopyrite probably represents fairly well the grade of copper ore that could be recovered by careful hand sorting. Copper was determined in the usual way. Silver was separated in a separate assay as silver chloride, from the other constituents that remained after cupellation, and was reduced to a button and weighed as metallic silver. Gold was removed by solution of its chlorides in ethyl acetate; about 0.01 ounce per ton was found.

For determination of the platinum metals, separate samples were assayed in the regular way, except that they were scorified to lower the copper content. For cupellation, 3 milligrams of silver was added. The final button was heated for a long time in aqua regia. The silver was removed by precipitation as chloride, and any remaining silver chloride that separated from the combined filtrates overnight was also filtered off. The filtrate, worked down to a very dilute hydrochloric acid solution, was yellow, indicating platinum metals of the order of some tenths of an ounce per ton. Palladium was determined by precipitation with dimethlyglyoxime under control conditions, in which the effect of platinum would be eliminated. Platinum metals were then precipitated with formic acid and ammonium formate, and platinum was determined colorometrically, By separate assay, the other metals of the platinum group—osmium, iridium, rhodium, and ruthenium—were determined to be present only in negligible quantities. The results of the determinations are summarized below.

Assays of selected samples rich in chalcopyrite from Copper Hill mine dump

[E. T. Erickson, assayer]

Sample	Copper (percent)	Platinum (ounces per ton)	Palladium (ounces per ton)	Gold (ounces per ton)	Silver (ounces per ton)
1	17.66	0.24	[1] 0.30	[2] 0.04	1.21
2	13.1	.14	[3] .12	.01	2.52

[1] Platinum and palladium determined on one-half assay ton sample.
[2] Maximum value, may be considerably too high.
[3] Platinum and palladium determined on 1 assay ton sample.

Thorough microscopic examination of a few polished sections of ore rich in chalcopyrite has failed to disclose the mode of occurrence of the platinum metals. They may exist in solid solution in the chalcopyrite, or they may form extremely small discrete particles intergrown with the chalcopyrite or with the iron oxide minerals.

Thorough sampling by the Bureau of Mines shows that in a small area immediately surrounding the glory hole the rock averages 1.87 percent copper, 0.49 ounce of silver, and 0.005 ounce of the platinum metals. These values fall off sharply away from the glory hole so that the average copper content in the workings outside of the glory hole is only 0.14 percent Samples taken from 5-foot cuts at 10-foot intervals for the entire length of the lower tunnel average 0.08 percent copper and 0.0034 ounce of platinum metals. A comparison of the content of the platinum metals of the samples collected by the writer with that for the deposit as a whole shows that the relative proportion of platinum metals increases markedly with higher copper content.

OTHER COPPER DEPOSITS

Chalcopyrite is widely distributed in the central part of the La Plata district, though with few exceptions it is present only in minute amounts at any given locality. Every specimen collected from the two syenite stocks during the writer's investigation contains a little chalcopyrite, which occurs as disseminated grains and in threadlike veinlets. However, the data available indicate that the other copper-bearing areas contain less copper than the Copper Hill deposit and little or no platinum.

A large area near the head of Bedrock Creek, between the Allard tunnel and the divide (pl. 2), shows evidence of mineralization similar to that at Copper Hill. The area was more or less thoroughly prospected for gold deposits in the early days of the district, and many claims were staked. The results of that prospecting were not encouraging, however, and there has been no activity in the area for several years.

The slopes are rugged, and exposures are better in general than in most other parts of the district. The bedrock is completely bare over large areas near the tunnel. Much of the rock exposed on the surface and in the tunnel is porphyritic, but syenite, metamorphosed sedimentary rock, and pegmatitic dikes are also present. Along parts of their contact with the syenite the sedimentary rocks are strongly brecciated, but elsewhere the contact is vague and indistinct, largely because of incomplete replacement of the country rock by syenite.

The fresh-appearing syenite has a granitoid texture and consists of highly perthitic feldspar with later albite and microcline. Ferromagnesian minerals are almost wholly absent, but a little magnetite occurs scattered throughout. Calcite occurs in areas between feldspar crystals and as veinlets with pyrite. Inclusions of sedimentary rock have a hornfels texture and consist mainly of hornblende and feldspar. Quartz is not common, but a few grains, accompanied by cherty or cryptocrystalline silica, were seen in some thin sections.

Pyrite and chalcopyrite are sparsely disseminated through the syenite. Near the Allard tunnel the rock is traversed by numerous veins and dikes. They trend and dip in all directions, but many of the strongest have trends between northeast and east and are nearly vertical. Most of them consist of coarsely bladed dark-green augite intergrown with orthoclase. At places the augite is clearly later than the feldspar and carries pyrite and chalcopyrite. Individual veins range from less than an inch to more than 2 feet in width. Many of them can be traced for several hundred feet; others pinch out within short distances. The large dike on the surface above the tunnel has offshoots to the south at an acute angle which form a horsetail structure.

In addition to the dikelike bodies described above, there are many quartz veins that contain chalcopyrite and pyrite. Also, the rock is cut by a number of discontinuous veins, from one-sixteenth of an inch to 5 inches in thickness, made up of dense, siliceous fluorspar intergrown with rather coarsely crystalline quartz. The fluorspar is dark blue to purple when freshly broken, but weathering lightens its color to pink or lilac. Some of it contains a few grains of pyrite. Galena, in veins or lenses, is reliably reported to occur near the Allard tunnel.

Near the head of Bedrock Creek weathering and oxidation have made more headway than on Copper Hill. Much of the pyrite in the rocks has there been altered to limonite, and the outcrops are prevailingly red or yellow to brown. In places the primary copper minerals have been converted to malachite, azurite, and chrysocolla, and a few large rock surfaces are coated with films of these green and blue minerals. The Copper Age mine, situated near the present Allard tunnel, developed a vein rich in the red copper-oxide cuprite and in native copper.

Five specimens representing different types of material in and near the Allard tunnel were submitted to E. T. Erickson for assay. They consisted, respectively, of nearly pure pyrite, of chalcopyrite, of cuprite, of augite with a little chalcopyrite and quartz, and of an intergrowth of feldspar, quartz, fluorite, and sulfide minerals. The samples were treated precisely like those from Copper Hill (p. 65). It was found that platinum and palladium, if present, each amounts to less than 0.01 ounce per ton.

Near the crest of the divide, at the head of Bedrock and Boren Creeks, the geologic features and ore deposits are similar in general to those near the Allard tunnel. In places the rocks contain considerable chalcopyrite, both disseminated and in quartz veins, but in most of the area pyrite is much more abundant than chalcopyrite. This ground as a whole therefore holds out even less promise than that in Copper Hill and near the Allard tunnel of becoming a source of copper. Locally, as in the Boren Creek group, it contains deposits that have been worked in a small way for gold.

The type of mineralization in both the Allard tunnel and the Copper Hill workings is somewhat similar to that in the New Cornelia mine at Ajo, Ariz.[68]

GOLD WITH SULFIDES

CONTACT-METAMORPHIC DEPOSITS

Most of the limy beds in the highly metamorphosed central part of the district have been altered to minerals that are commonly regarded by geologists as products of contact metamorphism. Many of these deposits contain a little gold, and a few have yielded workable bodies of ore. Their most abundant and widespread minerals are andradite, garnet, augite, magnetite, and hematite, which commonly form coarse-grained intergrowths that have nearly or quite replaced the original limy material of the country rocks; but hornblende, epidote, and probably several other silicates may be found in many places. Quartz and calcite are widespread but generally much less abundant than the silicates. Chalcopyrite and pyrite, which are intergrown with the silicates and iron oxides in many places, are later than the other minerals but seem to belong to the same general period of mineralization. Pyrite is locally abundant, forming deposits transitional toward the pyritic-gold deposits exemplified in the Doyle mine, but chalcopyrite is commonly rather scarce. Galena is present in the Bay City mine and possibly elsewhere.

The size and shape of these contact-metamorphic bodies depend in large part on the size and shape of the parent limestone bodies. Thus the basal Pony Express limestone member of the Wanakah formation (La Plata limestone of former reports) has been replaced by extensive layerlike bodies of mixed silicates or of magnetite and hematite; so too have the limestone conglomerates (locally called "Bay City lime") in the lower part of the Dolores formation in places where their pebbles consisted mainly of limestone. On the other hand, the more shaly limestone conglomerates and the lenses and nodules of limestone in the Cutler and other formations have been replaced only by scattered nodules and irregular knots of the silicate minerals.

Gold in small quantities is widespread in these deposits. Most of it is probably contained in the sulfides, but according to reliable reports some bodies of essentially pure magnetite and of garnet contain appreciable quantities of gold. No gold was seen in any of the primary ores that were examined. Whatever gold these deposits contain must be very finely divided. Most of it probably occurs in discrete particles, intimately intergrown with the sulfides and iron oxides, though some of it may be in solid solution.

Though contact-metamorphic bodies occur throughout the metamorphic area outlined in plate 2, all those

[68] Gilluly, James, Geology and ore deposits of the Ajo quadrangle, Arizona: Univ. of Arizona, Bur. of Mines Bull. 141, 1937.

that are known to have been mined lie near the edges of this area. They include the ore bodies in Bay City mine, which is the most productive of this class, the Gold Farm and Silver Falls mines and several prospects in Tomahawk Basin and near Diorite Peak. Several of the near-surface ore bodies worked in the past in the Lady Eleanora and Bonnie Girl mines were of this type, but more recent work in the Lady Eleanora has explored deposits that are more closely allied to the mixed sulfide and telluride deposits.

All the contact-metamorphic gold-bearing deposits have several features in common. Their relation to the edge of the metamorphic area has been mentioned. With all of them, except one low-grade gold-bearing magnetite body that has replaced the Pony Express limestone near Diorite Peak, have been formed by replacement of limestone conglomerates at or near the base of the Dolores formation. All of them are comparatively small, and though pockets of high-grade oxidized ore have been found in several of them, none of these deposits has produced any notable quantity of ore.

Of greater practical import than any of the above generalizations, however, is the fact that all known workable ores are partly or entirely oxidized. The oxidized ore bodies that have been worked are similar in most respects to the unoxidized ones described above, except that the copper and iron sulfides are largely altered to limonite, and that they have been enriched in gold. Available information suggests that much of the gold in the weathered zone is residual, and that it has been concentrated by removal of other materials rather than by solution, transportation, and redeposition of the gold itself.

As stated above, the gold in the primary deposits is widely distributed but apparently not concentrated anywhere in commercial quantities. The fact that none of the stopes in the mines mentioned above extend more than 25 to 30 feet below the surface, although the mines expose primary contact-metamorphic bodies at greater depths, is cogent evidence in this regard. The fact that great numbers of other deposits of this type have been only superficially explored by prospectors is proof that they have not been found to contain encouraging quantities of gold.

GOLD-BEARING PYRITE DEPOSITS

GENERAL FEATURES

Many deposits in the central part of the district contain pyrite and minor quantities of quartz almost to the exclusion of other minerals. Sericite, chlorite, and kaolin found at some places in the wall rocks appear to be genetically related to the ores. Finely divided gold is commonly associated with the pyrite, but in only a few places is it sufficiently abundant to render the primary deposits workable by present methods of mining and metallurgy. Weathering and oxidation, however, have concentrated the gold in the near-surface portions of several of the deposits. One of them, the Century, contained a comparatively small but very rich body of oxidized ore, and many others have yielded ore containing from 0.25 ounce to 2 ounces of gold to the ton.

Except the Mancos View and nearby prospects on Helmet Peak and the Barr Menefee property southwest of Schubert Flat, which is doubtfully referred to this class, the known pyritic-gold deposits are all confined to the area of metamorphism in the central part of the district. They are especially numerous on Jackson and Bragdon Ridges and near the heads of Bear and Boren Creeks. As the rocks in the central area are all rather thoroughly silicified, the character of the original rocks in this area has controlled the deposition of these ores in but few places. The deposits fall into three closely related groups—veins, bed-replacement bodies, and breccia bodies.

VEINS

The most instructive examples of the pyritic gold veins are to be seen in the Century, May Rose, and Monarch mines and in the Timberline workings of the Doyle mine. As seen in these mines and elsewhere, the veins generally follow narrow, steeply dipping shear zones, in which the rocks are broken or brecciated along series of closely spaced overlapping fractures. Some of these zones have sharply defined walls, but others have gradational limits. The zones range from several inches to 10 feet or more in width, and not many of them are continuous for more than a few hundred feet along their strike. The chief minerals in most of them are fine-grained massive pyrite and granular to coarsely crystalline quartz, pyrite being commonly much more abundant than quartz. Chalcopyrite and barite are widespread but nowhere abundant. A few veins, notably those of the Boren Creek group, contain a little galena, sphalerite, and marcasite. The vein minerals were deposited largely in open spaces; they fill interstices between breccia fragments or form veins and veinlets within the shear zones. A few veins, notably those of the Monarch mine, were formed by replacement of the country rocks.

The veins near the head of Bear Creek and those on Jackson Ridge, exemplified by the Century and Timberline deposits respectively, form distinct units and cut rocks that are themselves but slightly brecciated or pyritized. On the other hand, the "veins" on Bragdon Ridge and Tirbircio Creek—for example those of the Monarch, May Rose, and Bonnie Girl properties—all lie within an extensive breccia zone. A northeastward-trending belt of veins at the head of Boren Creek, which has been exposed by the workings in the Boren Gulch group of prospects, forms a connecting link between these two types. Some of the veins in this belt are in the ill-defined zone of alteration and breccia that extends from Gibbs Peak to Spiller Peak (see p. 47);

others, particularly those toward the northeast end of the belt, are in relatively unbroken monzonite or silicified sedimentary rocks. The Timberline and other veins on Jackson Ridge are closely allied to the bed-replacement body described below and resemble it in character except that they commonly contain a higher proportion of quartz.

Except for the Century and nearby veins, which are productive only where they cross beds of sandstone that was originally brittle and which become barren or die out in shaly beds, the character of adjacent wall rocks seems to have had little effect on the size or distribution of these deposits. This fact is not surprising in view of the restriction of the deposits to the metamorphic area, where most of the rocks are equally brittle; but it serves to distinguish the pyritic-gold veins from most other deposits in the district.

Many of the deposits have been enriched by weathering agencies near the surface. The weathered zone ranges in depth from a few inches to several feet. In none of the developed mines is it known to extend more than about 50 feet below the surface, but oxidation may conceivably have extended to greater depths in some places, particularly where the veins are open and hence favorable to penetration by surface waters. In the oxidized ores, the pyrite has been partly or entirely altered to soft, pulverulent limonite, which is mixed with residual quartz of the vein filling. So far as known, the gold is everywhere finely divided and intimately mixed with the limonite. The enrichment of gold is doubtless due to residual concentration incident to removal of lighter and more soluble constituents of the vein matter by the weathering agencies.

Too little development has been done on any of these veins to permit confident statements as to tenor or distribution of ore bodies. It seems probable that gold is rather evenly distributed through the pyrite in most of the unaltered ore bodies. In the Century, however, there is good evidence that the best primary ore was deposited immediately beneath a structural trap formed by the relatively tight shale of the Morrison and that oxidation later formed an even higher-grade body of ore in that place. The same relations may possibly occur elsewhere. It seems safe to say that few if any of the primary ores contain more than 0.2 ounce of gold to the ton, and many of them certainly contain much less. Most of the oxidized ores that have been explored or worked have contained from 0.2 ounce to 2 ounces of gold to the ton, but the rich shoot in the Century mine yielded nearly 14 ounces.

REPLACEMENT BODIES

Only two places are known where gold-bearing pyrite has extensively replaced a bed or layer of rock, and only one of the resulting deposits is of economic importance. This is on the south side of Jackson Ridge and constitutes the "blanket vein" explored by the various openings of the Doyle mine. The other deposit was worked in the Peerless mine, on the north slope of Jackson Ridge, near the West Mancos River. Little is known of the Peerless deposit, but it apparently consisted of a nearly horizontal tabular body of pyrite, arsenopyrite, and chlorite at the contact between the Dolores formation and the Entrada (lower La Plata) sandstone. This body probably replaced a lens of limestone such as those that occur at or near this horizon in other parts of southwestern Colorado. As the Doyle deposit is described in detail in the paragraphs on the mine, a brief summary of its more important features will suffice here. The sedimentary rocks on Jackson Ridge, which range from the upper Dolores through the Dakota (?), dip to the northwest at angles of 7° to 10°. With the exception of the Pony Express (La Plata) limestone member of the Wanakah, all the rocks have been altered to quartzite or to hornfels. The limestone has been almost completely replaced by fine grained to coarse-grained pyrite, with a varying but commonly small proportion of sugary quartz and a little chalcopyrite. On the south slope of the ridge and beneath the floor of Rush Basin, the bed ranges from 6 inches to more than 5 feet in thickness and has an average thickness of 2 feet. It thins toward the northwest and apparently pinches out entirely along the West Mancos River.

According to company reports, the entire bed consists of rock that contains from 0.20 to 0.35 ounce of gold to the ton. It is said, also, that the gold content is especially high in proximity to the several pyrite-bearing veins and fault fissures that cut the bed but, as pointed out in the mine description, the stope maps and other evidence do not entirely bear out this relation. The gold is believed to be distributed through the pyrite as finely divided particles of native metal, though none was seen in the specimens of primary ore that were examined. Nearly all the ore within 250 feet of the surface is oxidized to soft spongy limonite, but no ore was seen that was either completely oxidized or entirely unoxidized. Ore produced in the past, largely from near-surface workings where it was rather thoroughly oxidized, yielded from 0.75 ounce to 2.5 ounces of gold to the ton.

The similarity in areal distribution and in mineral content of the pyritic veins of Jackson Ridge and the "blanket" replacement deposits indicates a close genetic relation between the two types, and it seems probable that the limestone bed was replaced by solutions that rose along the fissures now filled with pyritic vein materials. The Doyle type of deposit also, except for the presence of pyrite instead of telluride minerals, is similar in many respects to those worked by the Incas mine (pp. 125–129). It is even more closely related, however, to the contact-metamorphic bodies in the central part of the district, some of which contain much pyrite associated with silicate and iron oxide minerals. Silicate minerals were not formed in the deposit on Jackson Ridge, probably because the solutions and emanations that produced the metamorphism there were farther from their source than those that produced the contact-metamorphic bodies.

BRECCIA DEPOSITS

The district contains several extensive breccia zones in which pyrite is widely distributed but almost nowhere abundant. All these zones contain a little gold, but none of them, with the possible exception of the Little Kate deposit in Tomahawk Basin, seem rich enough to constitute a workable ore body under present methods of mining and milling.

Two broad northeastward-trending breccia zones that extend, respectively, from Gibbs Peak to Spiller Peak and from Burnt Timber Creek to Baker Peak ridge, have been noted in the section on structural geology. Within these zones the rocks are sheared and brecciated along numerous northeastward-trending fractures. Pyrite, which contains a little gold, is widely distributed, but it is abundant only along the stronger fractures, where it constitutes the bodies that have been described above as gold-bearing pyritic veins. None of the rock between these veins seems likely to contain much more than 0.03 to 0.05 ounce of gold to the ton, though a few small bodies of rock may be found to contain more, particularly where the pyrite has been thoroughly oxidized.

The Little Kate breccia body in Tomahawk Basin is considerably different from those just mentioned. As described on pages 39, 136 and illustrated in plate 8*c* and figure 47, this is an irregular mass of breccia along the southeast side of the diorite stock, 2,200 feet long, 200 to 650 feet wide, and at least 600 feet deep. The breccia consists of angular to rounded fragments of sedimentary and igneous rock, set in a matrix of more finely comminuted rock. Chlorite is more abundant than elsewhere in the district. and pyrite, chalcopyrite, magnetite, and hematite are widely distributed. The breccia is cut by numerous steeply dipping veins, few of them more than a foot wide, which fill parts of silicified fracture zones from 6 inches to 10 feet in width. The veins contain quartz, pyrite, chalcopyrite, and some calcite, in addition to gold that is probably associated with the sulfides. The breccia body, exclusive of vein matter, appears to contain from 0.01 to 0.04 ounce of gold to the ton and is possibly somewhat richer in places. The veins contain more gold than the breccia.

MIXED SULFIDES WITH GOLD AND SILVER

In point of past production, the class of deposits described here is second in importance only to the telluride deposits, but the total value of mixed sulfide ore produced through 1937 is less than $250,000, against a total production of several million dollars' worth of telluride ores. The deposits are closely similar to the telluride deposits except in mineralogy, and even in this respect the distinction is one of degree rather than of kind, for many of the mixed sulfide deposits contain small quantities of the telluride minerals, and all the telluride deposits contain sulfides.

The Red Arrow and adjoining Outwest mines are the most productive and important of the group, which also includes the district's discovery mine, the Comstock, as well as the Daisy-Hibernia, Florence W., Lucky Four, Jumbo-Morovoratz, and the Little Nona. Less productive deposits include those of the Black Diamond, Honey Dew, Kentucky, Kiabab, Iron King, Lady Eleanora, Lady Maurine, Lucky Strike, Texas Chief, and Thunder mines and prospects. The mines listed above, as shown in plates 1 and 2, are almost as widely distributed throughout the district as the telluride deposits, but all the more productive ones lie outside of the metamorphosed central area and are most numerous on and near the hinge fold that bounds this area. Nearly half of the deposits are in the Entrada and Junction Creek (lower and upper La Plata) sandstones, and most of the remainder are in the Cutler formation.

All but one of the known deposits of this class consist of irregular veins that range in thickness from less than an inch to about 5 feet and that occupy steeply dipping breccia zones. The zones range from a few inches to more than 10 feet in width and less than 200 feet to more than 1,000 feet in length. In the Lady Maurine prospect however, the ore minerals are scattered throughout a 40-foot breccia zone. Along the Red Arrow, Comstock, and several other veins are measurably displaced country rocks, but elsewhere the breccias represent shear zones along which there was little or no fault movement. In most places the walls of these veins are more sharply defined than those of the telluride veins.

The deposits are characterized by the relative abundance of base-metal sulfides. Pyrite, chalcopyrite, galena, and sphalerite are the most abundant and widespread metallic minerals, but gray copper (tetrahedrite) is conspicuous in many places. Arsenopyrite is present in ore from at least one mine, the Lady Eleanora, and cosalite or a related mineral and native amalgam are reported from the Comstock. Sulfosalts of silver occur in the ore of the Daisy-Hibernia and Texas Chief mines, and small quantities are possibly present in the ore from several others where these minerals appear to indicate a genetic relation to the ruby silver deposits exemplified by the Cumberland mine. Telluride minerals are sparingly present in several of the breccia deposits.

The predominant gangue mineral in most of these deposits is quartz, but coarsely crystalline barite is characteristic of the Red Arrow and of several similar veins, notably the Kiabab, Kentucky, and Florence W. Carbonates, including calcite, siderite, and ankerite, are widely distributed but seldom abundant. Irregular and relatively small masses of the metallic minerals are commonly distributed through massive crystalline quartz, and they fill interstices between intergrowths of the gangue minerals. Crystals of sulfide minerals occur in a few vugs, but in general the sulfides are massive.

Native gold is by far the most valuable constituent of most of these ores, though many of them contain sufficient lead and copper to increase their value. In the Red Arrow and Outwest mines much of the gold occurs as coarse "nuggets" and irregular, partly crystallized masses up to 5 pounds in weight, which are intergrown with quartz, barite, and tetrahedrite. Similar but much smaller masses, together with irregular veinlets of gold, are present in ore from the Comstock, Daisy, and other mines, though much of the gold in nearly all the ores of this class is intimately intergrown with the sulfides, particularly with chalcopyrite and tetrahedrite. So far as known, the greater part of this gold is "free milling"—that is, it can be separated from the enclosing sulfides by mechanical processes.

Except in a few mines, silver is a decidedly less valuable constituent of the ores than gold. Most of the silver ore produced by the Jumbo-Morovoratz and Little Nona was oxidized, and the silver is believed to have been in the form of cerargyrite and argentiferous cerussite. The primary silver-bearing minerals are not certainly known, but some of the silver was doubtless derived from argentiferous galena and tetrahedrite. Some if not most of the silver in the Daisy-Hibernia and Texas Chief mines is in the form of silver sulfosalts, such as pyrargyrite, associated with argentite and argentiferous tetrahedrite.

The several veins that form the Honeydew deposit are so different from others of the mixed sulfide group that they might almost be regarded as a separate class. They contain little or no gold and silver and are characteristically very coarse textured. The vein matter consists of intergrowths of clear and glassy to opaque quartz, orthoclase feldspar, and accessory barite and ankerite. Galena, chalcopyrite, and pyrite fill interstices in the gangue. The Honeydew deposit deserves special mention, not because of its past or present economic importance but because of its bearing on the possibility of finding replacement bodies at depth in the limestones of the Hermosa formation. This possibility is discussed in the section on the future of the district.

The deposits of the base-metal sulfide group vary so widely in mineral composition that no general statement can be made as to their tenor. In some of the mines the ores contain only negligible quantities of the precious metals; in others, such as the Red Arrow mine, where ore containing several hundred ounces of gold to the ton has been produced, 1-ounce to 2-ounce ore is considered to be of "medium" grade. Except in the Little Nona and Jumbo-Morovoratz mines there is little evidence that any of the deposits has been greatly enriched.

Because of the similarity of these deposits to the telluride deposits, certain features of both classes of deposits will be discussed together after the telluride deposits have been described. Among these features are ore shoots and their control, wall-rock alteration, relations to deposits of other kinds, and outlook for the future.

COPPER DEPOSITS OF THE BEAR CREEK DISTRICT

By E. N. Goddard

INTRODUCTION

A group of four small and relatively unproductive copper deposits lies on the north side of the La Plata Mountains, along Bear Creek and near the junction of that stream with the Dolores River. They are closely associated with monzonite porphyry dikes, but except for a likeness to the Red Arrow extension prospect on the East Mancos River they do not seem to resemble either the ore deposits of Rico to the north or those of the La Plata district to the south. They appear rather to belong to the "Red Beds" type of copper deposits, which are widely scattered through southwestern Colorado, New Mexico, southeastern Utah, Texas, and Oklahoma,[69] and which are considered by most geologists who have studied them to be of common origin.[70]

In the summer of 1932 the writer, assisted by C. D. Hier, spent 3 days in studying these deposits. As these ore deposits are generally included in the La Plata district and have not been previously described, it seems advisable to include a brief description of them with this report. The Bear Creek copper desposits are in the northeast corner of Montezuma County, from 11 to 13 miles south and southwest of Rico. Two of them are readily accessible from a good automobile road and from the narrow-gage Rio Grande Southern Railroad, both of which follow the Dolores River, but two can be reached only by way of trails 3 miles long in one direction and 9 miles in the other.

Few data are available on the history of these properties. Burchard [71] noted in 1882 that the Bell Hamilton mine was one of the most thoroughly developed properties in the La Plata district. Irving [72] visited

[69] Fischer, R. P., Sedimentary deposits of copper, vanadium-uranium, and silver in southwestern United States: Econ. Geology, vol. 32, No. 7, fig. 1, p. 907, 1937. Bastin, E. S., The chalcocite and native copper types of ore deposits: Econ. Geology, vol. 28, figs. 1 and 2, pp. 412–413, 1933.

[70] Emmons, S. F., Copper in the Red Beds of the Colorado Plateau region: U. S. Geol. Survey Bull. 260, pp. 221–232, 1905. Lindgren, W., Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 76–79, 1910. Butler, B. S., and others, The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, pp. 152–158, 1920. Finch, J. W., Ore deposits of the western states, Am. Inst. Min. Met. Eng. Lindgren volume, pp. 481–487, 1933. Bastin, E. S., op. cit., pp. 407–443. Fischer, R. P., op. cit., pp. 906–951.

[71] Burchard, H. C., Report of the Director of the Mint for 1882, p. 508, 1883.

[72] Irving, J. D., Notes on the Rico, La Plata, and Durango quadrangles (manuscript report in files of U. S. Geol. Survey).

the mines in 1897, but at that time they apparently were not being worked. No records of their production have been found, but according to Jess Robinson, a rancher and prospector in the region for many years, about 6 carloads of ore containing from 4 to 30 percent of copper have been shipped from the district.

GEOLOGY

Rocks—The geology of the area has been mapped and described by Cross, Ransome, Spencer, and Purington [73] and plate 13 has been compiled from their maps. The rocks are essentially the same as those in the La Plata district proper, described above in detail by Eckel. The sedimentary rocks, which range from the upper part of the Cutler to the top of the Mancos shale, are intruded by sills and dikes of monzonite porphyry. The Dolores River and Bear Creek are deeply entrenched in the nearly horizontal beds, and the formations are fairly well exposed in the canyon walls. The sills shown in plate 13 are merely the northward extensions of those shown in plate 2. One 50-foot dike of monzonite porphyry can be traced southeastward from near the mouth of Bear Creek diagonally across its valley for a distance of about 3½ miles. A much shorter dike, about 40 feet wide, which trends northeast, is exposed at the Bell Hamilton mine. These two dikes, with which the known copper deposits are associated, are composed of a brownish-gray felsitic groundmass containing small white phenocrysts of plagioclase and rather scarce limonite-filled cavities that probably represent original augite, or possibly hornblende. Cross [74] described the rock as a pyroxenic monzonite porphyry. The groundmass appears to be made up chiefly of orthoclase with very little quartz. It is partly altered to sericite or to sericite and clay minerals.

Structure.—In the southern part of the district, the sedimentary rocks dip 20° to 25° NW., reflecting the structure of the La Plata dome, but farther north they swing to a regional dip of 2° to 7° SW. Only a few faults are found in the Bear Creek region. The four shown in plate 13 are taken from Cross' maps and were not visited by the writer. Along the borders of the dikes are many small faults, slips, and fracture zones of small displacement. Most of them are parallel to the dikes, but some are parallel to the bedding of the sediments. One of the most prominent of the faults is on the east side of the dike at the Missouri Girl mine (see fig. 38), in the northern part of the district. The fault zone here is about an inch wide and dips steeply east; the displacement of the bedding and the grooving on the wall seem to indicate that the east wall moved up almost vertically. Perhaps this and other faults and slips were formed as a result of readjustment after the intrusion of the dikes.

COPPER DEPOSITS

The copper deposits are without exception associated with the monzonite porphyry dikes, in which respect they differ from all but one of the "Red Beds" copper deposits that have been described. The only other reported occurrence of a "Red Beds" copper deposit associated with an igneous rock is in the Tularosa district, New Mexico, described by Graton.[75] Here the copper deposits are associated with a mass of diorite porphyry. Three mines or prospects, the Missouri Girl, the Dixie Queen, and the Brown Bear, are along the persistent dike in the northern part of the district and the Bell Hamilton is on the smaller dike in the southern part (pl. 13).

The chief ore mineral is chalcocite, but native silver is reported from the Bell Hamilton mine, and a little pyrite is locally associated with the ore. Malachite is a common oxidation product and forms thin films on chalcocite and on fracture surfaces, but it is nowhere abundant.

The copper deposits are limited to the lower part of the Dolores formation and lie within 40 feet of the borders of the monzonite porphyry dikes. Where the dikes penetrate formations other than the Dolores, the rocks appear to be entirely barren. This fact is best illustrated at the Dixie Queen mine, where the lower tunnel, which is in the Cutler formation and extends along the wall of the dike, shows no ore whatever, whereas the upper tunnel, which is in the Dolores formation, exposes copper minerals. The lower part of the Dolores formation is made up chiefly of gray and red sandstone and sandy shale and subordinate limestone conglomerates. Plant remains, mostly stems, fragmental leaves, and thin lenticular layers of coaly material are numerous in these beds. The copper ore occurs along carbonaceous layers within 2 or 3 feet of the faults, fracture zones, and slips that border or parallel the monzonite dikes. Most of the chalcocite occurs in small seams, lenses, or nodules in or bordering the layers of coaly material (see fig. 5), but in places

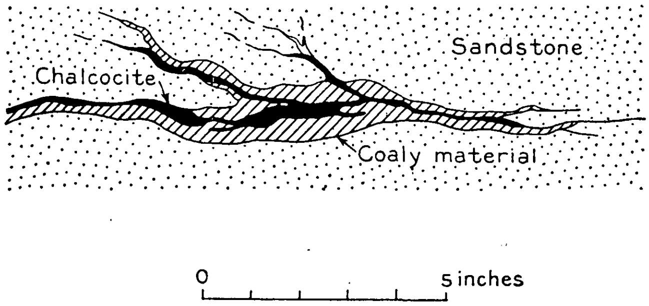

FIGURE 5.—Sketch showing chalcocite veinlets in a layer of coaly material; from point marked "a" in figure 22 (upper tunnel, Dixie Queen mine).

[73] Cross, Whitman, and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Rico folio (no. 130), 1905. Cross, Whitman, Spencer, A. C., and Purington, C. W. U. S. Geol. Survey, Geol. Atlas, La Plata folio (no. 60), 1899.

[74] Cross, Whitman, and Ransome, F. L., op. cit. (Rico folio), p. 7.

[75] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., op. cit., pp. 187–190.

chalcocite forms small crosscutting veinlets or fine disseminations in the sandstone near plant remains, and here and there it has replaced limestone pebbles in the limestone conglomerate. In the Missouri Girl mine the border of the dike encloses small nodules of chalcocite, each one surrounded by a small halo of bleached, sericitized porphyry. Beds of red sandstone have turned gray alongside fault fissures and dikes that cut them; the gray zones are mostly a few inches to several feet in width, but in places they extend as much as 40 feet from the dikes. Minute grains of pyrite are commonly disseminated in the gray sandstone. It seems probable that this alteration has been caused by hydrothermal solutions that followed the intrusion of the dikes. Similar phenomena have been described by Bastin [76] as associated with the silver veins in the Dunton district, 15 miles to the north, where, as Bastin wrote, "thermal waters accompanied by gaseous emanations" were still issuing from the rocks. Bastin suggests that the disseminated pyrite has resulted from a reduction of the ferric iron in the red beds to the ferrous state by "mineralizing solutions," and this seems also to be the most reasonable explanation for the disseminated pyrite in the Bear Creek copper deposits.

The grade of ore produced in the past was variable, depending largely on the degree of sorting that was done. Ore that was carefully hand-picked contained as much as 25 to 30 percent of copper, but shipments of unsorted ore are reported to have contained 4 to 5 percent. No records are available as to the silver content of the ore.

Little ore of shipping grade was seen by the Survey party. The deposits appear to be very small. As will be seen from the mine descriptions, the mine workings are not extensive, and the showings of ore hardly encourage further development. It is possible that with a high price for copper, leasers operating on a small scale could hand-sort the ore and make a small profit, but it seems unlikely that any large-scale operations can ever be successful in the Bear Creek district.

ORIGIN OF THE COPPER DEPOSITS

The copper deposits at Bear Creek have a number of features in common with the "Red Beds" type of copper deposits; the ore is exclusively in a "Red Beds" formation, the ore mineral is chalcocite and is associated with plant remains and coaly material, and the ore and gangue minerals common in hydrothermal copper deposits are scarce or absent. However, the Bear Creek deposits differ markedly from most deposits of the "Red Beds" type in being closely associated with monzonite porphyry dikes and related fault fissures.

Three theories have been advanced for the origin of the "Red Beds" type of copper deposits. The sedimentary or syngenetic theory was once generally accepted, but later it was more generally believed that the copper originally disseminated in the rocks was concentrated by meteoric waters.[77] More recently, Fischer [78] has favored the sedimentary theory for deposits of this type in southwestern United States. Graton,[79] as a result of his study of the Tularosa district, New Mexico, where copper deposits of the "Red Beds" type are associated with a mass of diorite porphyry, came to the conclusion that some, at least, of the "Red Beds" deposits have had a hydrothermal origin.

A sedimentary or syngenetic origin for the Bear Creek deposits can be eliminated at once, for the ore is clearly concentrated along the porphyry dikes, which were intruded long after the sediments were deposited. It might be argued, however, that the dikes and their related fissures acted as a structural control for downward-percolating waters, or for rising artesian waters as suggested by Emmons [80] and by Butler.[81] Such waters might have dissolved sparingly disseminated copper from the "Red Beds" and concentrated it along the fissures and dike walls. The fact that there is an almost total lack of ore minerals other than chalcocite and of gangue minerals other than calcite lends support to this theory. However, the fact that the copper deposits are found only in association with the dikes and not along any other fissures far from the dikes suggests a close genetic relation between the deposits and the dikes. In addition, the rather strong alteration of the dikes and the bleaching of the red sandstone bordering the dikes are rather characteristic of alteration by hydrothermal solutions. For these reasons, the writer is inclined to favor a hydrothermal origin for the Bear Creek copper deposits though it is admitted that the evidence is far from conclusive.

RUBY SILVER VEINS

A class of deposits that is relatively distinct, both geographically and geologically, from all other deposits in the district consists of the ruby-silver bearing veins. They are characterized by relatively abundant proustite and pyrargyrite accompanied by other sulfosalts of silver. They lie along a belt 3 miles long and less than half a mile wide, that extends eastward from the central part of Cumberland Basin to Fassbinder Gulch. The Cumberland mine contains the best example of the ruby-silver deposits—the only one, indeed, that is sufficiently developed and accessible to provide an adequate picture

[76] Bastin, E. S., Silver enrichment in the San Juan Mountains, Colo.: U. S. Geol. Survey, Bull. 735, pp. 116–117, 1922.

[77] Emmons, S. F., Copper in the "Red Beds" of the Colorado Plateau region: U. S. Geol. Survey Bull. 260, pp. 223–225, 1905.

[78] Fischer, R. P., Sedimentary deposits of copper, vanadium-uranium, and silver in southwestern United States: Econ. Geology, vol. 32, No. 7, pp. 940–941, 1937.

[79] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., op. cit., pp. 187–190, 1910.

[80] Emmons, W. H., The Cashin mine, Montrose County Colo.: U. S. Geol. Survey Bull, 285, p. 127, 1906.

[81] Butler, B. S., and others, The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 157, 1920.

of the type; other deposits of this class are worked in the Kennebec, Mineral Wonder, Muldoon, Ruby King, and Tippecanoe mines. The total production from mines of this group is not known, but it is doubtless less than $100,000 and probably less than the amount that has been spent in their development.

The country rocks consist of nearly horizontal redbeds of the Cutler and Dolores formations, into which several comparatively thin sills and a few dikes of diorite-monzonite porphyry have been intruded. In general, the rocks are soft and unmetamorphosed, for the entire belt lies outside the central area of metamorphism. The veins occupy a series of rather closely spaced fractures that strike from N. 60° E. to due east. Several individual veins can be traced for distances of more than 2,000 feet. More than half of them dip steeply toward the north, but along most of the individual fractures the dip varies considerably or even changes direction. Along parts of several of the fractures the country rocks have been displaced as much as 5 to 10 feet vertically; elsewhere there is no measurable displacement.

The fracture zones within which the rocks are sheared and brecciated range from less than 6 inches to more than 12 feet wide. In most places the fractured rock is rather thoroughly silicified. So far as has been observed, the variations in width of the fracture zones, and hence of the ore deposits, are closely related to the character of the wall rocks. In the sedimentary rocks, particularly in shale and mudstone the veins are narrow, but in places where the fractures traverse bodies of relatively brittle porphyry they widen abruptly.

The veins and veinlets consist principally of white massive to coarsely crystalline vuggy quartz that contains the ore minerals and that was formed largely by partial replacement of the breccia fragments and of early barite. In places a single quartz vein was formed an inch or more in width; elsewhere, particularly where the fracture zones are wide, several irregular veins were formed, all of them roughly parallel to the walls of the zone and separated by lenses or layers of silicified breccia. In a few places the entire fracture zone was replaced by vein matter.

The ore consists mainly of the ruby silver minerals, proustite and pyrargyrite, but contains stephanite, argentite, and probably other sulfides and sulfosalts of silver. Gold was relatively abundant in the Snowstorm vein, which is regarded as an extension of the Cumberland vein, and most of the other veins contain a little gold. Most of the gold is probably free, though tellurides are reported from the Cumberland. Pyrite, chalcopyrite, sphalerite, and galena are widespread but nowhere abundant. In the ore seen, the metallic minerals form small irregular grains and imperfect crystals embedded in massive white quartz. White to clear crystals of quartz, some of them very large, and a little calcite were formed later than the ore minerals; so also was white dickite, which fills vugs and cavities in the vein matter in many places. Barite, which is second in abundance to quartz, occurs as irregular masses enclosed in and partly replaced by quartz and as small clear crystals implanted on quartz. Two generations of barite are thus represented, one earlier and one later than the quartz. Some of the quartz encloses negative pseudomorphs that retain the shape of earlier barite crystals. The wall rocks are bleached and partly silicified for distances of a few inches to 5 feet or more on each side of the veins. In general the width of the zone of alteration varies directly with the thickness of the veins.

Slight oxidation of the deposits has resulted in fairly abundant green and blue stains of malachite and azurite. Doubtless other secondary minerals, including those of silver, were formed, but none were seen during the present study. No essential change in the primary mineral composition of the Cumberland vein takes place within the 1,000 feet that it has been developed vertically; the workable ore shoots, however, evidently are of very small vertical extent as compared to their length along the strike. This follows from the fact that the veins are in general widest, and also richest, where they transect porphyry, which is mostly in the form of thin sills.

The Snowstorm mine, according to available production figures, produced some ore in which gold nearly equaled silver in weight. In all the other mines of the group, however, silver is commonly by far the more abundant, the weight ratio of silver to gold ranging from 12 to 1 to nearly 1,000 to 1. Available information indicates that the tenor of the ore varies even more widely than the gold-silver ratio. Some small lots of ore that contained several hundred ounces of silver to the ton have been produced in the past, and more may be found in the future. Most of the ore produced up to 1937, however, had yielded somewhat less than 100 ounces of silver to the ton, and much of that then exposed in the accessible workings certainly contained less than 20 ounces.

TELLURIDE VEINS AND REPLACEMENT BODIES

DISTRIBUTION

The telluride veins and replacement bodies are by far the most important commercially of the various types of ore deposit in the La Plata district and have yielded more than 95 percent of its total production. With the exception of the Red Arrow, all of the mines that have yielded more than $100,000 worth of ore, the May Day, Idaho, Neglected, Incas, Gold King, and possibly the Small Hope, are in deposits of this class.

Although known telluride deposits, large and small, are scattered throughout the district, they are most numerous, in three rather localized areas. One of them is in the northeast part of the central mountain mass, centering near Lewis Mountain and extending from near Baker Peak to Snowstorm Peak. It includes the Gold King, Bessie G., Eagle Pass, Ashland-Ten Broeck, Jennie Lind, Western Belle, and many other mines and prospects. A second area lies south of Madden Peak and Deadwood Mountain, near the south edge of the district. There are fewer known telluride deposits in this area than in the one just mentioned, but these few include the May Day, Idaho, and Incas, besides the Lucky Discovery and several others. It is thus by far the most productive area in the district. A third group of deposits, somewhat different from most of the others, centers about Diorite Peak, in the north-central part of the district. The Small Hope is reportedly the largest producer of this group, which also includes the Mountain Lily, Tomahawk, and Black Diamond mines and many other deposits, some of which have been only superficially explored.

The Lady Stafford and nearby deposits, between Helmet Peak and Jackson Ridge are the farthest west of any of the known telluride veins, and the May Day and Idaho are the farthest south. The Neglected mine, 5 miles from the center of the district is the farthest northeast, whereas the Lost and Mason mines, near the Animas River, are 10 miles east of the La Plata River and far outside the area shown in plates 1 and 2. All the known telluride deposits in or near the district lie within a roughly rectangular area, 14 miles long from east to west and 5 miles wide.

With certain exceptions, no deposits of any commercial importance occur within the central metamorphic core of the mountains, but a glance at plate 2 shows that two of the main groups of deposits lie along and near the hinge fold that encircles this core while the third, most southerly group, lies within the belt of east-west faults that takes the place of the hinge fault across the south edge of the La Plata dome.

The exceptions noted above are nearly all in one or the other of the two diorite stocks. They are on the inner side of the hinge and close to it, and, even more significantly, they are in rocks that have escaped the extensive silicification which characterizes most other rocks in the metamorphic area. No deposits are known to occur in syenite, syenite porphyry, or monzonite, though many of them are associated with bodies of diorite-monzonite porphyry. Each of the sedimentary formations in the district contains some telluride deposits, but the Cutler formation and the beds formerly called La Plata formation (Entrada sandstone, Wanakah formation, and Junction Creek sandstone) contain many more than the others. As will be shown later, this general geologic distribution is in large degree related to the physical character of the rocks, but other conditions also had an important effect in controlling the localization of the ores.

VEINS

Telluride veins occupy parts of many of the "ore-bearing" faults and fractures that are described in the section on structure (pp. 46–47) and shown in plate 2, and they share many of the characteristics of these structural features.

Many fault zones are somewhat mineralized throughout their extent, whereas others are virtually barren. In nearly all of them workable ore bodies are separated by long stretches that contain little or no ore, even though they may contain large or small quantities of quartz and other worthless minerals.

In general the deposits consist of irregular and commonly discontinuous veins and veinlets that traverse the breccia and sheared rock composing most of the fault zones. Some deposits consist of single, well-defined but highly lenticular veins, but most of them are vein zones made up of belts of interlacing small veins and veinlets, similar in most essentials to that sketched in figure 11. Some of these veins and veinlets merely fill interstices in the sheared country rock; others follow fractures or replace the country rock, as is shown by the presence in the vein matter of rounded masses of "ghosts" of the original rock fragments.

Some veins fill the fault zones completely, having clean-cut walls, marked by gouge or by mere slips, beyond which the vein matter does not extend. Most of the veins, however, are narrower than the enclosing shear zones. They may occur anywhere within the zones, exhibiting no preference for either wall, and may swing from one wall to the other within a short distance. In this type of deposit, or where the breccia zones themselves grade into unfractured wall rocks, the vein walls are indefinite, and it is commonly necessary to resort to careful assay control to determine stope widths as well as lengths.

Quartz is the predominant mineral in all the known veins. Its color ranges from white through green to dark gray, and its texture from extremely fine grained and dense to rather coarsely crystalline. Much of it is mottled or rudely banded. Quartz that has a sugary texture and is tinted various shades of green by intergrown roscoelite is highly regarded as an indication of good ore in many deposits, and most of it is of shipping grade even where no ore minerals are visible to the unaided eye. In at least one mine, however, the Durango Girl, ore rich in roscoelite is of comparatively low grade and ore minerals are associated with white or colorless quartz in many places. It is unsafe, therefore, to judge grade of ore from the color of the quartz alone. Black and gray quartz commonly owe their darkness to finely divided pyrite, which is rarely associated with the better-grade ores.

The quartz of many if not of most veins contains subordinate quantities of barite, ankerite, and calcite crystals, all of which line vugs extensively. White powdery dickite, a clay mineral, is widespread and is abundant in many deposits, most notably in the Neglected. It commonly fills vug and other openings in the veins and adjacent breccias or forms late veinlets in the ore. Light-colored fluorite has been seen in vugs in the Gold King and is said to be present in the Mason veins.

The ore minerals, which include most of the known telluride minerals and free gold, are very erratically distributed even within definite ore shoots. The gold and tellurides and the associated sulfide minerals-pyrite, arsenopyrite, tetrahedrite, galena, and sphalerite—commonly form small, highly irregular masses and blebs intergrown with the quartz. Locally, however, the ore minerals form comparatively large masses that are nearly free of gangue, and in many places they form distinct though short and irregular threads and veinlets in the quartz. As a general rule percentage of tellurides, and hence of gold and silver, decreases with increase in the percentage of sulfide minerals, particularly of pyrite.

The higher-grade ore in the veins worked at the May Day and Idaho mines is like the common type described above, but the low-grade and medium-grade ore of these mines is entirely different in appearance. It consists of rather friable mineralized sandstone that has been weakly fractured but that is relatively unaltered. Fracture planes in this material are coated with dark films of ore minerals, consisting at least in part of tellurides intergrown with pyrite and arsenopyrite. Only long experience or actual assay will enable one to distinguish workable ore of this kind from barren rock.

The veins in the vicinity of Diorite Peak also differ considerably from that of the more usual kind. They generally have hard silicified cores, flanked by zones of very soft "gougy" material, which grades into unaltered wall rock. The cores that have been formed by replacement of the diorite country rock of dense, finely crystalline quartz contain small irregular masses of telluride and halloysite and other minerals. The soft walls are composed in large part of chlorite. As this material can be removed with hand tools in most places, mining is relatively simple and inexpensive.

In many of the smaller mines telluride veins that averaged less than 1 foot in thickness and that were locally less than 2 inches thick have been profitably worked. The workable parts of most of the more productive veins are considerably wider, however, ranging from 1 foot to as much as 15 feet in width. The average stope width in most of the larger mines is probably in the neighborhood of 3 to 5 feet. Almost without exception the ores are richest where the veins are widest, even though the ore minerals may be confined to a small part of the vein zones. Some veins split and enclose wedges or "horses" of country rock between the splits. In some of the mines, such as the Gold King, the ore commonly follows only one of the splits; but in others, such as the Neglected, the ore occurs along both splits, and the wedge of rock between is sufficiently mineralized to constitute workable mill ore.

Discussion of wall-rock alteration, of ore shoots and their control, and of the vertical range of the telluride deposits is reserved for later sections, as these features are similar in most respects for two other classes of deposit—the mixed sulfide and the ruby silver veins.

REPLACEMENT BODIES

Some of the richest ores that have been produced in the district have been taken from replacement bodies in limestone, though the total production from this kind of deposit has been far smaller than that from the veins. Workable deposits are known to occur only in the May Day, Idaho, and Incas mines, and since the limestone ores in these mines either have been worked out or were inaccessible, little first-hand knowledge of the type could be obtained.

All the known replacement deposits are in the Pony Express (La Plata) limestone member of the Wanakah formation, and all are closely associated with productive veins. Few of them extend more than 50 feet on either side of the veins, and the values in them commonly decrease rather uniformly away from the veins. In the May Day and Idaho mines, the replacement bodies, like the productive portions of the related veins, are close to intersections of the latter with strong barren faults. In the Incas, the best ores were found in the limestone at and near its common intersection with ore-bearing fractures and a porphyry dike. In this mine a layer of sandstone immediately above the limestone was also ore bearing in places. With the exception of the above-named mines, the only known telluride mine in which the Pony Express limestone is present is the Lucky Discovery. No ore has been found in the limestone there, but this bed has not been explored close to its intersection with the more productive veins.

So far as can be determined, the replacement bodies are made up largely of calcite, ankerite, and other mixed carbonates; they contain some barite in places, but very little quartz anywhere. The ore minerals, which comprise the tellurides and native gold with minor amounts of sulfides, are apparently scattered through the carbonate gangue, but locally they are concentrated, and solid masses of mixed tellurides several feet in diameter have been found in some places.

TENOR

The tenor of the La Plata telluride ores ranges between such wide limits in different deposits and even within individual deposits that few valid generalizations can be drawn. Ores that have been produced in the past have contained from less than 1 ounce to more than 400 ounces of gold to the ton, and there have been some small shipments that yielded several thousand dollars to the 100-pound sack. The silver content of the ores ranges between even wider limits than that of gold. Gold exceeded silver by weight in most of the ore produced by the Neglected mine, and in several others, such as the Ashland-Ten Broeck, Bessie G., and Incas, the weight ratio of gold to silver has approached unity. In most of the ores, however, silver surpasses gold in weight though seldom in value. Exclusive of the year 1894, for which the production records are of doubtful accuracy, the ratio of gold to silver in all the ores produced from 1878 to 1937, inclusive, has been about 1 to 8 by weight. The May Day and Idaho are the only important mines in which the average ratio has been much greater than this.

Like gold and silver, the base metals, lead, copper and zinc, range between rather wide limits in the ore as mined. With few exceptions, none of the crude ore contains enough of any of these metals to add to its smelter value, but some of the flotation concentrates have contained fairly high percentages of one or more base metals.

Generalization of available data on tenor is made more difficult by the general practice of hand sorting the ores to bring them up to shipping grade. Until recently no ore that contained less than about $50 worth of gold and silver to the ton could be shipped profitably, and in some of the smaller and more inaccessible mines $75 to $100 has been considered the lower limit for shipping ore. During the past several decades, the modern milling methods that have been adopted at the Gold King, May Day, Idaho, and other mines have permitted the production of much lower grade ores. The ore is usually hand sorted before milling, the better grade being shipped crude and only the lower-grade material put through the mills.

PLACER DEPOSITS

Although the first gold discovered in the district was in the form of placer deposits along the La Plata River, placers have never played an important part in the district's mining history, and the total production from them is negligible. Considerable attention was given to placer mining in the early days of the camp; several placer claims were patented (pl. 14), and a little gold was produced. During the present century, there has been comparatively little interest in placer mining, although desultory prospecting has been carried on from time to time. The Red Arrow lode deposit was discovered as a direct result of a prospecting campaign.

Plate 1 shows the distribution of all deposits of alluvial material that are known or reliably reported to contain gold. Nearly all of them are situated on the La Plata and the East and West Mancos Rivers, or on their tributaries. Small deposits are known on Junction Creek, but much of the gold in these streams probably represents metal that was lost by mills at the Neglected, Durango Girl, and other mines.

With one exception, that of the Gold Bar, the known placer deposits are stream gravels in present stream beds. They range from a few inches to 80 feet or more in thickness and are made up of sand, gravel, and boulders; some of the boulders are very large. The gold is relatively coarse and rough in most places and is very unevenly distributed, although as usual it is commonly most abundant at or near bedrock. Some cracks and fissures in the bedrock contain appreciable quantities of gold, particularly along the East Mancos River.

Gold Bar, which extends southward from Mayday to Hesperus, is composed in large part of glacial outwash gravels. No thorough tests have been made of the Bar and only small-scale, sporadic attempts have been made to work it. Available information suggests, however, that it is the largest and perhaps the most promising placer deposit in the district. Most of the gold is in fine particles, but some coarse gold and a few worn masses of vein matter that contained tellurides are said to have been recovered. The gold is irregularly distributed, and the many large boulders would interfere with economical handling of the material. South of Hesperus the high benches along the La Plata River are reported to contain very fine flour gold at least as far south as the New Mexico line, but they are not known to contain workable concentrations.

The placer gold in and near the La Plata Mountains is obviously derived from the eroded parts of the local ore deposits and has been concentrated by Quaternary streams draining the mineralized area. As it seems highly probably that much gold was present in the parts of the ore deposit that have been removed by erosion since Tertiary time, it is fair to ask why the resulting placer deposits are so few and in general so low in grade. Part of the explanation seems to lie in the fact that much of the gold in the primary deposits is in the form of tellurides. The telluride minerals themselves show little tendency to concentrate in placers, partly because they are relatively light, but also because they break down to fine particles as a result of physical weathering processes. Chemical weathering, which has played a minor role in alteration of the La Plata ores, produces fine-grained "mustard" gold, which would tend to move far from its original source. The gold in the placer deposits therefore must represent native metal that has been concentrated from primary deposits of several kinds.

The low grade of the placer deposits is probably also due in part to the fact that heavy glaciation, the comparatively great widths of some of the valleys during the glacial epoch, and the continued reworking of placer material all tended to collect the gold into small pockets that were spread over large areas.

WALL-ROCK ALTERATION

The immediate wall rocks of the platinum-bearing chalcopyrite deposits and the contact-metamorphic deposits, as well as of the pyritic veins, replacement bodies, and breccia deposits, are not appreciably different from the surrounding country rocks. With the exception of the syenitic rock that contains the chalcopyrite deposits and the limestone beds and nodules that enclose the contact metamorphic deposits, both of which are relatively fresh in most places, the host rocks had already undergone the extensive metamorphism that characterizes the central part of the district. The sedimentary rocks are largely silicified, whereas the porphyry bodies, though locally silicified, are generally sericitized or kaolinized.

Most of the other ore deposits of the district are commonly surrounded by envelopes of altered wall rock. The zones of alteration are too narrow to serve as useful guides to ore, but in many places they have had much to do with localizing the ore deposits. The intensity of alteration varies widely from place to place. Silica, sericite, chlorite, and halloysite characterize the three most important alteration products, but other kaolin minerals, tourmaline, epidote, and ankerite have been formed in places. Small quantities of fine-grained pyrite are disseminated through all the altered wall rocks, regardless of the mode of alteration, which depends in large part on the character of the original rock and seems to bear no direct relation to the character of the ore deposit with which it is associated.

In many places, particularly where the veins are very narrow or otherwise weakly developed, the alteration halo is less than an inch thick. More commonly, however, it is from 6 inches to 2 or 3 feet thick. Nowhere is the wall-rock alteration known to extend much more than 10 feet from the vein walls. Locally this alteration is limited to the zones of brecciated and sheared rock that enclose the veins, but elsewhere it extends for some distance into the unfractured walls.

Silicification is the dominant kind of alteration, particularly of the sedimentary rocks. Its intensity ranges from a minor addition of fine-grained silica, accompanied by some lightening of color in the red beds, to nearly complete replacement of the rocks by silica. The thoroughness with which shales, mudstones, and sandstones are silicified depends more upon the structure than upon the character of the rock. In many places the ground-mass of the porphyry is silicified, but silicification seldom affects the phenocrysts. In the Neglected mine the porphyry closet to the vein is silicified, but this gives way outwardly to rock in which chlorite and sericite are abundant. This gradation has not been noted in other deposits. The principal effect of silicification is to render the rocks more brittle, and hence more subject to fracturing, than they were originally.

Sericite and various subordinate quantities of associated carbonates, halloysite, and other kaolin minerals are the most common alteration products of the igneous rocks. Sericite has commonly replaced the feldspar phenocrysts first but locally it has replaced phenocrysts of hornblende and augite, and even the groundmass. In the Neglected mine the fragments and pebbles of feldspar in arkosic sandstone beds of the Cutler formation have been strongly sericitized near the vein, so that these rocks are very soft as compared with the interbedded shales, which have been silicified. Sericitization of the igneous rocks commonly produces soft and incompetent rocks, and the veins are therefore commonly narrow where the wall rocks contain much sericite.

In the vicinity of Diorite Peak the most characteristic product of wall-rock alteration along the veins in chlorite, which is accompanied by halloysite and other clay minerals and a little epidote. In the Small Hope, Tomahawk, Mountain Lily, and other mines of this area the hard siliceous cores of the veins that contain the ore minerals are flanked by zones of very soft chloritic material, which grades within short distances to unaltered rock. Weak alteration of this kind also characterizes the Little Kate breccia deposits in Tomahawk Basin, but elsewhere it is decidedly rare.

An unusual type of alteration characterizes the Neglected deposit, but it has not been observed elsewhere. In the more strongly altered zone next to the vein the groundmass of the diorite porphyry dike has been silicified and its feldspar phenocrysts altered to sericite and a little halloysite. The hornblende phenocrysts are represented by intergrowths of tourmaline, sericite, and chlorite. Tourmaline and sericite give way outward to chlorite mixed with a little epidote and carbonate.

Wall-rock alteration seems to have preceded and accompanied ore deposition in most veins, but clear-cut evidence of the age relations is largely lacking. In nearly all the veins the width of the altered zone varies directly with the width of the veins. Part of this variation was due to variations in width of the original fracture zones through which both the altering solutions and vein matter were introduced, and this width was controlled in turn by the character of the original rocks and by structural features. But in many veins, notably the Gold King and the Neglected, there is much evidence that silicification and other alteration preceded the deposition of vein quartz and of ore minerals. Silicification was followed by a reopening of fractures probably caused by relatively minor earth movements. Where the rocks had been silicified they were extensively brecciated, and this brecciation provided access for the ore solutions, which arose during the reopening or immediately afterward. Where they were sericitized or kaolinized the fissures remained relatively tight, and vein matter was deposited only in a few especially favorable places.

In the Diorite Peak deposits the mutual relations between vein material and wall-rock alteration are not entirely clear. All the evidence indicates that the quartz vein matter was formed by replacement of diorite rather than of chlorite or of clay minerals. The soft altered rock alongside the veins, moreover, would tend to prevent rather than to favor the development and maintenance of open fractures that would permit entrance of siliceous ore-bearing solutions. It seems likely, therefore, that the alteration of the wall rocks was contemporaneous with, or later than, the formation of the veins.

ORE SHOOTS AND THEIR CONTROL

GENERAL STATEMENT

Ore shoots, or parts wide enough and rich enough to be workable, constitute a small proportion of nearly all of the deposits. Many ore shoots are mere "pockets" only a few feet long and yielding but a few pounds or a few tons of ore, though some of these pockets are phenomenally rich. Others extend for several hundreds of feet in one or more dimensions. The horizontal extent of the shoots in the May Day and Idaho mines is comparatively small, but a shoot in the May Day has been mined continuously from the surface to a depth of 450 feet. The richer of the two shoots in the Gold King is 250 to 350 feet long parallel to the strike and has been opened for 200 feet vertically; its lower limit apparently has not been reached. A second stope in the Gold King is approximately horizontal, with a height of 60 to 150 feet and a length of 900 feet. Shoots in several other mines are nearly as large as those just mentioned. All the shoots, both large and small, are much shorter in one dimension than in others, and nearly all are much elongated in one direction. Some are elongated essentially in a vertical direction, others pitch at various angles and directions, and a few are horizontal.

In every known place the ores are richer where the veins are wide than where they are narrow. All the ore shoots, moreover, that have been sufficiently well explored to permit thorough study have resulted from a combination of one or more favorable structural features with rocks that were either originally favorable to ore deposits or were made so by areal or local metamorphism. These two main influences on localization of ore shoots are discussed separately below, and the effects of individual structural and lithologic features on the veins are shown diagrammatically in figure 6.

INFLUENCE OF STRUCTURAL FEATURES

Changes in dip and strike, splits in the veins, and intersections of the veins with various kinds of fracture zones have all played parts in the formation of ore shoots. Difference in local characteristics of the ore-bearing veins themselves have influenced distribution of ore shoots to a marked degree, regardless of what kind of rock they traverse. All the known veins are wider and contain richer and more abundant ore in places where they dip steeply than where their dip is

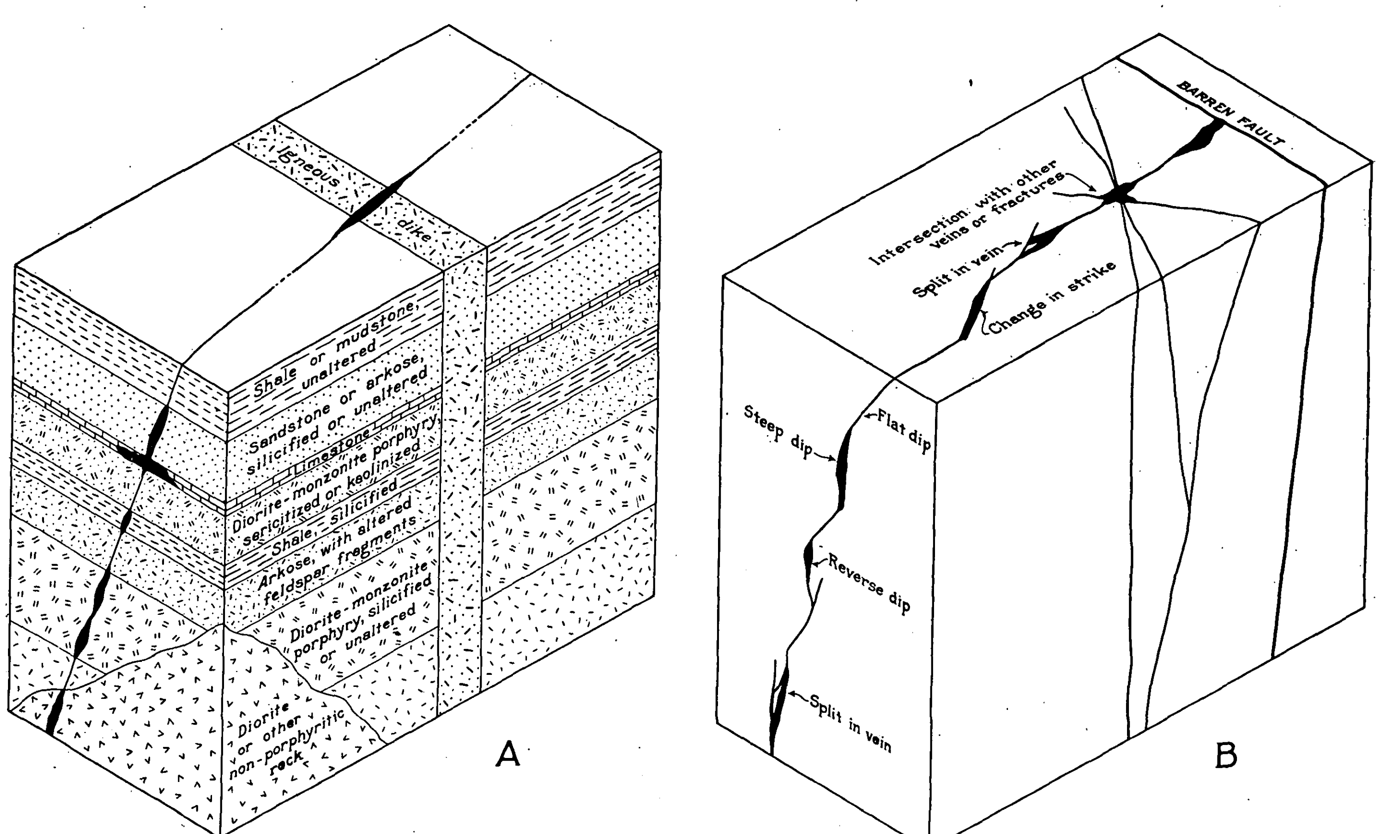

FIGURE 6.—Diagrams showing influence of rock character (A) and of structural features (B) on ore shoots along veins.

low. This relation is perhaps best shown in the Gold King and Durango Girl mines. It follows directly from the fact that nearly all of the ore-bearing faults in the district are normal faults, along which the steeper parts of the walls are more widely separated and more brecciated than the other parts. Reversed dips are rare, but the few known examples are associated with ore shoots.

Several ore shoots are clearly associated with slight changes in strike of the veins. This relation is most apparent in the veins near Diorite Peak, where all the country rock is diorite, but it can also be seen in the Ashland-Ten Broeck and other veins.

Places where the vein splits and reunites within a comparatively short distance, enclosing a horse of country rock, are merely a special example of change in dip and strike. Two very productive ore shoots were partly controlled by splits, and evidence of other splits may have been obliterated by more or less complete replacement of horses by vein matter. In the main ore shoot in the Gold King, both parts of each split are mineralized to some extent, but most of the workable ore is in the split with the steeper dip. Both splits of the Neglected vein, on the other hand, contain high-grade ore and the horse of rock between them is strongly altered and contains much low-grade mill ore and a few stringers of high-grade ore.

Intersections of the ore-bearing veins with other fractures, with breccia zones, and with barren faults—all known collectively as "cross actions" by the local miners—have determined the location of shoots in many deposits. Intersecting fissures that for the most part are not mineralized owe their favorable effects on the ore-bearing veins largely to the fact that more breccia and larger openings form near the intersection than elsewhere. Instructive examples include the Ashland-Ten Broeck and Camp Bird veins. It seems probable, also, that the intersection of the Eagle Pass vein with the Jennie Lind is responsible for ore shoots on both veins.

The only good example of an intersection of a productive vein and a strong breccia zone is afforded by the Gold King vein. There, the richer of two ore shoots is clearly related to a body of breccia, whose shape is not fully known but within which the vein widens, splits, and contains much more ore than elsewhere. The physical conditions that control the shoot are clear. The breccia is silicified and hence more brittle than the other wall rocks; and the vein fracture was naturally more irregular where it traversed the breccia than in the rocks that were not shattered.

The most productive veins in the district (the Idaho and May Day) are at intersections of veins with strong barren faults. Similar control of ore shoots is evident in the Black Diamond and is strongly indicated in the Comstock and Lucky Discovery, though the relations are not as clear cut in any of these mines as in the May Day. The localization of ore deposits at such intersections seems to be due in very large part to the fact that most of these barren faults contain much clay gouge. The gouge was impermeable and prevented the lateral movement and dispersion of the ore-bearing solutions by damming them as they rose along the fissures.

INFLUENCE OF ROCK CHARACTER

The Pony Express limestone member of the Wanakah formation (La Plata limestone of former reports), which contains telluride deposits in the May Day, Incas, and other mines, and pyritic-gold deposits in the Doyle mine, clearly owes its importance as a host rock to the fact that limestone is especially favorable to chemical replacement by ore-bearing solutions. The same statement is true of the limy beds near the base of the Dolores formation, which contain contact-metamorphic deposits in several places. The control exerted on ore deposits by the noncalcareous rocks is physical and structural rather than chemical.

The original character of the country rocks exerts far more influence on the distribution of ore shoots outside of the central metamorphic area than within it. The reason for this difference obviously is that all the rocks in the central part of the district have undergone silicification, which renders all kinds of rock equally brittle and hence equally easily fractured. Good examples are afforded by the veins of the Doyle mine on Jackson Ridge, which seem to be as wide and as well mineralized in the silicified shale of the Morrison formation as they are in the underlying Junction Creek sandstone. The Century vein on Bear Creek is an exception to the general rule, for the vein is strongly developed in the Junction Creek (Upper La Plata) sandstone but pinches out completely where it enters the overlying silicified shale. The explanation seems to be that the main period of fracturing on the vein preceded regional silicification.

Outside the metamorphic area, rocks that were originally competent or that were silicified along fracture zones prior to ore deposition are more favorable to ore deposits than those that were originally soft or that were rendered so by processes of wall-rock alteration. Sandstone, arkose, and limestone are favorable host rocks for ore deposits in most places because they brecciate easily and favor the formation and maintenance of wide, pervious fracture zones. The only notable exception to the rule is in the Neglected mine, where feldspars in the arkose layers of the Cutler formation have been sericitized. As a result, the vein is weaker and less well mineralized between walls of arkose than between those of partly silicified shale. Porphyry, whether or not it has been silicified, is relatively brittle, so that fractures tend to remain open in it. It is therefore favorable to ore deposition, and many shoots throughout the district are associated with porphyry. Examples include the Neglected, Durango

Girl, Cumberland, Comstock, and one of the shoots in the Gold King. Porphyry that has been strongly sericitized or kaolinized is soft, and fissures that traverse it are commonly tight. An extreme example of this condition may be observed in the Lucky Discovery mine, in which the veins pinch markedly where they cross porphyry dikes.

Shales and mudstone are soft and are rarely favorable to ore deposits. This is so in general even where the rocks have been locally metamorphosed, and in most mines the ore shoots become narrow or pinch out completely where the veins enter these rocks. As noted above, however, special circumstances render the shale in the Neglected mine more competent and favorable than the arkosic beds.

As to the relative favorability of the various formations, it is difficult to generalize because the boundaries between formations are not determined wholly by lithologic differences. The Entrada sandstone, the Wanakah formation, and the Junction Creek sandstone (La Plata of Cross) are by far the most favorable units in the district and contain many of the most productive deposits, including the May Day, Idaho, Incas, Red Arrow, Lucky Discovery, and Century. Structural features have partly controlled the ore shoots in all these mines, but all the shoots are essentially limited in vertical extent by the thickness of the rock formations listed above. Judging by the number of productive deposits that it is known to contain, the Cutler formation appears to stand next to the formations named above. This good record is doubtless due in part to the fact that the Cutler is exposed at the surface in much of the productive area, but it is also due in part to the relatively great number of brittle sandstone and arkose beds that this formation contains. Exposures of the Rico and Hermosa formations, which are physically similar to the Cutler, are very small. Even so, they are known to contain two deposits, the Gold King and the Lucky Strike. No deposits are known to occur in the Dakota (?) sandstone, though rich float ore in rock of Dakota aspect is reported to have been found near the May Day mine. The formation is brittle and should be favorable to ore deposits. Its generally barren character is therefore probably due to the fact that most of its exposures lie outside the mineralized area. The shale of the Morrison formation (McElmo of former reports) and the marl of the Wanakah formation (middle La Plata shale of former reports) contain but few deposits anywhere in the district. True, the ore shoots in the May Day and Idaho mines continue though these rocks, but the veins that contain them are unusually strong and fault displacements along the veins are such that at least one wall is composed of brittle rock in most places. Aside from the contact-metamorphic deposits of the Bay City, Lady Eleanora, and other mines, the red shales and mudstones of the Dolores formation seem to be the least favorable to ore deposits of any rocks in the mineralized part of the district. The Mancos shale, which for the most part lies outside the mineralized area, contains very few deposits. The Dolores formation is the country rock of much of the ruby silver-bearing belt of veins in Cumberland Basin and eastward, but most of the known ore shoots in that belt are clearly related to bodies of porphyry.

All the igneous rocks appear to be about equally favorable to ore deposits, and the presence or absence of ore shoots in veins that traverse those rocks depends more on the character of local metamorphism than on the original character of the rocks. Diorite-monzonite porphyry is associated with more ore deposits than other igneous rocks though there are many productive veins in diorite. Disseminated chalcopyrite deposits occur in syenite, as do several pyritic-gold bearing fissures and breccia zones. No productive veins are known to occur in monzonite, but many small veins, some of which are fairly promising, traverse the monzonite stock between Mount Moss and Babcock Peak.

BLIND ORE SHOOTS

Several blind shoots, shoots that did not crop out at the surface, have been found and worked in the May Day and Idaho mines. The ore body exposed in the Grassy Hill tunnel of the Small Hope mine (see pp. 165–167) is probably blind and is on an entirely different vein from that which was developed by the upper workings. No other examples of totally blind shoots are known, but several highly productive deposits have been exposed by erosion only because of particularly favorable circumstances. In general, shoots whose tops are limited by shale or other unfavorable rocks cannot be located by surface prospecting unless these upper, unproductive beds have been removed by erosion, or unless lateral extensions of the shoots have been exposed along stream valleys. Such deposits as the Red Arrow and Century, whose upper limit is largely controlled by the shale above the Junction Creek sandstone, might never have been discovered had not erosion happened to cut into the sides of the ore shoots. The original upward extent of the Neglected shoot is not known, but it is clearly related to a dike that does not reach the present surface and has a nearly horizontal top. The deposit may not have been exposed at the surface when the level of Gaines Gulch was only a few feet higher than it is now.

SUMMARY OF CONTROLLING FACTORS

From the facts presented in the preceding paragraphs, it seems clear that the "favorability" or "unfavorability" of structural features and of rocks depends almost entirely on the extent to which the rocks were able to produce or maintain open spaces along the fractures. It is likewise clear that ore shoots can only be formed in places where favorable structural features are combined with favorable rocks. For example, a vein that cuts soft unmetamorphosed shale can hardly be expected to contain an ore shoot, no matter how steeply it dips nor how much it changes in strike. In some places, three or more favorable factors have combined to determine the location of an ore shoot. Thus, the Incas deposits occur at the common intersection of the Pony Express limestone with a porphyry dike and with mineralized veins. So too with the replacement bodies in the May Day, which were formed along veins in limestone where they intersected barren faults. The great diversity in shape and inclination of ore shoots depends on a variety of factors, foremost of which are the shapes of favorable rock bodies and the patterns formed by the intersections of these bodies with various structural features. It is hardly necessary to add that not all open, brecciated zones along veins contain workable deposits of ore. Ores were necessarily formed only in fractures that not only were accessible to ore-bearing solutions but were actually traversed by them.

VERTICAL RANGE OF ORE DEPOSITS

The main ore body on the May Day vein extended to a depth of 450 feet below the surface and thus had the greatest vertical range of any single ore shoot that had been developed up to 1937. The over-all vertical range, however, of all the shoots in this and the adjoining Idaho mine, exceeds 1,250 feet. The only place in the district where deposits are known to have a greater range than this is on the south slope of Lewis Mountain. There, openings on the parallel Ashland-Ten Broeck and Gold King veins have demonstrated a range of 2,500 feet without material change in grade and character of ore.

Workable deposits have been found near the tops of several of the highest peaks in the district, or at altitudes of approximately 13,000 feet. The lowest altitude reached by mine workings is in the May Day, from which ore has been mined at an altitude of less than 8,400 feet. For the district as a whole, therefore, the total vertical range of developed deposits is slightly more than 4,500 feet.

An increase in content of free gold in near-surface ore has been reported from several mines and was doubtless due to secondary enrichment. Other than this, no visible differences in composition or texture of the various types of ore can be correlated with altitude or with depth below the present surface. Deposits occur, moreover, throughout the stratigraphic section from the Dakota (?) sandstone down to the Hermosa formation. These observations, together with the knowledge that blind shoots can and do exist in places, go far to justify further exploration of many veins at lower levels. The subject is further discussed in the section on the future of the district (p. 82).

MUTUAL RELATIONS AND ORIGIN OF THE ORE DEPOSITS

While relations between the different types of deposits are far from clear, it seems certain that they were formed through a wide range of temperature and, possibly, of pressure. Probably, however, they were all formed during one general period of hydrothermal activity, which followed closely on the emplacement of the nonporphyritic rocks.

There is some evidence of zoning in the deposits. Thus, the platinum-bearing chalcopyrite, the contact-metamorphic, and most of the pyritic-gold deposits are confined to the central, metamorphosed, part of the district. The telluride, ruby silver, chalcocite, and base-metal sulfide deposits, on the other hand, are widely distributed, though most of them, including all the more productive ones, are outside the metamorphic area.

The contact-metamorphic deposits, whether gold-bearing or not, and the platiniferous chalcopyrite of Copper Hill and Bedrock Creek were almost certainly deposited at high temperatures and relatively close to the source of the emanations from which they were formed. The pyritic-gold deposits all appear to be genetically related to one another, as they are closely similar in composition and exhibit all gradations between different forms. There is much similarity between the pyritic "blanket" body of the Doyle mine and some of the contact-metamorphic bodies, indicating that the two types are related, though the pyritic bodies must have been formed at somewhat lower temperatures or slightly farther from the source of the solutions.

The gold and silver-bearing mixed sulfide deposits are so similar to the telluride deposits in form, distribution, and mineral composition that there can be little doubt that the two types are genetically related and essentially contemporaneous. The presence of fairly abundant orthoclase in the Honeydew ores suggests a link with the contact-metamorphic and disseminated copper deposits; this deposit is more closely allied to these classes than it is to the other mixed-sulfide deposits or to the tellurides.

Some features of the Black Diamond vein, which is richer in sulfides than most other veins in its vicinity, is suggestive of a transition from the gold-bearing pyrite deposits through the mixed-sulfide deposits to the telluride deposits. At the Black Diamond mine itself the vein contains appreciable quantities of telluride. In its southwestward extension, along Boren Creek, it seems to grade into the pyritic type of vein filling that characterizes the deposits of that area.

The ruby silver veins are in a separate belt from all the other deposits. Their general structural relations, the presence in them of gold and of mixed sulfides in a gangue of quartz, barite, and dickite, and the reported presence of tellurides, all indicate that they are closely related genetically both to the telluride deposits and to the gold and silver-bearing sulfide deposits. Sporadic occurrences of the sulfosalts of silver in the Ashland-Ten Broeck, Gold King, Daisy, and other mines point in the same direction. The reason for the restricted areal distribution of the ruby silver ores is not known.

The telluride, sulfide, and ruby silver veins were doubtless deposited from hydrothermal solutions that rose along fault fractures and other conduits. The solutions must have been highly tenuous, else they could not have passed through the extremely tight spaces that characterize fissures in the softer rocks; and viscous solutions could not have traveled the long distances from their source that is evidenced by the wide vertical and horizontal distribution of these deposits. The solutions were richest in silica but contained appreciable quantities of various metals and other elements. The chemical nature of the solutions is not known. The widespread occurrence of sericite as an alteration product of the igneous rocks near veins indicates that the earliest solutions were alkaline, or at least neutral, in character, for sericite is commonly believed to be deposited from alkaline solutions. On the other hand, the occurrence of halloysite in many of the wall rocks, and of abundant dickite and a little fluorite in the veins, would be considered by most geologists as evidence that the solutions were acid during some parts, at least, of the ore-forming period.

Whatever the character of the ore solutions, it is clear that the vein minerals were deposited in open places in the veins, largely because of relief of pressure. Change of temperature was also an important factor in places. Tightening of the veins above open places, owing to difference of rock or to other causes, may also have been a factor in localizing some shoots by obstructing flow and allowing time for the solutions to cool and deposit their load of mineral matter.

The difference in relative quantities of sulfides, native gold, and tellurides between the two most important types of deposit may mean that there were original differences in the relative abundance of the elements in the ore-depositing solutions, or that in certain places conditions of temperature and pressure prevented precipitation of the telluride minerals in appreciable quantity.

The telluride ores are commonly regarded as epithermal deposits—that is, deposits formed relatively close to the surface and at low temperatures and pressures. The La Plata deposits certainly possess many of the characteristics of the epithermale class. The known vertical range of the telluride deposits is more than 4,500 feet, however, and the cover of sedimentary rocks over the now exposed ore-bearing rocks at the time of ore deposition could not have been less than 5,000 feet and may have been as great as 9,000 feet. The ores must therefore, have been formed at far greater depths below the surface than is considered characteristic of typical epithermal deposits.

FUTURE OF THE DISTRICT AND SUGGESTIONS FOR PROSPECTING

The ore hitherto produced by the La Plata district has come from a very few comparatively large deposits. supplemented by small shipments of usually high-grade ore from a large number of minor deposits. The developed parts of nearly all the known ore bodies, both large and small, had been largely worked out when the district was studied in 1935–37. Yet even though the visible reserves of ore are negligible, the available facts appear to justify the hope that the future production of the district is relatively bright.

Such hopes derive support from the fact that the productive life of most individual mines has been short. The history of a mine has usually consisted in the discovery, development, and exhaustion of single ore shoots or of several closely spaced and thus easily discoverable shoots. Exhaustion of the shoot usually meant temporary or permanent abandonment, or at best a desultory attempt to find more ore. In a few mines, such as the May Day and Idaho, where the returns from the ore body first found appeared to justify it, further development was prosecuted vigorously. In the May Day and Idaho this later work was rewarded with discovery of several additional ore bodies, but elsewhere, as in the Lucky Discovery and Neglected, the results of this later development work were discouraging. In some places failure to find new ore can be traced to ill-advised exploration methods arising from ignorance of the geologic conditions. In others it has been proved that no other ore bodies exist within the explored ground.

In a few mines the lower limit of development has been set by such obstacles as a heavy flow of water, but as a general rule the lowest workings mark a local discontinuity if not the actual bottom of the ore shoot that was being mined. As related in the foregoing pages, the known vertical range of ore deposits in the district as a whole is far greater than that of the ore shoots hitherto developed in any one mine, and the lower limits of the productive zone are not yet known. It seems clear, moreover, that favorable conditions for ore shoots are produced by a large variety of geologic conditions, that many veins contain several ore shoots, separated by nearly barren stretches, and that some ore shoots do not crop out at the surface. The outlook for discovery of new ore bodies along many of the known veins is therefore promising, providing the exploratory work is intelligently undertaken.

Not only may new shoots be found in known deposits, but new deposits may be discovered. None of the really productive deposits was found until after 1900, and the new discoveries made since then have occurred at widely separated intervals. There is no apparent reason for believing that 1933, the year the Red Arrow was found, marked the end of the discovery period for new ore bodies, particularly in view of the poor exposures that characterize much of the district.

Although determinable quantities of platinum and palladium have been proved in the disseminated ores from the Copper Hill mine, the content of copper and the platinum metals and the quantity of ore now showing would not encourage further mining. Possibly, however, the ore body mined at the glory hole dips in such a way that it was missed by the lower tunnel. Also, in the large area near the Copper Hill workings that is covered by glacial drift, talus, and soil, scattered exposures indicate that the geologic relations are similar to those near the known deposit. Exploration at or near the glory hole, possibly by means of drilling, might reveal additional ore.

The contact-metamorphic deposits offer little hope of any important new discoveries. As has been pointed out above, most of them are small and irregular, and few of them contain primary ores rich enough to be workable. Most of the richer oxidized ore bodies have doubtless been discovered and either exhausted or abandoned. There is of course a possibility that some oxidized bodies have been overlooked, or that workable deposits of primary ore may yet be found. They should be looked for along and just inside the borders of the central metamorphic area.

The pyritic-gold deposits have produced comparatively little in the past, though fairly large expenditures have been made in developing some of them. Most of the richest, those that were enriched by secondary processes, have presumably been found and mined out. Some possibility remains that small rich oxidized shoots, like the one worked in the Century mine, may have been overlooked. The best hope of further production from these bodies, however, appears to be in large-scale, low-cost operations on primary ores. Such methods would call for extensive prospecting and development of the deposits as well as careful research on metallurical processes. The possibility of finding other pyritic replacement bodies like that of the Doyle mine cannot be entirely discounted, but it seems to be remote. They can be expected to occur only along or close to the edge of the central metamorphosed area. All of the few remnants of limestone beds that are exposed in this zone, however, are either replaced by contact-metamorphic deposits or are essentially unaltered, and it does not seem possible that any extensive bodies like that of the Doyle mine can have been overlooked in the past.

The ruby silver veins of the Cumberland type offer little hope of important future production as compared with the telluride deposits and those of some other classes. Comparatively small bodies of high-grade silver ore may yet be found by further development of known veins or in new deposits. Search for such deposits would best be confined to the known ruby silver belt; it seems most likely to be successful in the eastern part of the belt, where, because exposures are poorest, deposits are most likely to have been overlooked in the past. As is noted under the description of the Cumberland mine, more complete development of that deposit, either in depth or in the ground that is already partly developed, may prove the existence of a large body of low-grade silver ore, which might be workable with modern methods of mining and milling.

By far the greater part of the ore produced in the past has come from deposits of the telluride and the gold-bearing mixed-sulfide classes, and these bid fair to retain their leading position in the future.

Many of the principles that control the location and extent of ore shoots are set forth in a preceding section, but unfortunately the presence or absence of favorable conditions cannot always be foretold in advance of actual exploration and part development. At many places, however, knowledge of the significance of various geologic features can give help in judging the probability of finding ore bodies. So far as possible the descriptions of individual mines in the latter part of this report contain suggestions for further prospecting, based on application of these principles.

Except in the vicinity of Diorite Peak the distribution of known deposits of these classes offers little encouragement to further exploration within the central metamorphic area. Outside this area, however, and especially near its borders, further exploration in many places would appear to be justified. Most of the veins that characterize the hinge fold encircling the central area have probably been found, but much of the exploration has been only superficial, and many ore shoots may possibly remain undiscovered. The strong faults in the southern and northwestern parts of the district probably deserve more exploration than they have already received. The faults themselves are commonly barren; search for ore should be confined to intersections of the faults with mineralized veins.

As most of the eastern part of the district is heavily covered with vegetation and its rocks are poorly exposed, it probably has been less thoroughly explored than any other part. The widespread distribution of known telluride deposits within this area, notably those in the Neglected and Mason mines and the Ohio-Indiana prospect, offers hope that other deposits remain undiscovered.

Although workable ore deposits will seldom be found in soft or incompetent rocks, any signs of mineralization in shale or other rock of similar character deserve investigation, as they may point the way to larger or richer deposits in underlying, more brittle rocks.

Largely because the rich silver-lead deposits in the neighboring camp of Rico replace limestone beds in the Hermosa formation it is widely believed locally that similar deposits should underlie the La Plata district. Unfortunately, no geologic evidence of such deposits has been found, but the comparison cannot be ignored, and cautious exploration in areas of known mineralization would appear to be warranted. The lower levels of the Gold King mine are along a vein in or just above the upper beds of the Hermosa, so that deeper exploration of that vein might reveal any replacement deposits in the limestones. Other favorable ground for prospecting is in the vicinity of the Honeydew mine, near which veins of base-metal sulfides crop out at the surface. There, however, the top of the Hermosa must lie at least 500 feet below the surface. It should be remembered that limestone beds are thickest and most numerous in the lower and middle parts of the Hermosa, at least 1,000 feet below any exposures of the Rico formation in the district. The uppermost part of the formation, however, contains a few thinner beds of limestone.

Even though some of them are very rich, most of the district's deposits are small and "pockety." It is therefore expensive and difficult to explore and develop them completely, and unless a vein is developed by mine openings that are very closely spaced both horizontally and vertically, worth-while ore shoots may be entirely missed. Few single mines will repay large company operations, and in the future as in the past most of them will probably be worked in a small way by owners or lessees. It seems possible that consolidation of several deposits with a single overhead to cover management and technical guidance would prove profitable.

Many of the older dumps appear to warrant thorough examination and sampling. The mines from which they came were operated at a time when ores that contained less than $50 to the ton could not be handled at a profit, and much ore of moderate grade was wasted. The results of random sampling of several dumps, as recorded in the mine descriptions, indicate the presence of much easily accessible material that should yield a profit under modern methods of treatment.

MINES AND PROSPECTS

Nearly all the mines of the district are shown in plate 1, and all patented mining claims, both lode and placer, are shown in plate 14. All available data regarding the mines and the more important prospects are given below. Much essential information is lacking, particularly for the older mines that have been inactive for many years. The writer's observations on many mines have been supplemented by published and unpublished reports by other geologists and mining engineers. Field notes by C. W. Purington, of the Geological Survey, who examined most of the mines that were open in 1896, were especially helpful. Large parts of some of the mine descriptions are based on reports and maps collected in 1934–36 by the Works Progress Administration Mineral Resources Project, which was under the direction of the State Planning Commission. A few descriptions of old and now inaccessible mines are drawn from the annual reports of the Director of the Mint, even though some of the information contained therein is known to have been overly optimistic.

The results of sampling in some of the mines were made available by interested engineers and operators. Those recorded below or summarized in the text are believed to be fairly reliable, but it should be borne in mind that the telluride ores are in general so spotty and irregular that even the most careful sampling may give misleading results. Chiefly as a guide to further studies, a few samples were taken in the course of this work. Methods of sampling varied with conditions, but, with certain limitations described below, the samples are believed to be representative. They were assayed by E. T. Erickson in the chemical laboratory of the Geological Survey. The methods recommended by Hillebrand and Allen [82] for assay of gold telluride ores were followed for the samples that appeared to contain tellurium.

The mines are described in alphabetical order; their probable place in the scheme of classification adopted on page 63 is indicated by the numbers 1 to 5 following the name of the mine.

(1) Disseminated chalcopyrite with platinum and palladium.
(2a) Contact-metamorphic deposits containing gold in sulfides.
(2b) Gold-bearing pyrite deposits.
(2c) Deposits of mixed sulfides with silver and free gold.
(3) Chalcocite veins.
(4) Ruby silver bearing veins.
(5) Telluride deposits.

Wherever possible, formation contacts and other geologic features shown on the mine plans are projected to floor level. Where the directions of these features are not known, they are arbitrarily mapped as normal to the walls of the workings.

Production figures prior to 1902, where available, have been taken from the annual reports of the Director of the Mint and from the reports of the Colorado State Bureau of Mines. In a few places other sources of information have been used. The figures for the years 1902–43 are taken from the mine production figures of the Geological Survey and the Bureau of Mines, which were generously made available by C. W. Henderson, Supervising Engineer, Bureau of Mines, Denver.

ALLARD (1) [83]

The Allard tunnel is near the bank of a tributary to Bedrock Creek, at an altitude of about 10,250 feet. An abandoned wagon road of uniform grade connects

[82] Hillebrand, W. F., and Allen, E. T., Comparison of wet and crucible-fire methods for the assay of gold telluride ores with notes on the errors occurring in the operations of fire assay and parting: U. S. Geol. Survey Bull. 253, 31 pp., 1905. See also Bugbee, E. E., A textbook of fire assaying, p. 201, New York, John Wiley & Sons, 1922.

[83] Numbers in parentheses refer to classification of deposits (see above).

the workings with La Plata, 1¼ miles to the east. The tunnel was driven before 1921 on an unpatented claim by the Allard Mining Co. No ore was ever produced, and the property has been inactive for many years. The main tunnel extends N. 31° W. for 740 feet. Five hundred feet from the portal a side drift trends S. 74° W. for 100 feet, then turns to N. 45° W. and continues 90 feet. All equipment had been removed, but the mine workings were in good condition in 1944 (fig. 7). The

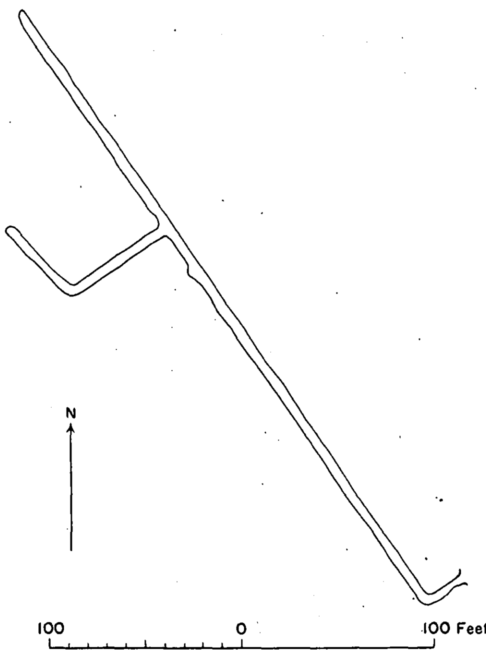

FIGURE 7.—Plan of the Allard tunnel.

tunnel is within the border of the larger of the two syenite stocks shown in plate 2 and was driven to explore the disseminated copper deposits, which crop out in the vicinity. These deposits have been described on pages 63–66. The tunnel merely serves to provide another exposure of the deposits, which are almost perfectly exposed on the surface over a large area. Mineralization of the type seen in the tunnel appears to extend at least 1,500 feet westward from the Allard tunnel and to altitudes 400 to 500 feet above the tunnel.

In 1943 the Allard tunnel was sampled by the Bureau of Mines. A summary of the results of this work follows:

	Copper (percent)	Silver (ounces)	Platinum (ounces)
From portal to 280 feet	0.147	0.14	--------
From 200 to 580 feet	.543	.23	0.003
From 580 to 740 feet	.192	.24	--------
West drift along 212 feet	.486	.22	--------

ASHLAND-TEN BROECK (5)

The Ashland and Ten Broeck mines explore parts of one vein on the south slope of Lewis Mountain. The Ashland workings are at an altitude of 12,400 feet and lie 1,500 feet northeast of the central peak of the Lewis group. The old Ten Broeck openings are on the southeast slope of the mountain facing Junction Creek, 1,000 feet from the central peak and at an altitude of about 12,000 feet. They can be reached over a good trail from Eagle Pass. The Brawner crosscut tunnel, whose portal is 1,000 feet north of the Gold King mine, is 770 feet below the lower Ten Broeck adit.

The Ashland-Ten Broeck vein was discovered before 1880. In the report of the Director of the Mint for 1881, Burchard [84] mentions the Ashland, Sylvan Nos. 1 and 2, Ten Broeck, and T. T. T. as in the telluride belt. He says "the mass of the vein matter is low grade, averaging about $40 per ton, which will not, of course, pay for handling at present." Some ore was taken from these claims now and then between 1881 and 1890, but there is no further record of activity until 1908, when the Ashland produced a small lot of ore. The Ashland was active until 1913. In that year, also, the Ten Broeck was reopened, and it produced ore in 1913, 1914, and 1917. Between 1917 and 1921 the Brawner tunnel was driven to develop the vein at depth. George F. Brawner, who was also responsible for the development at Copper Hill, was in charge of the operations. After the tunnel was completed and the vein drifted on, the mine closed down, and it had not been reopened up to 1943.

The recorded production of the Ashland and Ten Broeck mines is about $10,000. This figure includes a shipment of one carload of ore in 1883 that assayed $136 in gold and silver to the ton and probably yielded about $1,400.[85] The recorded production is shown in the following table, but the figures for the years prior to 1902 are probably not complete:

Recorded production of Ashland-Ten Broeck mines, 1883–1943 [1]

Year	Mine	Ore (dry tons)	Gold (fineounces)	Silver (fineounces)
1883	Ashland	[2] 10	68	----------
1887	do	----------	12.5	12
1888	do	----------	20.0	15
1890	Ten Broeck	----------	13.5	78
1908	Ashland	3.5	8.6	17.5
1910	do	14	58.32	103
1911	do	30	53.14	137
1912	do	17	34.09	92
1913	Ashland and Ten Broeck	15	48.26	92
1914	Ten Broeck [3]	160	242.47	462
1917	do	21	64.82	107
	Total recorded production	----------	623.70	1,115.5

[1] No production figures available for 1884–86, 1889, 1891–1901; no production 1902–43 except during years listed.
[2] Estimated.
[3] Also produced 34 pounds of copper and 316 pounds of lead.

The principal Ashland workings consisted of several open-cuts, a shaft 40 or 50 feet deep, and a short adit from which a 100-foot drift was opened on the vein. Most if not all of the the ore produced was taken from the open-cuts. None of the workings were accessible in 1935. A vertical section through the old Ten Broeck

[84] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1881, p. 418, 1882.
[85] Burchard, H. C., op. cit. (for 1883), p. 374, 1884.

adits, a plan map of these workings, and the drifts on the Brawner tunnel level are shown in plate 15. The Ten Broeck adits were caved and inaccessible in 1937; the Brawner tunnel was open, but bad air made it impossible to reach the drift on the Ten Broeck vein.

The country rock in and near the Ten Broeck adits and the drift on the Brawner tunnel level is largely diorite; that in the Ashland workings and the Brawner crosscut consists of flat-lying red beds of the Cutler formation and a few sills of diorite-monzonite porphyry. The sedimentary rocks are silicified except in the Brawner crosscut, where they are soft and generally unmetamorphosed.

The outcrop of the Ashland-Ten Broeck vein shows clearly on the drab slopes of Lewis Mountain as a light-colored band, which follows a zigzag course owing to irregularities in the topography. The vein strikes about N. 55° W. and can be traced continuously for a distance of 3,500 feet. Toward the northwest the vein stops at its junction with the Columbus vein, but the Euclid vein, which follows the same course, appears a short distance farther west. As shown in plate 15, the vein system is composed of several overlapping segments, which are broken by several cross fractures. The vein was lost in the west drift on the Brawner level. It may have been displaced along the strong Parole vein, and if so, its westward extension probably could be found with but little work. In the Ten Broeck adits and near the eastern extremity of the Brawner workings the vein swings to the east. This part of the vein may really be a split from the main vein, the southeastward extension of which might be found to underlie the sliderock between the Ten Broeck and Durango Girl mines. Like the nearby Gold King vein, the Ashland-Ten Broeck vein dips toward the north at an average angle of 70°. Doubtless there are local irregularities in the dip.

The ore is said to be similar to that of the Gold King mine, and most of the gold and silver probably occurs as tellurides. Galena and chalcopyrite are locally abundant. According to early reports the Ashland ore contained some native mercury.[86] The vein matter on the Ten Broeck dumps is chiefly dense quartz, with a little white to dark-gray chalcedony. Small irregular masses of pyrite are scattered through the quartz, and crystals of white barite are moderately abundant in vugs. The quartz encloses ghosts of feldspar crystals, and most of it undoubtedly was formed by replacement of the dioritic country rock. The following sampling record shows clearly that in general the richest ore occurs at or near places where the vein changes in direction or at its intersections with cross fissures.

The ore shipped from the Ashland in 1908–13 contained from 1.53 to 59.54 ounces of gold and 4.29 to 44.26 ounces of silver to the ton, and the Ten Broeck shipments of 1913–17 contained from 1.47 to 21.56 ounces of gold and 4.88 to 57.10 ounces of silver to the ton. The higher figures represent shipments of only a few hundred pounds.

[86] Burchard, H. C., op. cit. (for 1883), p. 374, 1884.

Sampling record, Ten Broeck mine [1]

Sample No.	Width		Gold (ounces per ton)	Silver (ounces per ton)	Remarks
	Feet, inches				
Upper levels					
1		2	0.15	0.15	Northwest fault.
2	1	0	.14	.66	Do.
3	5	2	.28	1.06	Do.
4	5	0	.98	.86	Do.
5	14	3	.58	1.42	2½ feet of quartz and 10 feet of wall rock.
6	2	2	.32	1.68	
7	3	0	.50	1.20	
8	2	0	1.70	2.00	
9	3	0	.60	.60	
10	2	6	.70	.50	
11	2	6	.44	2.16	
12	2	0	.29	3.08	
13	2	6	.08	.62	
14	3	9	.24	1.12	
15	5	9	.07	.53	Footwall gouge.
16	2	0	1.30	1.70	
17	2	0	.82	2.19	
18	3	0	.62	2.38	
19	2	0	1.60	4.40	
20	2	0	.48	.52	
21	2	0	1.22	.28	
22	3	0	.64	1.26	
23	3	0	.32	.90	
24	2	6	.68	5.32	
25		10	.28	2.52	Part of vein in hanging wall.
26	2	6	.48	2.53	Do.
27	1	0	1.30	8.00	Do.
28	1	6	.56	3.04	Do.
29	1	2	.74	2.86	Do.
30	1	4	.86	5.94	Do.
31	1	2	.34	2.86	Do.
32	1	0	.12	.58	25 feet up raise.
33	1	4	.12	1.08	Do.
34	1	4	.70	2.40	82 feet up raise.
35		8	.34	8.66	Part of vein in hanging wall.
36		8	1.08	3.72	Do.
37		10	.82	16.00	Do.
38		6	.98	7.62	Do.
39	1	2	.30	9.20	
40	1	6	.30	2.30	
41	1	6	.02	.98	
42	2	6	2.44	1.96	
43	2	0	.09	.71	
44	1	4	.58	1.92	
45	1	6	.16	1.24	
46	1	0	.20	1.80	
47		9	.44	4.76	Part of vein in hanging wall.
48	1	2	.36	2.94	Do.
49	1	2	.16	8.24	Do.
50		6	.02	.68	
51	1	0	.16	3.04	Includes 6 inches of wall rock.
52	1	0	.14	3.16	
53	1	0	.16	4.44	
Average	1	0	.55	2.86	
Brawner tunnel level					
54	2	0	0.05	0.60	
55	2	6	.18	4.20	
56	1	8	.08	1.36	
57	2	0	.03	.37	

See footnotes at end of table.

Sampling record, Ten Broeck mine[1]—Continued

Sample No.	Width		Gold (ounces per ton)	Silver (ounces per ton)	Remarks
	Feet	inches			
Brawner tunnel level—Continued					
58	1	4	0.26	4.02	
59	2	6	.06	2.34	
60	1	4	.07	.33	
61	1	0	.08	1.22	
62		10	.10	1.30	
63		8	.18	2.50	
64		6	.08	1.62	
65		6	.10	1.10	
66	1	0	.14	.36	
67	1	0	.04	.46	
68	1	2	.06	.54	
69	1	0	.07	.53	
70		10	.04	.96	
71	1	0	.07	.53	
72	1	0	.08	.62	
73		10	.12	2.78	
74		10	.21	5.09	
75	1	0	.08	.92	
76	1	0	.08	.72	
77	1	2	.10	1.10	
78	1	0	.50	1.10	
79	1	2	.10	2.80	
80	1	0	.08	3.62	
81	1	0	0.09	1.11	
82	1	0	.15	.85	
83	1	2	.07	.93	
84	1	0	.12	1.88	
85	3	0	.08	1.32	
86	1	4	.14	1.96	
87		10	10.91	1.92	
88	2	0	.44	2.56	
89	1	2	.74	1.80	
90	1	0	.60	1.81	
91	6	0	.24	4.16	Contains 1.2 percent copper.
92	1	2	.20	14.90	
93	1	0	.32	1.58	
94	1	4	.08	3.42	
95	1	4	.76	3.24	
96	1	6	.20	1.30	
97	2	0	.38	1.72	
98	1	2	.35	1.05	
99	1	4	.18	1.22	
100		8	.16	1.94	
101		8	.08	1.32	
102		8	.44	1.56	
103	1	4	.12	2.18	
104	1	6	.12	2.48	
105	2	0	.08	2.92	
106	1	6	.11	2.59	
107		8	.08	1.22	
108		8	.15	.55	
109		4	.08	.62	
110	1	2	.08	1.02	
111	3	0	.16	1.04	
112	3	0	.40	.60	
113	6	0	.08	2.62	
114	4	0	.16	.83	
115	1	0	.11	1.89	
116		6	.16	2.64	
117		6	.10	1.30	
118		6	.22	.48	

Sampling record, Ten Broeck mine[1]—Continued

Sample No.	Width		Gold (ounces per ton)	Silver (ounces per ton)	Remarks
	Feet	inches			
Brawner tunnel level—Continued					
119	1	0	0.92	18.60	
120	1	6	.72	2.12	
121	1	6	.40	4.00	
122	1	6	.65	3.00	
123	1	6	.20	1.54	
124		10	.10	.34	
125		10	.12	.30	
126		10	.09	.41	
127	1	0	.10	.90	
128		8	.08	1.45	
129		8	.20	.75	
130		6	.42	4.16	
131		6	.15	1.50	
132		6	.10	1.60	
133		4	.10	.60	
134	2	0	.16	.50	
135	2	0	.14	.50	
136		8	.78	9.50	
137		6	.30	3.55	
138	1	0	.84	.90	
139	2	0	.25	1.10	
140	3	0	.60	2.25	
141	3	0	.10	1.20	
142	3	0	.10	1.90	
143	3	0	.55	.85	
144	2	6	.06	.62	
145	2	6	.21	.50	
146	2	6	.62	1.30	
147	2	6	.60	1.32	
148	2	0	.10	.40	
149	1	6	.04	1.00	
150	-	--	2.50	12.08	30-foot grab sample.
151	3	0	.14	.80	
152	5	0	.12	2.68	
153	4	6	.12	1.86	
154	3	0	.18	2.32	
155	3	0	.10	9.20	
156	2	0	.12	6.08	
157	1	6	.06	14.05	
158	3	0	.17	4.44	
159	3	0	.08	8.48	
160	3	0	.10	2.10	
161	2	6	.11	6.30	
162		10	.05	5.37	
163	1	6	.11	3.19	
164	-	--	.10	48.72	Assorted quartz.
165	-	--	.08	16.58	Do.
166	-	--	.26	120.36	Do.
167	-	--	.06	30.30	Do.
168	-	--	.10	67.94	Do.
169	1	6	.12	7.40	
170	2	0	.05	1.00	
171	2	0	.05	1.10	
172	2	0	.05	3.80	
173	2	0	.01	1.00	
174	2	0	.06	13.60	
175	2	0	.15	.98	
176	1	6	.06	.74	
177	1	0	.10	.70	
Average[2]	1	7	.29	2.43	

[1] From private report by V. C. Perini and R. D. McCausland, 1921. See plate 15 for location of sample stations.
[2] Samples 150 and 164-168 excluded from average.

The sample record given above shows that on the Brawner level the vein is slightly narrower than it is in the upper levels and only about half as rich. Whether this condition is local or indicates an approach to the bottom of the ore shoot is not known. Nothing is known of the block of ground between the upper and lower levels. The uppermost workings are 1,400 feet above the Brawner level, and there is said to be little visible difference in the character of the ore in different workings. A large body of medium-grade ore is indicated by available data, but cannot be regarded as blocked out. Further exploration of the property appears to be justified.

Aside from the large body of apparently workable ore, the chief interest of the Ashland-Ten Broeck deposit lies in the fact that it demonstrates a great vertical range for the telluride ores. If the nearly parallel Gold King vein be considered a sort of downward extension of the Ten Broeck vein, it means that ore of similar character and grade occurs through a vertical range of at least 2,500 feet.

AURORA (5)

The Aurora group, which consists of the Aurora, Jim Smith, and Jewel patented claims, is on the east slope of the ridge between Snowstorm Peak and Lewis Mountain, about 1,000 feet southeast of the Bessie G. mine. The Aurora vein was discovered in the early eighties and was worked intermittently by the owners and by lessees from then until about 1900, since when the mine has been inactive. The total production was small. In a report prepared for the Works Progress Administration Mineral Resources Project in 1936, L. M. Wayt, the present owner, notes several small shipments of ore that contained 5 to 12 ounces of gold to the ton. All the ore produced was taken from a 27-foot shaft. In addition to the shaft, which was caved in 1937, the vein is developed by two crosscut adits about 125 and 350 feet, respectively, below the shaft collar.

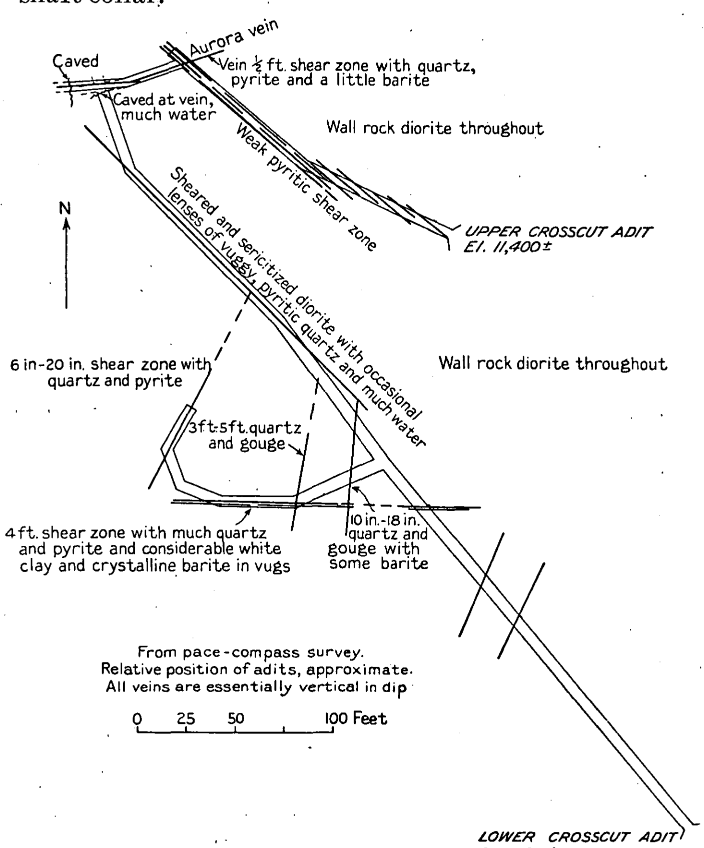

FIGURE 8.—Plan of Aurora mine.

As shown in figure 8, the upper adit reached the Aurora vein, at which a drift was turned to the west. In 1937 this drift was caved 50 feet from the adit and its total length is not known. The lower adit was caved at its junction with drifts to the east and west. The relations shown in figure 8 make it seem likely that these drifts followed the Aurora vein, but as the relative positions of the adits are based only on compass and aneroid measurements the correlation is not certain. Wayt says in his report, "it is not definitely established that the lower tunnel reached the main Aurora vein."

The country rock in the vicinity of the mine consists in large part of crosscutting bodies of slightly porphyritic but otherwise typical hornblende diorite. This grades imperceptibly into diorite porphyry, and all the rock is mapped as porphyry in plate 2. The diorite is somewhat kaolinized and pyritized, and is moderately soft in most places. Small masses of silicified redbeds of the Cutler formation are exposed at the surface, but none were seen underground.

At the surface the Aurora vein is marked by a narrow zone of iron-stained and decomposed rock, which contains some pyritic vein quartz. It there strikes N. 58° to 72° E. and is poorly exposed in general. Its eastward extension is probably the vein known as the Golden Wedge. Where exposed in the drift from the upper adit the vein is vertical. Near the adit its strike is N. 72° E., but 35 feet to the west it turns sharply N. 85° E.; it is 1 foot to 2 feet wide and consists of strongly sheared diorite containing much quartz and pyrite and a little barite.

The owner states in his report that "the ore in the shaft was 6 inches to 2 feet wide and consisted of telluride minerals in greenish-black quartz." Specimens from a half-ton pile of ore on the dump of the upper adit, taken from a part of the vein that was not accessible at the time of visit, consist of mottled to rudely banded gray, green, and white quartz, which is fine-grained to medium-grained. No ore minerals are visible, but the green quartz is typical of veins that contain tellurides. Vugs are lined with clear crystalline quartz and a few small crystals of barite and pink carbonate. Minute crystals of pyrite are perched on the quartz in places. The color of the gray quartz is due to finely disseminated pyrite, which also forms discontinuous veinlets that cut the quartz. A few small blebs of chalcopyrite are present. No evidence of replacement of country rock by quartz was seen in the specimens at hand, which, however, resemble specimens from other veins in which it is clear that the vein matter has replaced sheared country rock. A representative sample of this ore assays 0.16 ounce gold and 0.36 ounce silver to the ton.

The upper adit follows a broad, weakly sheared, pyritic zone, which trends northwest. A similar parallel shear zone, along which the diorite is strongly kaolinized and which contains a few lenses of vuggy quartz with some pyrite, was followed by the lower adit in the latter part of its course. Three northeastward-trending fissures and one fissure that trends due east are partly developed by a side drift from the lower adit. They range from 6 inches to 5 feet in width and consist of strongly sheared diorite, much gouge, pyrite-bearing quartz, and some barite.

Present information is too limited to serve as a guide to further prospecting. It should be noted, however, that several unprospected fissure intersections, any of which might contain small bodies of ore, are indicated on figure 8.

BARR-MENEFEE (2?)

The Barr-Menefee group of unpatented claims is on Horse Creek, about 1½ miles west of Schubert Flat. The claims are held by the Barr-Menefee Mining Co., which was organized in 1933 and which has since done a large amount of exploratory work. Development in 1937 consisted of two adits, 105 and 165 feet long, respectively, and a 100-foot shaft, in addition to numerous diamond drill holes and prospect pits.

As exposures are poor or lacking in the vicinity of the property, the geology of the deposit is not fully understood. Much of the development work has been done along or near a strong northeastward-trending fault zone. The rocks on the northwest side of the fault have been dropped down, bringing Mancos shale against Dakota (?) sandstone. The fault zone is 5 to 15 feet in width and consists largely of brecciated sandstone with much gouge. Pyrite is widely distributed, but vein quartz is not abundant. There seem to be several other mineralized fissures near the main fault.

A dark-gray to dark-green mafic dike, allied to others in the district, is exposed in a few places and apparently parallels the fault zone. It contains much fine-grained brown mica, but it is noteworthy chiefly because of the abundant spherical amygdules of calcite that it contains. These range from 2 millimeters to 1 centimeter in diameter. Small irregular grains of pyrite are sparingly distributed throughout the rock but are most abundant in the calcite. Sphalerite is rarely present. Near the fault zone and dike the Mancos shale is indurated and resembles porcelain.

Numerous assays for gold and silver, particularly of samples from diamond-drill cores, have given encouraging results. The shaft was sunk largely on the strength of a widely reported drill-core assay, which indicated the vein matter had a high silver and platinum content, and the intention was to explore further by means of a short crosscut to the vein at the bottom of the shaft. According to the local newspapers, the objective had not been reached in the summer of 1938.

BAY CITY (2a)

HISTORY, PRODUCTION, AND DEVELOPMENT

The Bay City mine, on the west bank of the La Plata River and just south of Bay City Gulch, was discovered in 1876. It produced some rich gold ore shortly after its discovery and has since been intermittently active. According to Fossett,[87] "the mine was opened on an 8-foot bed of ore in 1876. Samples from this bed were milled at Denver and yielded gold at the rate of $800 to the ton." The most recent work was done in 1934–35 by the Bay City Mines Co., Inc., a stock company. The new adit shown in figure 9 was driven by this company, but work stopped in the summer of 1935. It is reported locally that the Bay City has produced $100,000 from the old workings, but this figure is probably much exaggerated. The total production since 1902, as shown in the following table has been less than $3,000:

Production of Bay City mine, 1902–43 [1]

Year	Ore (tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1913	24	24.27	68	1,086	148
1917	84	73.34	154	2,600	--------
1918	28	6.60	55	385	--------

[1] From mine production figures compiled by U. S. Geological Survey and U. S. Bureau of Mines. No production for years not listed. Early production unknown.

The principal openings are shown in figure 9. The original workings consisted of a flat stope, about 75 feet long, which was open to the surface in several places and extended only about 30 feet into the side of the hill. The old adit opens off the stope and extends northwestward for 300 feet. The new adit, driven in 1934–35, is 200 feet long and extends westward. In addition to these openings, there are several short adits and open-cuts along the outcrop of the Bay City bed-vein between the mine and Bay City Gulch. The extension of the same deposit north of Bay City Gulch was formerly worked in a small way as the Gold Bug mine.

GEOLOGIC RELATIONS

The Bay City deposit is in a limy bed, locally called the "Bay City limestone," at the base of the Dolores formation. Near the portal of the old workings this bed is about 10 feet thick and consists of mottled light-gray to white massive limestone. Some of it has been altered to coarse-grained marble. The bed grades laterally from massive limestone to the limestone conglomerate, which is more typical of the lower Dolores beds, or to sandy mudstone. The gradation is well shown in the old adit. Northwest of the place marked "A" in figure 9, the limestone grades into limy mudstone; beyond point "B" the bed consists of red sandy mudstone and contains very little lime. Below the new adit the "Bay City" bed is covered with slide rock. In the prospect near Bay City Gulch it is almost completely replaced by contact-metamorphic minerals, but there the texture of the ore suggests that the bed was originally a limestone conglomerate. The rocks in the vicin-

[87] Fossett, Frank, Colorado: A historical, descriptive, and statistical work on the Rocky Mountain gold and silver mining region, pp. 428–429, Denver, 1876.

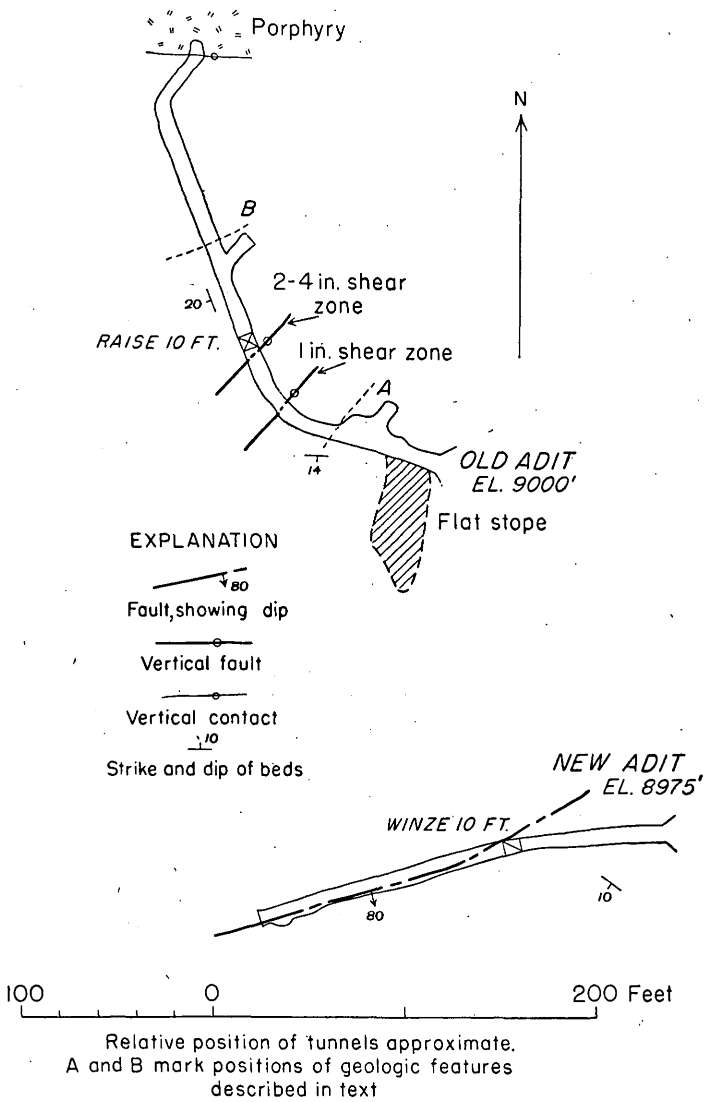

FIGURE 9.—The original workings, Bay City mine.

ity of the mine dip 10° to 20° southwest. The shaly and sandy beds are slightly silicified and bleached, though in general the beds are much less altered than those exposed farther north.

Several dikes of diorite-monzonite porphyry, which trend nearly due east, are exposed in the vicinity of Bay City Gulch. The south wall of one of them is exposed in the breast of the old adit.

ORE DEPOSITS

Although the ore and gangue minerals have replaced parts of the "Bay City" limestone bed, the contacts between ore and barren rock are sharply defined. As seen in the walls of the old stope, the ore body ranges from 2 to 3 feet in thickness and lies in the lower part of the limestone. At point "A", figure 9, the ore gives out completely along the strike. Although this edge of the ore body was probably controlled in part by a decrease in purity of the limestone, the unreplaced limestone that overlies the ore bed is apparently rather pure. Evidently the replacement process was selective and was governed by conditions that are not fully understood.

The metallic minerals in the ore bed are magnetite, specular hematite, pyrite, chalcopyrite, and galena. Yellow to brown andradite and yellowish-green epidote are the most abundant gangue minerals, quartz is moderately abundant, and there is some barite and calcite. The minerals are intergrown with one another, most of them being fine-grained to medium-grained. Crystal faces are rare. Nearly pure masses of galena, of chalcopyrite, and of the iron oxide minerals can be found in places.

Near the surface the ore is oxidized and consists largely of dark-brown limonite enclosing some residual masses of sulfides and much quartz and garnet. Although no gold was observed in the polished sections examined, it seems probable that gold in the primary ore was free and intimately associated with the sulfides. Most of the ore produced in the early days was almost certainly oxidized ore in which the gold had been concentrated to some extent.

NEW ADIT

Although the new adit is at a lower altitude than the old workings, it is stratigraphically at some distance above the "Bay City" horizon, because of the southward dip of the beds. The wall rock in this adit consists of comparatively unaltered red mudstone, which is silicified and slightly pyritized for distances of 6 inches to 2 feet away from each side of a steep fissure vein. The vein followed by the inner part of the adit strikes N. 75° E. and dips 80° S. Definite slickensides are not found on the walls, but other structural features indicate slight normal faulting. The vein ranges from 2 to 18 inches in thickness and averages about 4 inches. The vein matter consists of brecciated and silicified wall rock and contains considerable quantities of barite, pyrite, and chalcopyrite. The gangue minerals, none of which are abundant, are barite, ankerite, calcite, crystalline quartz, and white to brown gouge. The tenor of the ore is not known. The most logical places for further prospecting appear to be the intersection of this vein with the "Bay City" limestone or with the limestone conglomerate lenses that occur higher in the section, but there is no indication that large or commercial ore bodies exist there.

BELL HAMILTON (3)

by E. N. GODDARD

The Bell Hamilton mine is on the northeast side of Bear Creek, 1,500 feet from the creek and 9¼ miles southeast of Robinson's Ranch, at an altitude of about 10,100 feet. The workings consist of two crosscut tunnels, 100 and 300 feet long, both caved in 1932, and a 25-foot tunnel along a fault.

The mine was first opened about 1882. In the Mint report for 1882, Burchard[88] noted that the Bell Ham-

[88] Burchard, H. C., op. cit (for 1882), p. 508, 1883.

ilton was "among the most developed properties" in the La Plata district and that a crosscut adit, then 164 feet long, was being driven.

The workings are in red sandstones, shales, and grits of the Dolores formation, and one tunnel penetrated a bed of limestone conglomerate. These sediments are cut by a dike of monzonite porphyry about 40 feet wide, striking N. 25° to 30° E. and dipping 78° to 87° SE., which appears to play out southwestward in the vicinity of the Bell Hamilton workings. The dike rock is very similar to that forming the larger dike at the Missouri Girl mine, but has larger and fewer feldspar phenocrysts and very few phenocrysts of pyroxene. The borders of the dike are much fractured, and small faults and fractures parallel to the dike occupy a zone 10 to 20 feet wide on either side. The red sandstones are bleached for a width of from 1 foot to 3 feet on either side of these fracture zones and fissures.

Chalcocite occurs in small flat lenses, seams, or pebble-like masses in or adjacent to seams of coaly material along the fracture zones. In places chalcocite is disseminated along the bedding close to carbonaceous material, and locally it replaces pebbles in limestone conglomerate. Malachite commonly coats the chalcocite and fracture surfaces. Pyrite is disseminated in the sandstone alongside the fracture zones, and calcite fills numerous cavities and fractures in the sandstone.

The 25-foot tunnel follows a fault zone of sheared and brecciated sandstone 6 to 18 inches wide. Small slips branch from the fault and turn into the bedding. Small specks of malachite, probably derived from chalcocite, are disseminated in the bleached sandstone bordering the fault.

Burchard [89] stated that the lode was reported to be 30 to 40 feet wide and that one assay "gave over $3,000 in silver" to the ton. The ore was supposed to have contained "native and wire silver," but none was found by the writer. Jess Robinson stated that the copper ore was found on one side of the dike and the silver ore on the other, and that considerable sorted copper ore containing 25 percent copper was at one time stacked on the dump but was carried away by a cloudburst. Apparently no ore was ever shipped from the property, and no minable ore was observed by the writer.

BESSIE G. (5)

One of the best-known mines in the district is the Bessie G., on the steep east slope of the divide between Columbus Basin and Heffernan Gulch. The workings are 1,900 feet S. 20° E. of Snowstorm Peak and at an altitude of about 11,750 feet. The mine is most easily reached by the trail from Columbus Basin, though it can also be reached by a very steep and poor trail from Junction Creek. Called the Egyptian Queen when first opened about 1880, the mine was renamed the Bessie G. when the claim was patented in 1891. Two other patented claims, the Cleveland and the Big Four, lie east of the Bessie G. From its discovery to the present time the mine has been worked at various times by several successive owners and by many lessees. The mine is directly in the path of snowslides, so that attempts to work it during the winter have usually failed. It was idle in 1937. The following table shows its recorded production to have been nearly $120,000, half of which was produced in 1940–43, after the field work for this report was completed. The figures are probably incomplete for the years prior to 1902, and they do not include some ore that is known to have been "high-graded" from the property.

Recorded production of Bessie G. mine, 1887–1943 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1887	0. 83	76. 70	112
1888		28. 95	102
1889	. 84	28. 76	74
1891		403. 15	825
1892		524. 55	765
1894	12. 11	46. 73	102
1896	2. 23	99. 55	86
1899	9. 88	105. 70	303
1900	6. 82	177. 97	337
1901	4. 17	43. 71	103
1902	. 21	5. 54	5
1905	3. 95	9. 24	40
1906	. 28	2. 88	6
1907	. 12	1. 43	3
1910	3	26. 19	40
1911	3	119. 28	95
1912	6	427. 38	291
1916	. 67	43. 79	41
1917	3. 03	120. 50	103
1919	10	17. 50	28
1920	3	54. 40	57
1921	1	25. 60	21
1926	2	99. 68	82
1930	1	9. 20	19
1932	20	47. 12	31
1933	58	92. 81	95
1934	57	82. 29	78
1935	1. 30	3. 70	13
1936	3	29. 23	35
1939	3	74. 0	71
1940	32	438. 89	[2] 406
1941	32	660. 30	[2] 565
1942	46	245. 53	[2] 230
1943	25	245. 78	[2] 194

[1] Figures for 1887, 1889, 1894–1907, and 1917 compiled from records of individua shipments furnished by Reese McCloskey, Durango, Colo.; those for 1888, 1891, and 1892 are taken from annual reports of the Director of the Mint, and those for 1910–16 and 1919–37 from mine records of the U. S. Bureau of Mines. No records are available for other years from 1880 to 1901; there has been no production for years since 1902 except as noted.

[2] Also produced 88, 13, 25, and 61 pounds copper in 1940, 1941, 1942, and 1943, respectively.

Except for a few small open-cuts along the outcrop of the vein, all the workings of the Bessie G. mine are shown in figure 10. The upper adit was open for a short time in 1936 but was caved at the portal when the mine was revisited in 1937.

The country rocks in the vicinity of the mine are silicified redbeds of the Dolores formation cut by a complex mass of irregular dikes and sills of diorite and of porphyry. The vein follows the south wall of a

[89] Burchard, H. C., op. cit., p. 508.

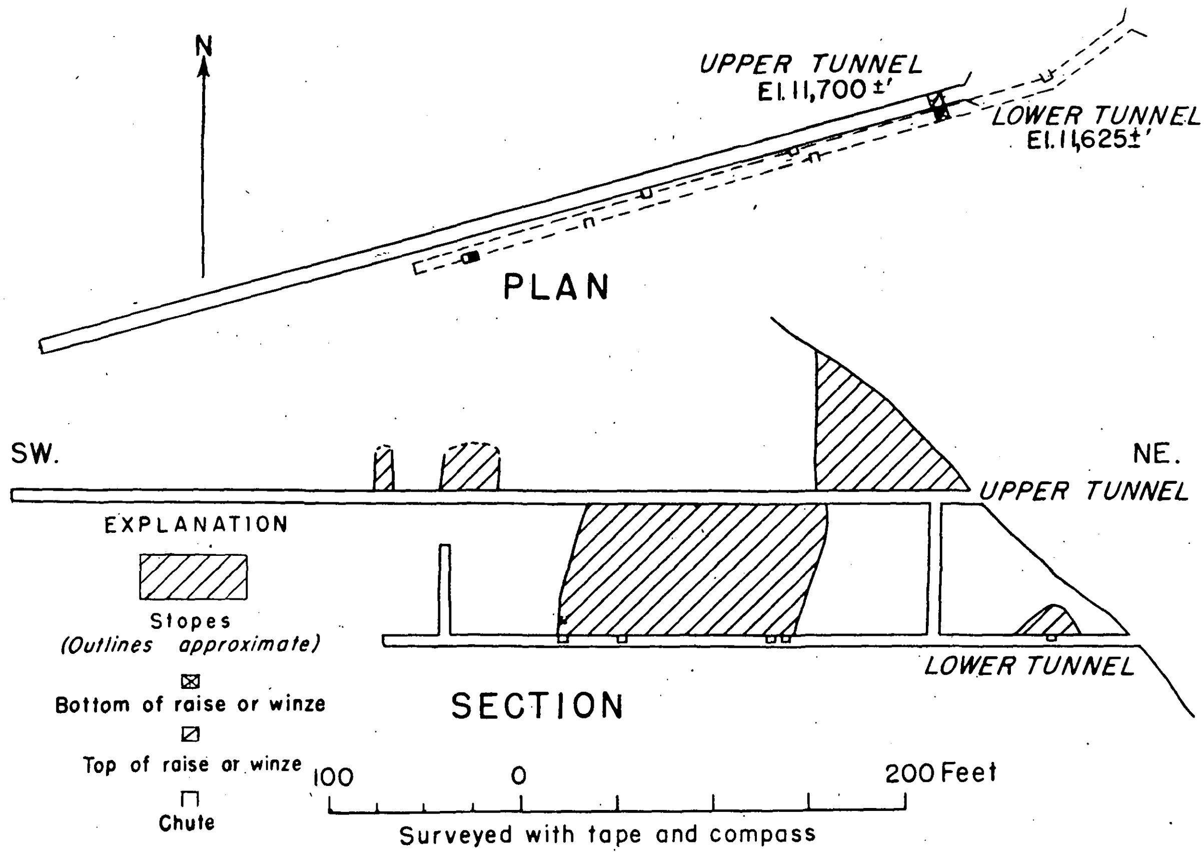

FIGURE 10.—Plan and section of Bessie G. mine, showing approximate size and shape of stopes.

porphyry dike about 50 feet thick, strikes approximately N. 75° E., and is nearly vertical. The wall of the dike is less sharply defined than that of most dikes in the district, and in most places it is difficult to locate the contact precisely.

The Bessie G. vein strikes N. 75° E. and dips steeply toward the north. At its outcrop on the ridge above Columbus Basin it consists of a 2-foot to 3-foot shear zone along which the porphyry and redbeds are altered and pyritized but which contains little or no vein quartz. Near the crest of the ridge the vein intersects a fissure of northwesterly trend, known as the Bessie G. and apparently stops. From the top of the ridge the vein can be traced about 1,000 feet northeasterly to a point in Heffernan Gulch where it crosses the Cleveland-Big Four vein, which trends nearly due east. A short prospect adit near this junction, 2000 feet below the main workings, exposes a strongly sheared zone that contains a 6-inch to 12-inch vein of pyritic quartz. The vein can be traced several thousand feet farther to the northeast but is poorly exposed, and little is known of its character.

In the main workings, the vein follows the south wall of the dike in general but leaves it in a few places. Where the vein is in sedimentary rocks it is only 4 to 6 inches wide, but where it is on the contact or in porphyry it consists of a shear zone 2 to 3 feet in width that contains innumerable veinlets of dark-colored quartz and much disseminated pyrite. The central part of the shear zone is traversed by a quartz vein that ranges from less than 1/8 inch to 6 inches or more in thickness. In some places the vein matter is confined

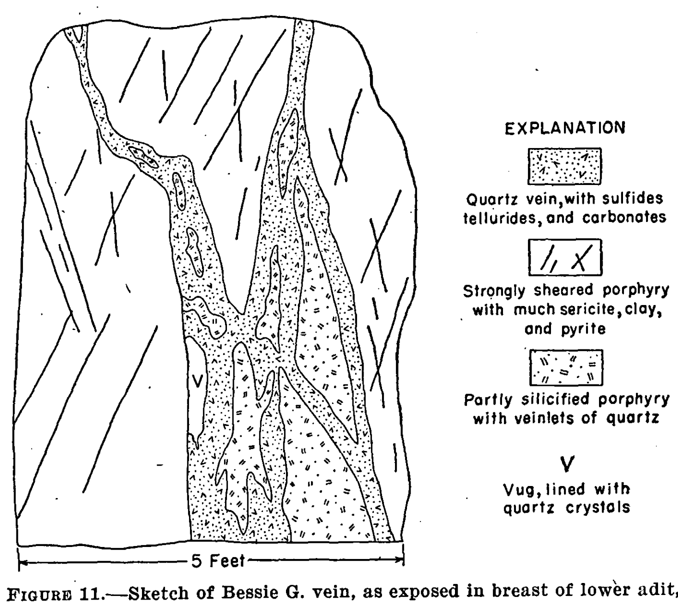

FIGURE 11.—Sketch of Bessie G. vein, as exposed in breast of lower adit, 1937.

to a single narrow vein, elsewhere it is more broadly distributed in a belt of interlacing veins and veinlets (fig. 11). The vein matter consists of sugary white and pale-green quartz in which tetrahedrite, chalcopyrite, arsenopyrite, and pyrite are locally abundant. Tellurides and free gold are visible to the unaided eye in many specimens and a few specimens contain cinnabar. The porphyry within the shear zone is locally silicified, but most of it is altered to soft white sericite and a clay mineral, possibly dickite. Beyond the walls of the shear zone the wall rock is generally unaltered. Figure 11 shows the character of the vein at the breast of the lower adit in 1937. At this place both the vein quartz and the shear zone are wider than at most other places where they were seen.

The structural control of the ore shoots is not known. The best ore seems to have occurred in narrow vertical pipes, but as these pipes have been stoped or lagged over, little could be learned about them. The history of the mine has been one of the discovery and removal of several pockets of rich ore, followed by extension of the workings through essentially barren rock in hope of finding other pockets. Several changes in ownership have taken place on the basis of rich ore left in the face.

As shown by the production figures cited above, the Bessie G. ore is very rich. The ratio of gold to silver, about 2:3 by weight, is far higher than in most other known telluride deposits in the district. Most of the ore shipped up to 1937 had been carefully picked vein quartz. The altered rock in the shear zone is reported to contain from 0.15 to 0.40 of an ounce of gold to the ton. Much of it, however, is not amenable to sorting, and, as transportation costs are high, it cannot be shipped crude. A channel sample taken by the writer in 1937 across the shear zone in the breast of the lower adit (fig. 11), where it was 4½ feet wide, was found to contain 1.56 ounces gold and 5.04 ounces silver to the ton. The vein quartz was not sampled separately.

The two dumps probably contained 4,000 tons or less of ore. They have been worked over several times, and considerable ore recovered from them by screening, washing, and hand sorting has been shipped. They are said to contain about 0.5 ounce of gold to the ton, which appears likely in view of the fact that many pieces of ore containing visible free gold and tellurides can be found by casual search of the dumps.

It seems to be unlikely that the mine is exhausted, and prospecting in any direction along the vein appears to be justified. The conditions are favorable for finding small, high-grade pockets, though not for finding large bodies of ore. Besides prospecting on the vein, it would seem worth while to drive short crosscuts into the walls to search for possible parallel veins.

BILLINGS (2c)

The Billings prospect is on Bear Sign Creek, at an altitude between 10,500 and 11,000 feet. Development consists of at least four northeastward-trending adits, only the lowest of which was open in 1936 (fig. 12). No production has been recorded.

All the workings are in the Junction Creek sandstone (upper La Plata sandstone of former reports) and on the south side of the main Parrott fault. Possibly the fault zone was the objective of most of the work. The regional dip of the beds is southwestward, but in the lower adit they dip west near the portal and southeast near the breast (fig. 12). Four weak fracture zones from 1 foot to 3 feet wide, characterized by pyrite, were cut in the lower adit. Some coarse-grained barite was found on the dump, but none was seen underground. According to some local residents, the sandstone close to the surface contained free gold that could be recovered by panning, but farther underground the rock was essentially barren. Possibly the gold was derived from some nearby undiscovered vein and was washed into crevices of the sandstone by meteoric waters.

BLACK DIAMOND (5)

The Black Diamond mine, which explores the Black Diamond and White Diamond veins, is situated above the Tomahawk mine, in Tomahawk Basin, near the crest of the divide between Basin Creek and Bear Creek. It is owned by August Ekburg, of La Plata, the original locator, who has held a group of nine unpatented claims since the late nineties. The workings are at altitudes

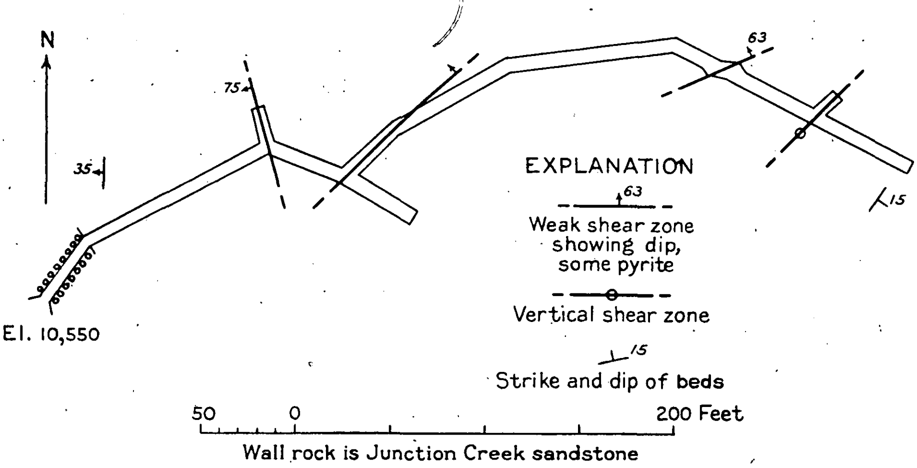

FIGURE 12.—Plan of lower adit, Billings prospect.

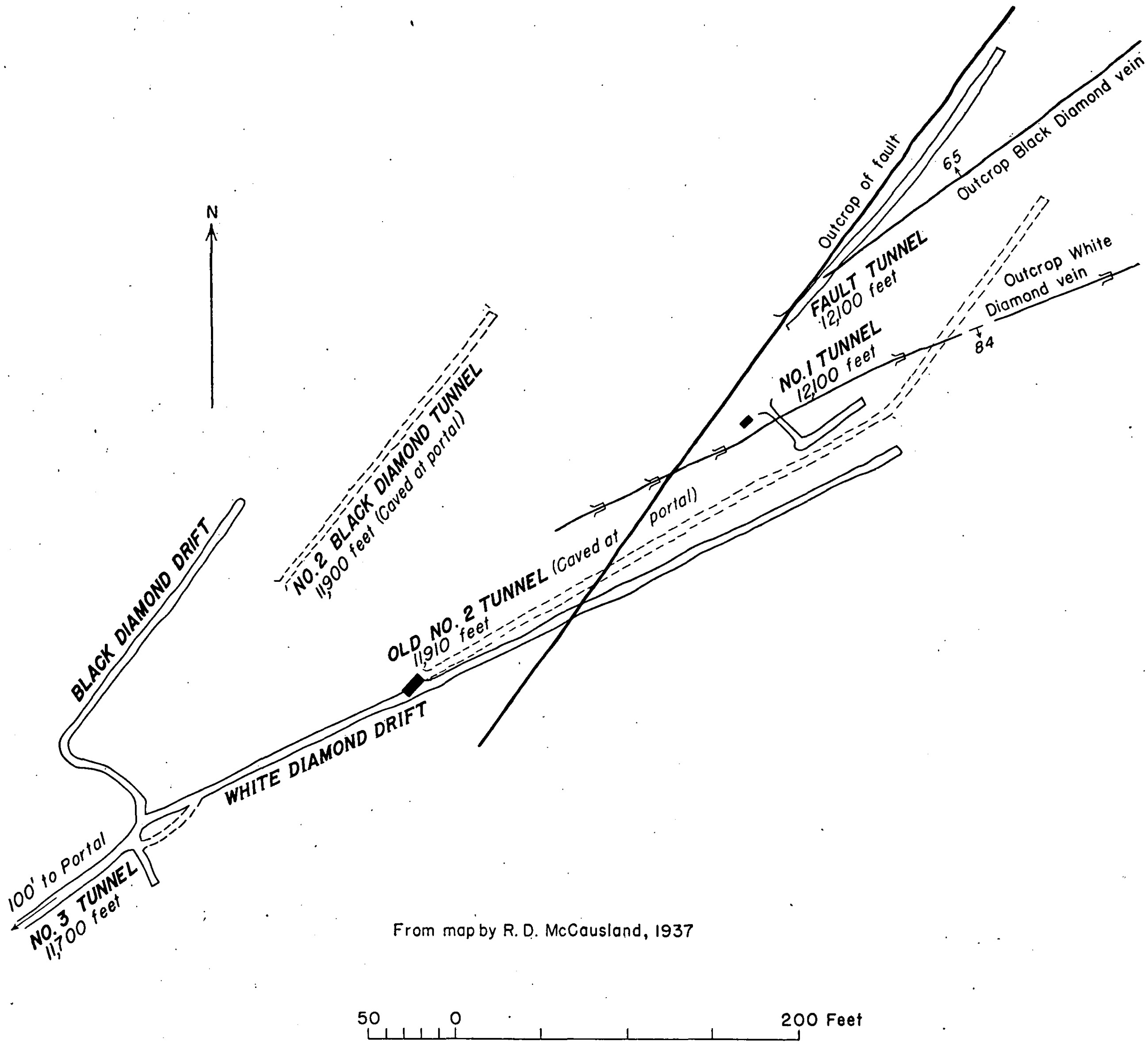

FIGURE 13.—Plan of Black Diamond workings.

of 11,700 to 12,100 feet. They can be reached by a steep switchback trail from the ruins of the Tomahawk Mill, which is connected with the road in La Plata canyon by an abandoned wagon road. Much of the following description is based on an unpublished professional report prepared in 1936 by R. D. McCausland and on other information supplied by Mr. McCausland and Mr. Ekburg.

The total production of the mine is not known, but it is small. Mr. Ekburg states that he shipped 3 narrow-gage cars of ore from the White Diamond vein during the period 1900–1906. All this ore was taken out during development work. Two carloads were paid for at the rate of $67 per ton and the other at $99 per ton, not including treatment charges of $12 to $14 per ton. If the cars each contained 10 tons of ore, the gross value of these shipments was about $3,700. The only production recorded by the Bureau of Mines is as follows:

Incomplete production of Black Diamond mine

Year	Ore (tons)	Gold (fine ounces)	Silver (fine ounces)
1920	1	2. 50	4
1921	1	3. 00	2
1935	. 15	. 90	----------
1938	4	9. 79	27
1939	9	8. 55	----------

The mine workings are shown in figure 13. When the property was examined at various times in the years 1935 to 1937 only the Black Diamond drift on the No. 3 level, the No. 1 tunnel, and part of the Fault tunnel were accessible.

The local geology and the relation of the Black Diamond to other mines in Tomahawk Basin are indicated in figure 47. The mine is several hundred feet away from the northwest border of the Diorite Peak stock.

The country rocks consist of the upper part of the Cutler formation and the lower Dolores beds, which dip toward the northwest at angles of 10° to 20°. The sandy and shaly beds are strongly silicified. The limy beds, particularly the limestone conglomerates of the lower Dolores, are replaced by garnet, magnetite, hematite, and some pyrite. Near the upper workings there is one thick sill of diorite-monzonite porphyry. All the rocks, including the sill, are cut by several later dikes of diorite and of diorite-monzonite porphyry, which form part of the complex network that characterizes the ridge between Diorite Peak and Mount Moss.

The workings are near the intersection of the Black Diamond and White Diamond veins with an unnamed barren fault. The space relations of the two veins and the fault are shown diagrammatically in figure 14.

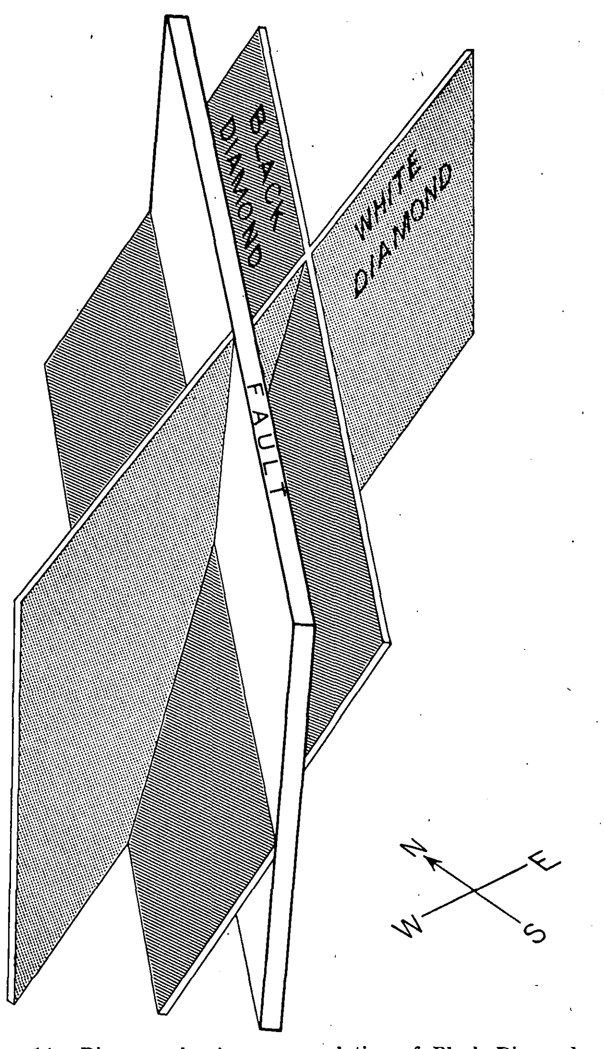

FIGURE 14.—Diagram showing space relation of Black Diamond and White Diamond veins and fault. Relative age of veins is uncertain.

The Black Diamond vein strikes N. 35° to 40° E. and dips 60° to 65° NW. Its outcrop on the steep slopes trends in general northeastward, with pronounced changes in direction at ridges and valleys. The vein zone can be traced northeastward from the mine to a point in the headwaters of Bear Creek three-quarters of a mile north of Diorite Peak. Below the lower mine workings it is covered by slide-rock, but it reappears in Basin Creek and can be traced southwestward across the ridge east of Babcock Peak and into the head of Boren Creek. It is thus almost continuously exposed for a distance of more than 2½ miles. The White Diamond vein strikes N. 65° E. and dips 80° to 85° SE. In the vicinity of the mine its outcrop is parallel with that of the Black Diamond. It has not been recognized below the lower workings, but it can be traced northeastward for several thousand feet into the head of Shoebeck Gulch.

The unnamed fault strikes N. 35° to 40° E., parallel to the Black Diamond vein, and, as it is almost vertical, its surface trend is nearly the same as its strike. As it is exposed in and near the mine workings and from there to the top of the ridge, it can be traced for about 1,000 feet, but it is lost beneath slide-rock both to the north and south. The beds on the west side of the fault are dropped down from 35 to 50 feet, and their contacts are displaced several hundred feet horizontally; there is no horizontal displacement, however, of the veins that cross the fault. As exposed in the fault tunnel and on the surface, the fault is characterized by a gougy zone from 2 to more than 10 feet wide. The relative age of the fault and of the two veins is not known, but as both veins widen in the vicinity of the fault it may be supposed that the fault was in existence before the ores were deposited and acted as a dam for the ore-bearing solutions. The broken condition of the veins and the great amount of gouge near the fault indicate clearly, however, that there was also some postmineral movement along the fault.

The No. 3 tunnel is tightly lagged in most places, and but little of the Black Diamond vein is exposed. According to McCausland, the vein consists of a zone of sheared and altered rock and much gouge and is 5 feet to more than 15 feet in width. In places it contains ore streaks and pockets, some of them rich in gold, consisting of coarsely crystalline pyrite-bearing quartz, considerable barite, and some galena and chalcopyrite. Where exposed on the surface the vein is narrower than in the No. 3 tunnel, being only 6 inches to about 4 feet. It is characterized throughout its extent by sporadic galena and chalcopyrite, which are generally scarce in this part of the district.

In the No. 1 tunnel the White Diamond vein has a core of brecciated and thoroughly silicified country rock, from 18 to 30 inches thick, flanked on both sides by 1 foot to 4 feet of soft, gougy, kaolinized and chloritized wall rock. The breccia core commonly contains streaks and veinlets of olive-green, finely granular quartz, a few specks of chalcopyrite and pyrite, and scattered irregular masses of visible free gold. On the dump of the No. 3 tunnel there are many pieces of ore that came from a vein 2 to 6 inches wide, and according to McCausland they are typical of the White Diamond vein on the No. 3 level. They consist of finely granular quartz, streaked in white, green, and dark gray. Blue chalcedony forms streaks and irregular blebs in the vein matter. Very small grains of pyrite and arsenopyrite are irregularly distributed throughout. Although no gold-bearing minerals were seen in the polished sections examined, some of the ore of this description is rich in gold, as shown by the assay of sample 390. The green color of the quartz and the similarity of the vein structure with that of the Mountain Lily, Small Hope, and other nearby telluride veins, strongly indicate that some of the gold is in tellurides.

As the underground exposures of the veins have not been systematically sampled little information on their average tenor is available. Scattered samples indicate that both veins, particularly the White Diamond, contain some very rich ore and that gold and silver occur in nearly equal proportions by weight. Forty-three samples of the White Diamond vein, taken by R. D. McCausland, contained from 0.10 ounce to 12.0 ounces of gold to the ton, with an average of 1.5 ounces. Most of the samples were taken from surface exposures or from the dumps. McCausland states that the last 200 feet of the No. 3 tunnel exposes a 4- to 6-inch vein averaging 3 ounces of gold to the ton, and that the altered wall rock will assay 0.08 to 0.20 ounce in gold over a width of 2 to 10 feet. Sixteen samples taken by McCausland across the Black Diamond vein where it is exposed in the No. 3 tunnel carried 0.08 ounce to 1.1 ounces of gold to the ton and averaged 0.33 ounce. Assays of three random samples taken by the writer agree closely with McCausland's results.

The mine is difficult to reach, transportation costs of materials and ore are high, and there are few places in Tomahawk Basin where buildings or other structures are safe from snowslides. The production to date has been very small partly because of the owner's limited means, which necessitated hand labor, and partly because of difficulty experienced in holding heavy ground. In spite of these adverse circumstances the mine seems to deserve further exploration. The high-grade streak in the White Diamond vein is at least as wide as that of the Bessie G. and other veins that have yielded noteworthy amounts of gold. There also seems to be a strong possibility that proper development would disclose relatively large quantities of milling ore in both veins.

BONNIE GIRL (2b)

The Bonnie Girl mine, formerly known as the Baker Contact, is above Tirbircio Creek, on the west slope of Baker Peak at an altitude of about 10,800 feet. A narrow road, which was passable for automobiles in 1936–37 connects it with the Gold King mill, 1 mile to the northwest. A large amount of money has been spent on the mine, but the production has been very small. The deposit was discovered in 1895 or earlier. Petre[90] says of it:

> On a tributary of the La Plata River * * * is the Baker Contact, a series of sedimentary beds capping the diorite over which has flowed a porphyritic mass containing possibly $1.25 in free gold to the ton, though, as on the Mancos, some small vertical fissures run as high as $12. Three years ago Smith and Moffat erected a 10-stamp mill to treat this body of low-grade material, then supposed to be worth $6 per ton; but very soon, finding it impossible to pay expenses, closed the works.

An elaborate 50-stamp mill was built at the mouth of Tirbircio Creek about 1904.[91] It used electricity generated from water power and was connected with the mine by an aerial tram. The mill ran for a few years, but the operation was not successful. There is a persistent rumor in the camp that at one time during this period great excitement was created by the production of a large quantity of amalgam in the mill. Much ado was made over this apparent success until the amalgam was sent to the mint, where it was found to consist of copper amalgam rather than gold. The mill stood idle for many years, but it was finally remodeled in part and is now known as the Gold King mill. Several unsuccessful attempts have been made in the past 30 years to reopen the mine. The production prior to 1902 was doubtless small. That since 1902 is shown in the following table:

Recorded production, Bonnie Girl mine, 1902–43 [1]

Year	Ore (dry tons)	Gold (fine ounces)	Silver (fine ounces)
1906	750	25.06	152
1908	30	33.67	15
1919	1	2.30	2

[1] Compiled from mine records of the U. S. Geol. Survey and the Bureau of Mines. Production prior to 1902 unknown; no production for years 1902–43, except as shown.

Most of the ore produced was apparently taken from a small open-cut in the side of the hill above the tram terminal and ore bins. This cut is barely 30 feet in diameter and 12 to 15 feet deep. Several adits with an aggregate length of about 700 feet were driven at various places in the search for ore. Just east of the open-cut, at an altitude of 10,800 feet, there is a 225-foot adit that trends N. 80° E. A short crosscut was opened in each wall 80 feet from the portal. There are no stopes or other openings. A lower adit, shown in figure 15, is situated below and a few feet east of the tram terminal.

The country rock in the vicinity of the mine consists of the upper part of the Cutler formation, which is cut by one thick sill and several narrow dikes of diorite-

[90] Petre, R. W., Mines of the La Plata Mountains, Colo.: Eng. and Min. Jour., vol. 66, pp. 667–668, 1898.

[91] Toll, R. H., La Plata Mountains, Colo.: Min. and Sci. Press, vol. 97, pp. 741–744, 1908.

monzonite porphyry, offshoots from the great porphyry mass that forms Silver Mountain and the upper part of Baker Peak. The sedimentary rocks are strongly metamorphosed, and garnet, specularite, and magnetite are abundant, particularly in beds and nodules that were originally limy. Chalcopyrite and pyrite are widely but not abundantly distributed. The mine is

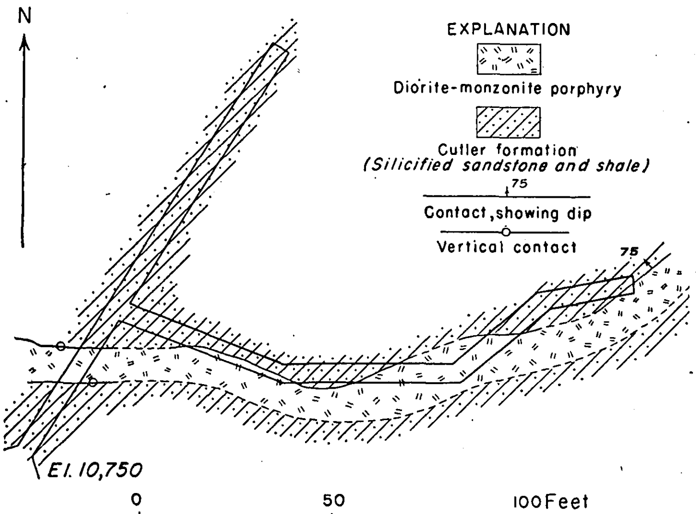

FIGURE 15.—Plan of lower adit, Bonnie Girl mine.

located on a broad, weak shear zone that extends northeastward from Bragdon Ridge into the head of Lightner Creek. No strong veins were seen in any of the mine workings, but there are many zones and lenses of brecciated and altered rocks containing a good deal of pyrite and a little quartz. One strong northeastward-trending vein is exposed on the crest of the Baker Peak ridge, above the mine. The southwestward extension of the same vein was apparently explored by a now inaccessible adit below the mine, at an altitude of 10,500 feet. At the altitude of the principal mine workings, however, this vein is represented only by a zone in which the shearing is somewhat stronger than elsewhere.

All the gold that has been produced is believed to have been free gold in thoroughly oxidized, near-surface ore. In the primary ore the gold is probably in the iron and copper sulfides. A little free gold can be recovered by panning surface samples taken from any place in the vicinity of the mine. Although no native copper was seen, the occurrence of chalcopyrite and the above-mentioned rumor that copper amalgam was found in the mill make it seem possible that there is some native copper in the oxidized material.

The property appears to contain a very large body of rock in which gold is widely distributed. The failure of the early operations and the tenor of the ore noted by Petre [92] suggest that even the oxidized material was too lean to yield a profit, and the primary ore is presumably even lower in grade. The deposit should therefore be examined and tested very thoroughly before any further attempt at large-scale production is made.

BOREN GULCH GROUP (1?, 2b)

The Boren Gulch group consists of a large number of unpatented claims situated at the head of Boren Creek, at altitudes of 11,000 to more than 13,000 feet. At one time the area at the head of the creek was entirely covered by claims, but now only a few claims are held by annual assessment work, and the property has been idle for some years. Most of the area is above timber line, and some of it is virtually inaccesible (pl. 4). It can be approached over trails up Boren Creek or Shaw Gulch, but in 1935–37 the upper parts of both trails, near the mine workings, were inaccessible to horses. There was some activity in this region before 1900, and a little ore may have been produced at that time. The production of the group since 1902 is shown in the following table:

Production of Boren Gulch mine, 1902–43 [1]

Year	Ore mined (dry tons)	Ore sold (dry tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1904	2, 000	3	2. 4	20	10	30	80
1905	------	¼	1. 02	2	------	------	------
1906	------	¼	. 77	2	5	------	16
1920	------	1	3. 40	3	------	------	------

[1] Compiled from mine records of U. S. Geological Survey and the Bureau of Mines. No production 1902–43 except for years listed.

The development work consists of 10 or more adits from 10 to 200 feet in length, said to have an aggregate length of nearly 2,000 feet. Most of them were caved in 1935–37.

The head of Boren Creek is in the southern part of the Spiller Peak monzonite stock, which has intruded and partly replaced the country rocks. The relations are described on page 40 and pictured in plate 4. Like the rocks near the head of Bedrock Creek, the rocks in the western and southwestern part of the basin, except the monzonite, are sheared and brecciated and in places are rather thoroughly sericitized and kaolinized. Pyrite, and to a less extent chalcopyrite, are widely distributed, particularly along certain zones of fractures. From this area of relatively thorough alteration several strong veins, 1 foot to more than 10 feet wide, extend northeastward through the monzonite and the rocks east of it. Some of these veins can be traced for several thousand feet, and one of them is the southwestward extension of the Black Diamond vein. In most places they consist mainly of brecciated and silicified country rock enclosing a minor proportion of vein quartz. Galena, sphalerite, marcasite, and barite are sporadically distributed through them; py-

[92] Petre, R. W., op. cit., pp. 667–668.

rite and chalcopyrite are much more abundant. The gold content of the veins is said to range from 0.05 ounce to 1.10 ounces to the ton. The tenor of the pyritic breccia in the western part of the basin is not known but is probably low.

Not enough data are in hand to indicate the value of the deposits on Boren Creek. They are unquestionably of low grade on the whole, but thorough prospecting might reveal enough gold in the rocks to justify large-scale, low-cost mining and milling operations. None of the ore has been tested for platinum, although its general similarity to the ore on Bedrock Creek and its content of chalcopyrite indicate that small quantities of platinum may be present.

BROWN BEAR (3)

By E. N. Goddard

The Brown Bear property is on the southwest side of Bear Creek, 2¼ miles southeast of Robinson's Ranch, at an altitude of about 8,700 feet. It is a mere prospect, from which no ore has been shipped. The workings consist of a tunnel 55 feet long (fig. 16).

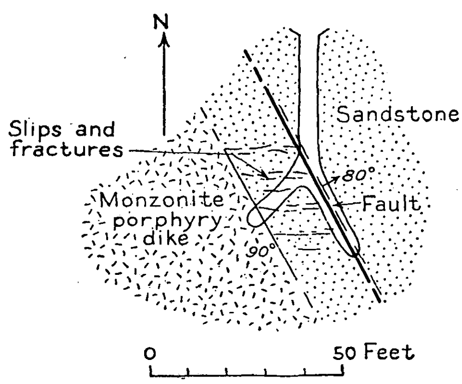

FIGURE 16.—Plan of the Brown Bear tunnel.

The tunnel is in the Dolores formation about 300 or 350 feet below the base of the Entrada sandstone. The Dolores here consists of red limy sandstone and shaly shale, both of which contain a little carbonaceous plant material. The tunnel is on the east side of the same monzonite porphyry dike that is exposed at the Missouri Girl; the dike here strikes N. 33° W., is vertical, and is about 50 feet wide. The sandstones are gray for as much as 30 feet on each side of the dike.

The northeast border of the dike is much fractured, and about 18 feet from it is a nearly parallel fault fissure, 1 inch to 12 inches wide, that strikes N. 30° W. and dips 80° E. Between these two principal fractures are numerous slips and fractures that strike approximately N. 80° E. and dip 80° N.

Chalcocite occurs rather sparingly in plant material in the fault and in fractures in the sandstone and the dike rock. Pyrite is finely disseminated throughout the shattered and bleached zone. Thin coatings of malachite and limonite occur along many of the fractures, and many fractures both in the sandstone and in the dike are filled with calcite.

Apparently no ore has been shipped from the Brown Bear claim, and no minable ore was in sight in 1932.

CAMP BIRD (2b?)

The Camp Bird prospect, on the patented Camp Bird claim, is at the junction of the La Plata canyon road with the old road to Tomahawk Basin, at an altitude of 9,900 feet. Aside from its somewhat unusual mineral composition, it is of interest chiefly as an example of the dependence of ore pockets on cross fractures. No production has been recorded. A considerable quantity of sulfide ore, which had doubtless been found too low grade to pay for shipment, was on the dump in 1935–37. The principal mine opening, shown in figure 17, is a northwestward-trending adit 110 feet long. A 15-foot adit was driven below the main adit near the La Plata River, and several small open-cuts have been dug along the outcrop of the vein. The vein trends northwest. It has not been found on the east side of the La Plata River, and has been traced only a few hundred feet northwest of the river. The relations shown in plate 2 indicate that the vein should intersect the westward extension of the Mountain Lily vein about half a mile from the portal of the main adit.

The prospect is situated near the southeastern extremity of the Diorite Peak stock of diorite. The wall rock in the main adit is dense, hard biotite diorite; that in the short lower adit is silicified shale of the Hermosa formation. For distances of 2 to 24 inches on each side of the vein the diorite is soft and contains much chlorite and sericite. In the main adit, the vein fills a shear zone in the diorite. The zone trends N. 50° W. and dips 80° to 85° NE., and is 1 inch to 5 feet wide. Most of the vein matter consists of quartz and pyrite that forms veinlets in the sheared and altered diorite. Blebs of chalcopyrite, most of them associated with pyrite, are fairly abundant, and a few crystals of chalcopyrite occur in vugs. In addition to quartz, the gangue minerals comprise both massive and scalenohedral calcite, mixed carbonate, some of which is brown and some pink, and delicate rosettes of barite in vugs. Tremolite forms clear to white rodlike crystals intergrown with pyrite.

As shown in figure 17, the vein is widest 35 to 50 feet from the adit portal near its intersection with a strong fracture zone. The fractures, which are most numerous on the northeast or hanging-wall side of the vein, trend and dip in all directions; the most important ones, however, are nearly vertical and fall into three groups that trend north, northeast, and east. At this place the Camp Bird vein widens, becoming 2 to 5 feet in width, and it contains much pyrite and chalcopyrite. Past the fracture zone it narrows again until near the breast of the adit, where it intersects a network of cross fractures. Here the vein becomes 6 to 18 inches wide but contains less vein matter than in the wide place

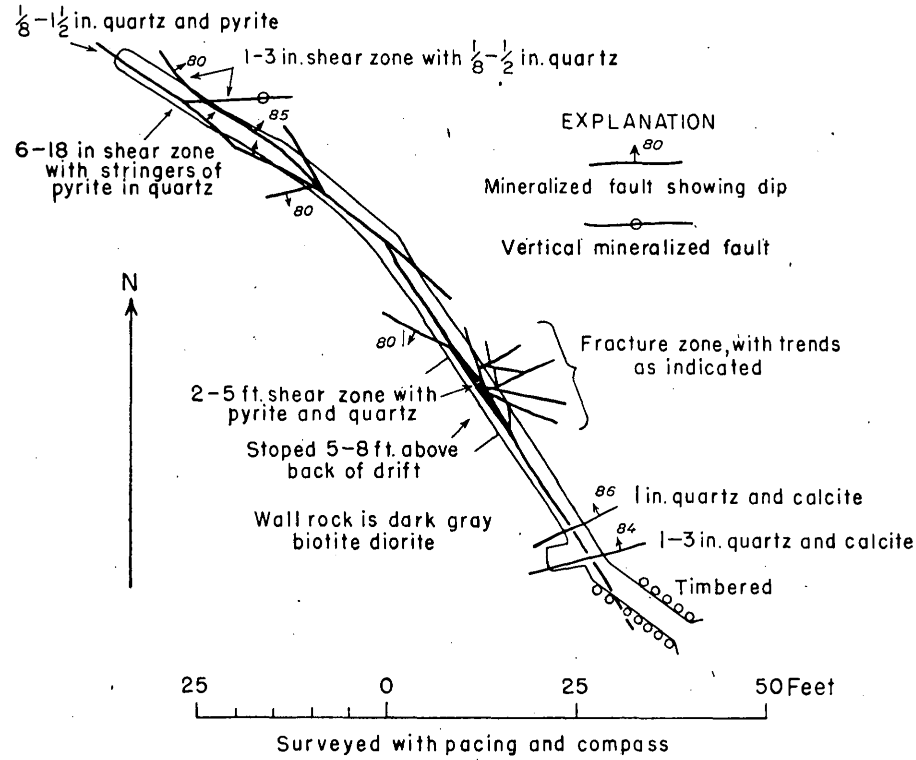

FIGURE 17.—Plan of main adit, Camp Bird prospect.

nearer the portal. In the short lower adit the vein strikes N. 55° W. and dips 73° NE. There it consists of 1 to 4 inches of pyrite-bearing quartz in a very weak shear zone.

CENTURY (2b)

The Century mine is on the west side of Bear Creek, half a mile east of Banded Mountain, at an altitude of 11,750 feet. It can be reached from the La Plata valley over the Fall Gulch trail, most of which was in poor condition in 1937. The mine was discovered before 1882 and yielded one lot of high-grade ore when first opened, but it has produced no ore since. Burchard[93] listed it as the leading mine of the district in 1882, but he had not then received any information as to its condition or production. In his report for 1883 he states that the development consisted of three drift adits, 78, 86, and 78 feet long, respectively, and a 45-foot shaft, which intersected the first level. The mine had produced 46.2 tons of ore, which when shipped to Denver had yielded $12,928.61, or an average of $279.84 a ton. Nearly all the value was in gold. Seventy-five tons of ore remained on the dump, and there is no record of its ever having been shipped. Some development work was done in later years, but the results apparently were discouraging; at the time of Purington's visit in 1896 the mine had already been abandoned, and no work has been done since.

The mine workings are shown in figure 18. The upper tunnel was caved in 1937, but the size of the dump indicates that it was from 50 to 75 feet long. The stope indicated on the map may have been worked in part as an open-cut from the surface, though probably at least part of it was overhand work from the upper adit. No vestige was seen of the third adit noted by Burchard in 1883.

The rocks are well-exposed near the head of Bear Creek and in the vicinity of the Century mine. They include beds of the Dolores, generally unmetamorphosed, and of the Entrada, Wanakah, Junction Creek, Dakota (?) and Mancos, which in contrast to the Dolores, are much metamorphosed, the sandstones being altered to quartzite and the shaly beds silicified or altered to hornfels.

All the workings are in the Junction Creek sandstone (upper La Plata sandstone of former reports). The base of the overlying shale member of the Morrison, here a dense hornfels, is about 50 feet above the upper adit. The Century vein strikes N. 70° to 80° E. and dips 85° S. It is strongest in the Junction Creek sandstone, but its eastward extension can be traced downward through the Entrada sandstone. Toward the west it stops abruptly at the contact between the sandstone and shale members, and not even a trace of shearing can be found in the shale. In the lower adit the vein consists of a 2-foot to 5-foot zone of strongly brecciated quartzite. The breccia fragments are cemented with sugary to crystalline white quartz, which also occurs abundantly as films and veinlets throughout the breccia zone. Pyrite is widely but rather sparingly distributed.

[93] Burchard, H. C., Report of the Director of the Mint upon the production of precious metals in the United States, 1882, p. 506, 1883.

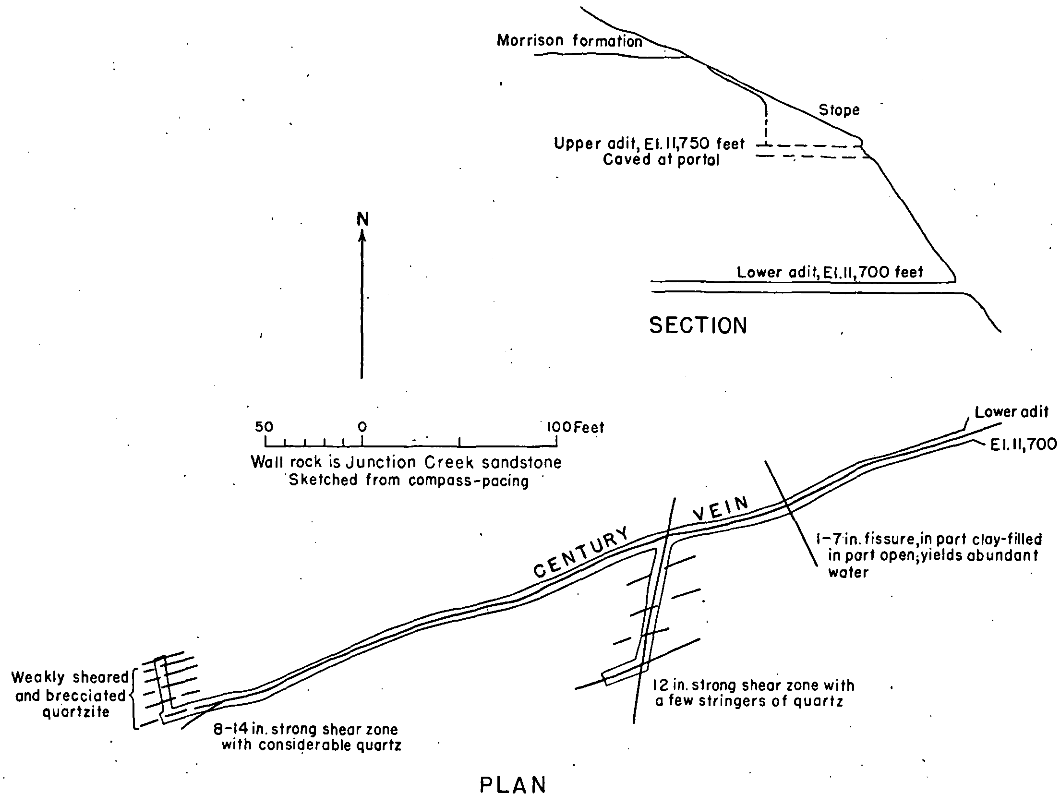

FIGURE 18.—Plan and section of Century mine.

The vein walls are sharply defined and are vertically slickensided. In the open-cut above the upper adit the vein is 18 to 30 inches wide. A similar but somewhat narrower parallel breccia zone is exposed in the breast of the south side drift. The wall rocks are slightly sheared over a width of at least 80 feet. Near the portal two northward-trending vertical fissures are exposed. The one nearest the portal, which is from 1 inch to 7 inches wide, is partly filled with light-colored clay, but most of it is open and yields abundant water. The second fissure, which is about 1 foot wide, consists, like the Century vein, of brecciated quartzite laced with veinlets of quartz.

Part of the ore piled on the dump consists of brecciated quartzite containing seams of limonite and a few seams and irregular masses of pyrite. Most of it, however, is sugary honeycomb quartz with much limonite. A few clear crystals of quartz, up to a quarter of an inch in length, and minute tabular crystals of barite are widely distributed in openings in the breccia. The limonite contains a little remnant pyrite, which proves its derivation from pyrite that was originally intergrown with the quartz. Finely divided free gold can be panned from the ore on the dump. According to old reports, the ore shipped from the Century was free-milling gold ore and contained some pyrite even near the surface. The lack of stoping in the lower adit, together with the assay results given below, indicate that the vein does not contain workable ore at that level. Although the ore in part may have been formed by surface enrichment, the greater bulk of the quartz and limonite in the upper workings as compared with that of the vein quartz in the lower ones indicates that the ore shoot was a primary feature of the vein. It was perhaps localized by the overlying shaly beds, which may have dammed the rising ore solutions. Three samples collected from the Century workings were assayed in the laboratory of the Geological Survey with the following results:

Samples from Century mine

(E. T. Erickson, assayer]

Sample No.	Location	Gold (fine ounces to the ton)	Silver (fine ounces to the ton)
421	From dump of lower adit	0. 02	0. 01
423	From twenty-five-ton pile of ore on upper dump	. 74	. 40
424	From small pile of ore on platform near upper dump	. 24	. 72

Sample 421 is believed to be representative of the surface part of the whole dump, nearly all of which came from the Century vein itself. There is some possibility that the fine material on the dump is not adequately represented and that thorough sampling would show a somewhat higher gold content for the dump as a whole. Many tons of material similar in appearance to sample 423, and possibly containing as much gold, could be sorted from the upper dump.

DEPOSITS NEAR THE CENTURY MINE

Several veins and breccia zones that occur in the vicinity of the Century vein are similar to it in most respects. Some of these deposits have been explored by means of open-cuts or short adits, but there is no record of their ever having produced ore. Like the Century vein they are strongest and widest in the Entrada sandstone and in the Junction Creek sandstone. A few veins and shear zones that are strong in a thick sandstone bed higher in the Morrison section are without exception weak or nonexistent in the shaly beds. The deposits consist of brecciated quartzite containing pyrite and a little barite and cemented with a varying proportion of vein quartz. Near the surface most of the pyrite is altered to limonite. All the thick sandstone beds are well-exposed, and consequently there is little likelihood that any very rich deposits have been overlooked. A few representative samples, assayed in the laboratory of the Geological Survey, indicate that gold and silver are widespread but generally in too small quantity to constitute workable ore. In order to provide a basis for definite statements, however, far more extensive exploration and sampling of the deposits, particularly of the parts below the oxidized zone, is necessary.

Samples from veins near Century mine

[E. T. Erickson, assayer]

Sample No.	Location	Gold (fine ounces to the ton)	Silver (fine ounces to the ton)
425	N. 80° W. vein, 12 feet wide, 2,500 feet S. 84° E. of Mount Moss, altitude 12,400 feet	0.01	0.07
426	N. 70° E. vein, 1,800 feet S. 25° W. of Century mine, altitude 12,300 feet. Sample represents middle 10 feet in a 20-foot zone	.05	.23
462	N. 73° W. vein, 2,000 feet north of Century mine; 2–4 feet quartz in 10–12 foot, breccia zone; from 50-foot adit at altitude 11,600 feet	.03	.99
463	N. 28° E. vein, 500 feet S. 45° E. of Century mine; 15-foot vein in very broad shear zone	.01	.11
464	N. 50° E. vein, 20 feet wide, 900 feet S. 23° W. of Century mine, altitude 11,800 feet	.08	1.74
465	Quartz only, from same vein as 464	.25	4.19
466	N. 57° E. vein, 20 feet wide, 350 feet S. 23° W. of Century mine, altitude 11,750 feet	.03	.05
467	N. 58° E. vein, 10–15 feet coarse quartz, 1,600 feet S. 15° W. of Century mine, altitude 12,000 feet	.02	.06
468	N. 50° E. vein, 10 feet wide, 2,000 feet S. 5° W. of Century mine	.01	Tr.

CHARLENE

The Charlene prospect, held by Charles Hepworth on an unpatented claim of the same name, is on the north side of Twin Canyon Basin, at an altitude of 9,600 feet and 1 mile southwest of the Red Arrow mine. It is reached most easily over a trail that branches from the La Plata-Montezuma County line trail. Although it has produced no ore, the prospect is noteworthy because it illustrates an unusual mode of occurrence of gold.

When the property was visited in the fall of 1936 the development consisted of a 40-foot adit, the course of which averaged N. 15° E., but it was so irregular that it swung back and forth across a zone 15 to 20 feet wide.

The prospect is 70 feet below the top of the Junction Creek sandstone (upper La Plata sandstone of former reports), which locally strikes N. 75° W. and dips 18° S. No real vein is exposed. Several minor slips marked by a little gouge are exposed in the breast of the adit; they trend N. 50° to 70° W. and dip 40° to 45° S. No other fissures or faults were found in the vicinity of the prospects, where exposures are poor, but one or more unrecognized parallel fissures may well occur near the Charlene, because the westward extension of the Parrott fault should pass within a few hundred feet of the claim. The sandstone in which the adit is driven is soft and friable, as the Junction Creek sandstone generally is where it is unmetamorphosed. The rock is not visibly mineralized, but all of it yields considerable free gold when panned. The west wall of the adit is said to be somewhat richer than the right wall, and, according to the owner, representative samples contain about 0.30 ounce of gold to the ton. If this much gold is found in rock at some distance from any known vein, thorough prospecting of the sandstone exposures along both sides of the East Mancos River is advisable.

COLUMBUS (5)

One of the better known mines of the district is the Columbus, near the head of Columbus Basin, which was formerly known as Silver Lake Basin. The shaft through which the deposit was originally worked is at an altitude of about 11,850 feet; the Lucky Boy tunnel is 350 feet lower. Although the road to the mine workings was not accessible to automobiles in 1935–37, it could have been made so with a small amount of work. The Columbus or Maverick vein traverses parts of the patented Maverick, Columbus, Gold Cup, Lorrillard No. 1, Legal Tender, and Crete claims. The mine was being actively developed at the time of Purington's visit [94] in 1896, but as the vein is well-exposed it was doubtless known long before that date. There is no record of its having been worked between 1900 to 1911. In 1912 and 1913 the Lucky Boy crosscut tunnel was driven, and two small lots of ore were shipped. Development and exploratory work continued until 1917, but since then no work has been done. The production prior to 1901, though unknown, was probably small. According to the Annual Report of the Colorado State Bureau of Mines, the Columbus produced 50 tons of ore in 1901, which yielded 91.10 ounces of gold and 168 ounces of silver. The production since 1902 is shown in the following table:

[94] Purington, C. W., La Plata quadrangle field notes, 1896. Unpublished.

Recorded production Columbus mine, 1902–43 [1]

	Ore (dry tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1912	14	20.45	32		
1913	6	4.91	33	26	70

[1] Compiled from mine records of U. S. Geological Survey and the Bureau of Mines. No production except for years listed.

As shown in plate 16, the mine was worked through a 350-foot shaft, from which drifts 50 to 650 feet long were opened at five levels. Some ore probably was taken from one small stope near the surface and several open-cuts along the outcrop of the vein. They are not shown in plate 16. The Lucky Boy crosscut, 1,070 feet long, connects with the shaft. It was driven to provide drainage and safety from snowslides. The aggregate length of the workings, two-thirds of which are on the vein, is nearly 3,000 feet. When visited in 1935–37 the shaft was caved and all the upper workings were full of water, which was held up by a bulkhead near the bottom of the shaft. The crosscut tunnel was open and in good condition.

All the workings of the Columbus mine proper are in a tongue of hornblende diorite extending northwestward from the Lewis Mountain stock. Northeast and southwest of the mine the vein cuts thoroughly silicified beds of the Cutler formation and several associated sills. On the southwest side of the basin the beds are nearly horizontal, but to the northeast, where they form part of the hinge fold that characterizes the La Plata Mountains, they dip steeply to the northeast.

The vein can be traced from the northeast side of the Columbus Basin into Ashland Gulch, a distance of 4,500 feet. Its strike varies from N. 50° to 62° E., and its dip from 59° to 70° N. Owing to the dip and topography, its surface outcrop is irregular and has a general course of N. 60° to 70° E. The vein follows a fault, which is possibly of the hinge type. On the divide between Columbus Basin and Ashland Gulch the rocks on the north wall of the vein have been faulted down a vertical distance of 70 feet. On the northeast side of the basin the beds that appear to be on the south wall of the vein are thrown down about 50 feet. Scissors faulting thus appears to have occurred along the vein, but it is possible that this interpretation is incorrect, and that sufficiently good exposures would serve to show that the Columbus vein actually comprises parts of two faults downthrown in opposite directions and intersecting at a small angle. This interpretation is shown graphically in figure 19.

On the Maverick claim, on the northeast slope of the basin, the vein zone is less than 5 feet wide; elsewhere it consists of a 30-foot to 60-foot zone of sheared, pyritized, and partly sericitized wall rock. The last drift on the crosscut level provides a good exposure of the vein zone, which here trends N. 60° E. and dips 55° to

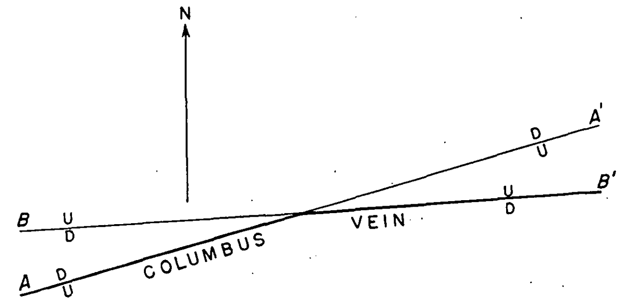

FIGURE 19.—Hypothetical interpretation of fault relations along the Columbus vein. The vein comprises parts of two intersecting faults, AA' and BB', which are downthrown in opposite directions. Another possible interpretation is that the vein follows a scissors fault.

66° N. The zone extends past the breast of the crosscut and is therefore at least 55 feet wide. It consists of soft, sericitized diorite, which contains much disseminated pyrite and a few thin irregular veinlets of dark-gray quartz. Purington, who saw the upper workings, describes the vein thus:

> The vein of the Columbus, called the Maverick vein, is the largest I have seen in this district. With its belt of impregnated porphyry [diorite—E. B. E.] it is some 30 feet in width in the tunnel, but of solid vein matter there is, on an average, 10 feet. . . . Where the vein is exposed on the face of the sandstone cliff between the shaft house and the ridge of Lewis Mountain there are on each side of it countless little quartz stringers which penetrate the sandstone in every direction. The vein stuff consists of dark quartz . . . and contains pyrite which is not thought to carry gold, but no tests of the auriferous character of the pyrite have been made. The gold is thought to occur mostly in the telluride form, and a paystreak is exposed in the bottom of the shaft 2 to 3 feet wide. Free gold is found in association with the telluride. The gangue minerals are calcite, quartz, and chlorite. Sometimes a small amount of silver occurs, but the largest content is in gold. The ore is said to run from $25 to $40 to the ton, and nothing under this will pay if the ore is shipped; if concentrated in a mill $15 ore will pay. No attempt at working the ore by a stamp mill has ever been made.

Ore on the dump near the shaft consists in large part of light- to dark-gray fine-grained quartz containing pyrite. Much of the quartz replaced the brecciated diorite and porphyry, and in it ghostly outlines of original phenocrysts and breccia fragments are widespread. Much pyrite occurs as tiny veinlets, crusts, and vug fillings. Most of it is fine-grained and has the megascopic appearance of marcasite. Porcelainlike crystals of barite are conspicuous in material on the dump, and minute clear tablets of it are implanted on small quartz crystals in a few vugs. No ore minerals were seen in the specimens examined.

The average tenor of the ore is not known. Petre's description [95] is in accord with that given by Purington and cited above. The west-pitching shoot of low-grade ore shown on Burdick's map (pl. 16) includes that part of the vein in which his samples indicate a tenor better than 0.15 ounce of gold to the ton.

[95] Petre, R. W., Mines of the La Plata Mountains, Colo.: Eng. and Min. Jour., vol. 66, pp. 667–668, 1898.

The O'Rourke tunnel, formerly known as the Grand Duke, on the south slope of Lewis Mountain, explored the southwestern extension of the Columbus vein. It was not accessible in 1935–37 and has produced little or no ore. Where the vein crosses the divide above the tunnel it strikes N. 62° E. and dips 59° NW. It consists of a 40-foot pyritized shear zone. The vein itself, which traverses the central part of the zone, is 12 to 24 inches wide. It consists of wall rock, mostly porphyry, that has been almost completely replaced by quartz. It contains considerable fine-grained pyrite, which is itself veined and partly replaced by quartz and a little barite. Two other short tunnels near the O'Rourke explore northeastward-trending shear zones which cross the Columbus vein and which contain quartz, pyrite, barite, and a little chalcopyrite and calcite.

COMSTOCK (2c)

The Comstock was the discovery mine of the district and has been intermittently productive ever since its discovery. It is situated near the west bank of the La Plata River, at the mouth of Root Creek. It has been owned by R. H. Toll of Pasadena, Calif., since about 1904. Some details of the mine's early history are in doubt. The first specific mention in the literature is by Fossett,[96] who says that some of the ore had yielded gold at the rate of $43,000 to the ton. According to Toll,[97] the discovery was made by A. K. Fleming, in the fall of 1873. During the following winter Fleming showed specimens of the ore, in Del Norte, Colo., to Captain John Moss, an old California miner in the employ of John and Tirbircio Parrott, San Francisco bankers. Moss returned with Fleming in the spring of 1874, and the two men located the North and South Comstock claims. Moss soon acquired Fleming's claim for $5,000 and turned the property over to his employers. Other writers [98] state that Moss was already operating a placer mine on the La Plata River in 1873, and it seems possible that the Comstock deposit may not have been discovered until 1874.

The vein was worked through a shaft, which was sunk on the common end line of the two claims, and by 1881 three drifts with a total length 150 feet had been opened on the vein.[99] A pocket of rich ore near the shaft was gouged out in a short time, and the mine was inactive from about 1885 until the late nineties, when control of the property was acquired by George Bauer of Mancos, who began development work. On his death in 1904 development ceased, and the mine has since been operated intermittently by various lessees.

The production of the mine is not known. Burchard [1] states that the total production to the end of 1883 was $10,000. Toll [2] says that the early production amounted to $60,000 to $70,000. Since 1904 the Comstock has produced about $4,500.

Production of Comstock mine, 1902–43 [1]

Year	Ore (dry tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1904	10	30	500		
1910	3	26.32	63	31	
1911	7	25.68	202	217	337
1912	4	15.37	79	157	76
1914	12	6.66	199	267	330
1918	7	8.90	147	252	
1930	11	31.20	243		
1931	9	19.90	157		190

[1] From mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The mine workings are shown in plate 17. The 40-foot level, the drift on the adit level, and part of the stope above the 92-foot level were open in 1937.

As shown in plate 2, the mine lies between two branches of the Parrott fault. The country rocks consist of relatively unmetamorphosed redbeds of the Cutler formation, which dip toward the south at low angles and are intruded by several irregular bodies of diorite-monzonite porphyry, most of which are dikelike bodies that trend east, parallel to the Parrott fault.

Most of the 40-foot level is driven in porphyry, but shale appears near the east end of the drift. The porphyry contact is vertical on the north wall of the vein but sill-like on the south wall. In this particular place the porphyry must have the general form of a sill, for there is no porphyry in the top of the stope above the 92-foot level. Surface exposures near the shaft are adequate to show that the porphyry does not extend very far to the north or south, and it therefore must be classed as an irregular dike that sills out in places. On the adit level two irregular, westward-trending porphyry dikes are exposed. Except for a thick bed of coarse arkosic sandstone exposed in the eastern part of the lower drift, all the sedimentary rocks in the mine are shale.

The Comstock vein follows a fault that trends slightly east of north and dips steeply east. The displacement of igneous and sedimentary contacts (pl. 17) shows that the east, or hanging wall, moved downward and to the north at an angle of about 35°. The vertical displacement is only about 5 feet. The walls are sharply defined and are slickensided in places. The vein cannot be traced northward past Root Creek because there are no exposures, but it probably continues north as far

[96] Fossett, F., Colorado: A historical, descriptive, and statistical work on the Rocky Mountain gold and silver mining region, pp. 428–429, Denver, 1876.

[97] Toll, R. H., La Plata Mountains, Colo.: Min. and Sci. Press, vol. 97, pp. 741–744, 1908; Comstock mine, Mancos [Colo.] Times Tribune, Oct. 1, 1937. Also personal communication.

[98] Lee, H. A., Annual report of the Colorado State Bureau of Mines for 1897, p. 71, 1898. Jackson, W. H., The pioneer photographer, pp. 228, 243, New York, 1929.

[99] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1881, p. 418, 1882.

[1] Burchard, H. C., op. cit. (for 1883), p. 375, 1884.

[2] Toll, R. H., op. cit. (Min. and Sci. Press), p. 741.

as the main branch of the Parrott fault. It has not been identified north of the fault. South of the mine it has been exposed in several places by means of shallow test pits and shafts and has been traced for a distance of 800 feet or more. Several minor splits of the vein appear in the underground workings, but they have not been thoroughly explored.

In the upper workings the vein consisted of a 1-foot to 8-foot zone of brecciated and silicified rock. The pay streak, which lay near the footwall of the breccia zone, ranged from 1 inch to 18 inches thick, and averaged 10 inches. At the north end of the drift on the adit level the vein is 3½ feet wide and consists of brecciated and pyritized arkose, much stained by copper salts. The southeastward-trending split at the north end of the drift contains more quartz and sulfides than the main vein. Wherever on this level one or both walls are of shale, the vein narrows to a mere crack, marked by a film of gouge, but near the porphyry dike at the south end of the drift it widens to a 2-foot breccia zone. The rock is most strongly brecciated near the footwall, along which there is a 1-inch vein of sulfides. The influence of the wall rocks on the size and character of the vein is obvious from the map. Slight changes in dip or strike of the vein probably also influenced its width.

The ore from the upper workings is composed of veinlets of quartz and irregular masses of silver-bearing galena, dark sphalerite, pyrite, chalcopyrite, free gold, and the telluride minerals. Tetrahedrite, covellite, and limonite were found in specimens of ore from the old dumps, and the writer was shown a specimen of dense white quartz from there that contained much pyrite and sphalerite and was crowded with seams and irregular masses of free gold. As noted in the section on mineralogy, cosalite, or a related mineral, and native amalgam have also been reported from the old workings. Near the south breast of the drift on the adit level, interstices in the silicified breccia are filled with quartz and a little brown ankerite. Pyrite, black sphalerite, and galena are the principal ore minerals, but some tetrahedrite and chalcopyrite are also present.

More ore might possibly be found in the Comstock either at lower levels or along any of the unexplored splits off the main vein. Analogy with the May Day and Idaho mines, where north-south veins contain ore at their intersection with east-west barren faults, suggests that the intersection of the Comstock vein with the main branch of the Parrott fault would be worthy of exploration. This intersection is only about 250 feet north of the present workings, and a northward extension of the lower drift might prove interesting. There is no way of telling in advance whether the wall rock near the fault would be sandstone or porphyry, and hence favorable to ore, or shale, which would be unfavorable.

SOUTHERLY EXTENSION OF COMSTOCK VEIN

A few shallow shafts and cuts have been opened on the southerly extension of the Comstock vein, which can be traced past the center of the South Comstock claim, but no extensive development work has been done. The discovery cut on the South Comstock is 750 feet S. 14° W. of the main shaft and is near the center of an east-west porphyry dike about 125 feet wide. The discovery cut and others both north and south of it provide almost continuous exposures of the vein for a distance of about 75 feet. The vein is there 12 to 18 inches wide and in addition to quartz it contains much greenish-yellow sphalerite and some galena and pyrite. A narrow streak of white quartz enclosing considerable tetrahedrite lies along the east wall of the zinc-lead ore. According to Mr. Toll, a large sample of the zinc-lead ore that was sent to Salt Lake City in 1937 for a mill test yielded a lead concentrate that contained very appreciable amounts of gold, silver, lead, and copper.

Seventy-five feet south of the discovery cut and a few feet south of the porphyry dike the vein is cut by a fault, which trends nearly due east and whose south wall has moved west about 3 feet. This fault is probably a weak branch of the Parrott fault system. The claim map (pl. 14) indicates that the Washington vein, which trends N. 55° E., intersects the Comstock vein 750 feet south of the discovery cut on the South Comstock claim. There are few exposures in this area, and the writer did not find the Washington vein.

VEIN NORTH OF COMSTOCK MINE

So far as the writer was able to determine the Comstock vein has never been recognized north of the main Parrott fault. It may have been displaced by the fault, or it may never have extended beyond the fault. Twelve hundred feet north of the Comstock shaft an entirely different vein, erroneously regarded by local miners as the Comstock, has been explored in an open cut 100 feet long, two adits 35 and 50 feet long, and a shaft of unknown depth within a few feet of the country road. The vein strikes N. 31° W. and is nearly vertical. The wall rocks are largely porphyry, which is silicified near the vein. In places there is a little silicified mudstone. The vein is a 5-foot shear zone, which contains discontinuous lenses of ore as much as 5 inches thick. The ore is made up of quartz, barite, pyrite, galena and light-brown sphalerite. Its tenor is not known, and no production has been recorded.

COPPER AGE

The patented Copper Age claim trends N. 45° E. and extends across Bedrock Creek just southeast of the Allard tunnel (pl. 14).

According to the Mint Report for 1883,[3] 150 feet of development work had then been done on an 8-foot

[3] Burchard, H. C., op. cit. (for 1883), p. 375, 1884.

vein of red copper oxide and native copper, which carried considerable gold. The vein must have consisted largely of copper minerals, for its copper content was said to average 25 percent. The production of the mine is not known.

COPPER HILL (1)[4]

LOCATION AND HISTORY

The Copper Hill mine, which explores the only known platinum-bearing deposit in the district, is situated on the ridge between Boren and Bedrock Creeks, at an altitude of about 10,250 feet. Several good horseback trails and an abandoned wagon road connect the workings with the town of La Plata, half a mile distant. There are no patented claims on the hill, but some of the ground is covered by unpatented claims, the names of which are not known.

Little is known of the history of the mine. As early as 1902, two claims the Gold Eagle and the Deleware, had been located in the vicinity of the present mine, but no production has been recorded. The Copper Hill mine was worked by the Copper Hill Mining Co. from 1911 to 1917, and considerable copper ore was produced. Thereafter, it apparently remained idle until some time between 1927 and 1932, when the La Plata Mines Co., operators of the Gold King mine, took up a large group of claims on Copper Hill. This company erected a steam power plant at the mouth of Bedrock Creek, designed to supply part of the power for both the Copper Hill and the Gold King workings. Part of the machinery has since been removed, but some of it was still in good repair in 1937. This company did some development work on Copper Hill but produced no ore.

[4] Eckel, E. B., Copper ores of the La Plata district, Colorado, and their platinum content: Colorado Sci. Soc. Proc., vol. 13, No. 12, pp. 657–664, 1938.

DEVELOPMENT AND PRODUCTION

The chief mine workings consist of a small glory hole and a 600-foot tunnel. The location of the glory hole is shown in plates 1 and 2. It is a rudely oval open pit, roughly 50 by 75 feet in greatest dimensions and 30 to 50 feet deep (fig. 20). The flat floor of the pit is about 150 feet below the crest of the ridge. Several short tunnels at different altitudes have been driven into the walls of the pit. Ore was removed from the pit through a tunnel about 72 feet long at the level of the pit floor.

Between 500 and 700 feet southeast of the open pit and 250 feet lower, there is a tunnel that was evidently intended to serve as a low-level haulage way for ore from the glory hole (fig. 20). About 700 feet east of the glory hole there are several caved tunnels, possibly on the old Deleware claim. In addition to the workings described above there are several short adits, most

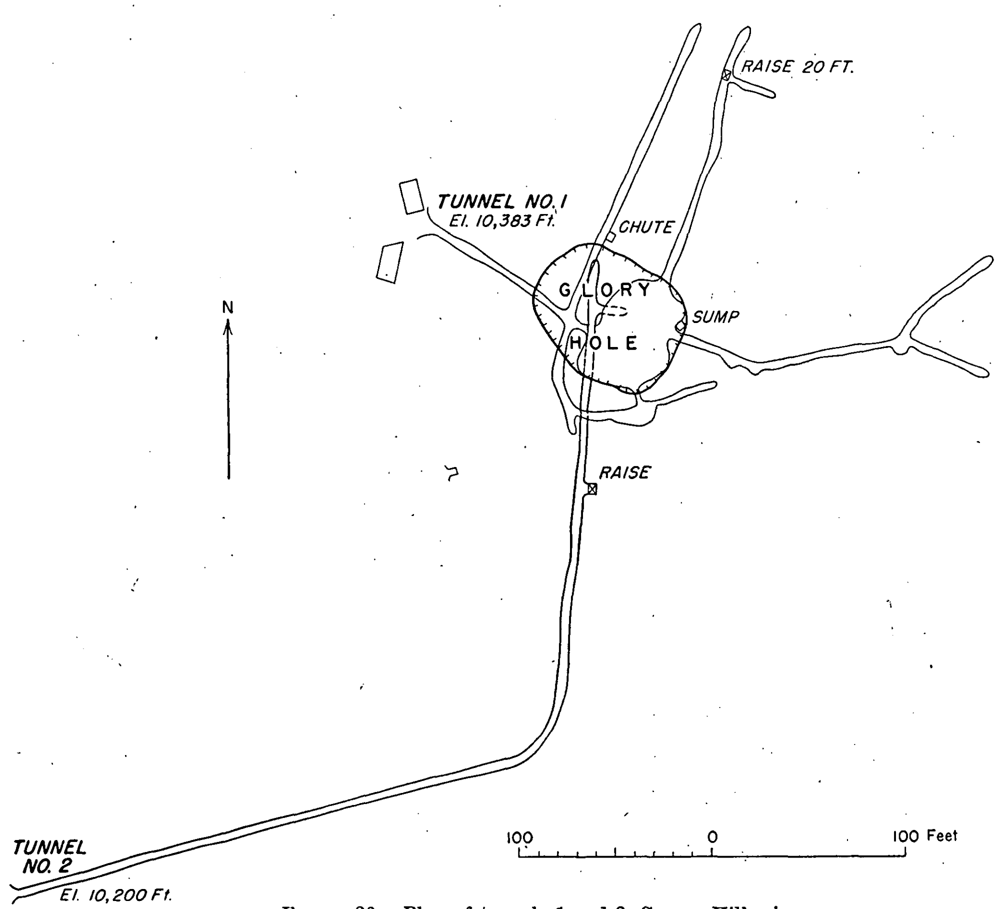

FIGURE 20.—Plan of tunnels 1 and 2, Copper Hill mine.

of which are caved, and a few small open-cuts scattered over the hill.

The recorded production of the Copper Hill mine is as follows:

Production of Copper Hill mine, 1902–43 [1]

Year	Ore (dry tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)
1911	464		1, 271	73, 133
1912	36	11. 62	54	82
1913	1, 347		2, 468	110, 602
1914	235	. 18	295	13, 503
1917	254	. 46	390	26, 545
Total	2, 336	12. 26	4, 478,	223, 865

[1] Compiled from mine records of U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

GEOLOGIC FEATURES AND ORE DEPOSITS

The geologic features and ore deposits of the Copper Hill mine have been described in the general section on ore deposits, page 64, and are not repeated here. Suffice it to say that the deposit is situated near the border of the larger syenite stock, and that the ore consists of veinlets and disseminated grains of chalcopyrite, magnetite, and hematite in an augite-orthoclase metamorphic rock.

TENOR OF COPPER HILL ORE

The tenor of the ore shipped from the Copper Hill mine, calculated from the figures cited above, is shown in the following table. The gold ore shipped in 1912, being obviously different in character from the copper ore produced in other years, is not included in this table.

Tenor of crude ore shipped from Copper Hill mine

Year	Silver (ounces per ton)	Copper (percent)	Silver and copper (ratio by weight)
1911	2. 74	7. 9	1:887
1913	1. 83	4. 1	1:653
1914	1. 25	2. 9	1:665
1917	1. 54	5. 2	1:982

The ratio of silver to copper by weight in the ore shipped was thus of the same order of magnitude for each of the 4 years of record. The average content was 1.97 ounces of silver and 4.8 percent copper. Sampling by the Bureau of Mines (p. 65) shows that the ore remaining is of much lower grade than that already mined.

POSSIBLE EXTENT OF COPPER HILL DEPOSITS

It is impossible under present conditions to make reliable estimates of the extent or shape of the Copper Hill deposit. The glory hole workings show that the fairly high grade ore body was about 60 by 80 feet in horizontal dimensions and about 50 feet deep. Nearly all of it has been mined. The tunnel southeast of the glory hole shows that ore of the same type but of very low grade covers a larger area and extends to considerably greater depths.

Exposures are too poor and scattered to allow prediction of extent on the basis of field mapping alone. The presence of the main deposit in a zone of metamorphic rock near the border of the stock suggests that extensions of the ore body might be found along or near the contact of the syenite with the intruded rocks. This contact is irregular and ill-defined and its position as shown in plate 2 is only approximate. Some of the similar but apparently nonplatinum-bearing deposits in the vicinity of the Allard tunnel are well within the body of the stock, so it would be unwise to confine prospecting entirely to the contact zones. Available data do not lead to optimism regarding extensions of the deposits.

CUMBERLAND (4)

The Cumberland mine is in the eastern part of Cumberland Basin and on the western slope of Cumberland Mountain. It explores the most productive part of the eastward-trending belt of silver-bearing veins which characterize the northern part of the district, and it also provides an excellent illustration of the dependence of ore on character of wall rock. The workings range in altitude from 11,520 to 12,350 feet. The mine can be reached over an abandoned wagon road that leads into Cumberland Basin from the end of the La Plata canyon county road. North of Fly by Night Gulch the road was not accessible to vehicles in 1937.

The deposits worked in the Cumberland and the adjacent Snowstorm mine were discovered in 1878. Little or no ore was produced until 1884, but from that year until 1890 both mines attained their greatest activity. All the important workings were opened, a 30-stamp mill (which was entirely unsuited to the ore) was built, and a considerable quantity of rich ore was produced. Both mines were idle during the nineties, but the Cumberland was revived in 1900 and again in 1909, since when it was worked intermittently until 1921. Both mines were inactive from 1922 through 1937. The early development was elaborate, particularly on the surface. In addition to the stamp mill, a well-equipped machine shop, jig-back tram, and steam plant, a wagon road, and several dwellings that would do credit to a prosperous city were constructed. Purington says in his 1896 field notes that $175,000 had been spent on the property, and from all appearances this figure is conservative. Several of the buildings were in a fair condition in 1937, but the mill, power plant, and machine shop were represented only by a tangled mass of rusting scrap metal. The recorded production of the Cumberland, shown in the following table, amounts to about $32,000. The production figures for 1884–87 are from a private engineer's report and are summations of returns from individual shipments. They are said to include all the data available but to be incomplete, and similar figures for supposedly different lots of ore together with other internal evidence in the report, make it seem possible that the source figures are inaccurate.

Recorded production, Cumberland mine, 1884–1943

Year	Ore mined (short tons)	Ore sold or treated (short tons)	Gold (fine ounces)	Silver (fine ounces)	Net value
1884 [1]	--------	97	120. 37	4, 592	--------
1885 [1]	--------	56	17. 31	6, 041	--------
1886 [1]	--------	. 05	--------	--------	$83. 80
1887 [1]	--------	3	--------	--------	316. 70
1888 [2]	--------	16	--------	--------	881. 45
1889 [2]	--------	--------	--------	--------	823. 59
1900 [1]	--------	8	19. 00	554	--------
1909 [3]	1, 100	35	130. 80	1, 624	--------
1910	302	10	12. 77	199	--------
1911	3, 046	100	271. 16	4, 814	--------
1917	--------	2	. 08	127	--------
1918	--------	15	2. 50	822	--------
1921	--------	101	84. 10	1, 332	--------

[1] Private engineer's report, unpublished.
[2] Kimball, J. P., Report of the Director of the Mint for 1888 and 1889.
[3] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines (for 1902–43). No production recorded for years not listed.

The uppermost working consists of an open-cut, 100 feet or more in length, near the top of Cumberland Mountain. Considerable ore is said to have been removed from stopes above the first level, which is 130 feet below the top of the mountain; this level is said to be 200 feet long, but only 50 feet was accessible when the mine was visited in 1936. The second level, 140 feet below the first, is said to be 220 feet long. It was caved at the portal in 1936. The third and fourth levels, which are 270 and 720 feet, respectively, below the second, are shown in plate 18. One of the raises from the third level connects with the second level. The vein has thus been partly developed through a vertical range of 990 feet. The portals of the upper workings are usually blocked with ice the year round.

The country rocks consist of soft, unmetamorphosed redbeds of the Cutler and Dolores formations, which here dip to the north and northeast at low angles, and a few irregular sill-like bodies of diorite-monzonite porphyry. The Cutler-Dolores contact lies between the second and third levels.

The Cumberland vein strikes N. 60° to 80° E.; its dip varies both in direction and amount, but a steep northward dip prevails. This vein extends eastward past the top of Cumberland Mountain. The Muldoon vein, farther to the east, is either the same vein or a closely parallel one. The Cumberland vein has not been explored in the floor of Cumberland Basin below the fourth level. The Snowstorm vein, on the southwest side of the basin, is supposed to be the westward extension of the Cumberland. The eastern part of the Snowstorm vein strikes N. 70° to 80° E., like the Cumberland, but the western part swings sharply toward the south and follows a course that is S. 35° W. For this reason and because the Snowstorm ore differs from that of the Cumberland, it is uncertain whether the Snowstorm is an extension of the Cumberland or a different vein.

Two porphyry dikes exposed in the open-cut on the Cumberland vein near the top of the mountain are offset about 5 feet to the west along the south wall of the vein, but this small displacement is not revealed in the lower workings. The vein is poorly exposed in the open-cut because the sides of the cut caved. The vein matter seen there is like that on the lower levels, described below, but contains less barite. The wall rock is red fine-grained micaceous sandstone.

The first level was driven at the contact between a porphyry sill above and redbeds below. The part of this level that was open for examination in 1936 was not on the vein, but it seems probable that the porphyry sill may have been responsible for the ore shoot above this level.

The third level presents one of the clearest examples of dependence of ore shoots on character of wall rock that is to be found in the district. The vein follows a strong fracture, which traverses soft red shale and mudstone, sandstone, and two masses of porphyry. The smaller of these masses (pl. 18) is clearly a dike, which trends northwest and dips to the northeast at an angle of about 60°. The southwest wall of the larger mass is sill-like and dips north at an average angle of 17°; its other wall dips steeply northeast and cuts across the sedimentary strata. There is no apparent displacement along the vein. The redbeds are partly silicified and bleached for several feet on each side of the vein. Where the vein traverses the redbeds, it is commonly only 4 to 6 inches wide and consists of comb quartz containing small quantities of silver and copper minerals. On entering the porphyry masses, the vein widens abruptly to 5 to 10 feet and contains minable ore. Both in and near the porphyry the vein is a broad zone of silicified breccia, which, depending on the character of the adjacent wall rock, consists either of sedimentary rocks or of porphyry. Replacement of breccia fragments by quartz is evident in places. The character of the vein filling does not differ materially in the two types of wall rock and is similar to that in the fourth level and on the dump, described below. There is no stoping on the vein except very close to the porphyry masses.

The wall rocks on the fourth level consist largely of red mudstone. In the crosscut to the level the beds are fresh, but in the drift they are partly silicified and bleached for 2 to 6 feet on each side of the vein. Several sill-like masses of porphyry are exposed along the south wall of the vein. They are not shown in plate 18, because the north wall of the vein is not exposed and thus the true distribution of porphyry cannot be shown for both walls. The vein consists of sheared and altered wall rock in a zone 5 to 12 feet wide. Within this zone are one or more veins of vuggy, crystalline to massive vein quartz from 1 inch to 15 inches thick. In places the quartz contains visible specks and blebs of ore minerals, but otherwise it appears to be barren.

As seen on the dumps and in the mine workings, the vein filling consists of fine to very coarsely crystalline, white to clear drusy quartz. Some of the quartz crystals are 4 inches long and 1 inch thick. Large negative pseudomorphs of barite crystals are rather numerous. Much of the quartz forms rosettes. A fine-grained black mineral, possibly a silver mineral, occurs near the base of the rosettes. Barite is next in abundance to quartz. Most of it consists of white, colorless, or light-blue tabular crystals, implanted on quartz crystals in cavities or on fracture planes in altered wall rocks. A light-pink, massive variety of barite forms irregular veinlets along the walls of crustified quartz vein matter and is clearly older than the barite that occurs in vugs. Many vugs are filled with white dickite. Purington notes the discovery of a large vug or "cave" that contained an unusually large amount of white clay rich in free gold. Pyrite and chalcopyrite are rather rare, but in places they form small masses and tiny specks. Most of the chalcopyrite is altered to azurite and malachite. Sphalerite, galena, and calcite occur in small quantities. As gold can be panned from the dumps, some of the gold is undoubtedly free, but tellurides also are said to be present. Although ore minerals visible to the unaided eye are decidedly rare, small specks of red and black silver minerals embedded in quartz can be seen in some specimens. Ruby and "brittle" silver minerals (proustite, pyrargyrite, and stephanite) and argentite are all said to have been found in the ore.

The minable ore is described as having been 12 to 18 inches thick in most places but locally much thicker. For example, the ore body was 7 feet thick in the stope above the third level, and in some other places as much as 12 feet of ore was mined. As the vein has not been thoroughly developed by means of raises or sublevels between the main levels, little information on the shape or extent of ore shoots is obtainable. But the occurrence of vein matter, uniform in character, at intervals through a vertical range of nearly 1,000 feet is amply demonstrated. Available information indicates that the vein is wider and richer in porphyry than in red beds, and as most of the porphyry is believed to form relatively thin sills, it is likely that the ore shoots are nearly horizontal and of small vertical extent. Twenty-five lots of ore shipped in 1884 and 1885 contained, on the average, 1.2 ounces of gold and 77 ounces of silver to the ton. Purington notes, however, that the average silver content of the ore in the mine as a whole was only 9 ounces, and that figure is in keeping with the results of recent sampling with which the writer is familiar.

It seems possible that a large tonnage of minable ore can be proved, but further development and sampling are necessary to block it out and to determine its tenor. The bottom of the ore has apparently not been reached, and exploration at lower levels might expose more ore, particularly in places where the vein cuts porphyry or the thick sandstone beds of the Cutler formation. But it would seem wise to direct attention first to thorough exploration of the ore body that is already partly developed.

DAISY-HIBERNIA GROUP (2c)

GENERAL FEATURES

The Daisy-Hibernia group of mines, which also includes openings on the Joe Graff, Lida May, Bluff, and Nellie Bly claims, is in the basin at the head of Lightner Creek. The Hidden Treasure, described separately, was probably in the same group, all the mines of which explore a series of quartz veins that contain galena, silver minerals, and free gold. The altitude of most of the workings is near 10,500 feet. They are in one of the most inaccessible parts of the district; part of it is heavily timbered, the slopes are rugged, and rock exposures are poor. Although the mines can be reached over a poor trail that follows Lightner Creek from the end of the old road on Deep Creek, the most ready access in 1936–37, was by means of a steep trail that leads downward from Puzzle Pass, on the west edge of the basin.

The veins were discovered in the early eighties, and much work was done on them in the following 15 to 20 years, after which they were only worked intermittently by a few lessees. The total production is unknown, and since 1902 no production is credited to any of the claims. According to reports of the Director of the Mint, the Hibernia produced $5,787 in gold and $481 in silver during 1891. The Joe Graff produced $413 in gold and $129 in silver in 1891, and $1,090 in gold and $342 in silver in 1892. No other figures than these are available, but it seems probable that the production from the Daisy claim exceeded that from the Hibernia.

There are one or more adits on each of the claims in the group and shafts on several of them. In 1937 the only accessible workings except a short crosscut on the Joe Graff claim, which had not been driven to the vein were those of the Daisy mine. The latter are the westernmost of the openings on the Daisy-Hibernia vein zone and are on a tributary of Lightner Creek, at an altitude of 10,350 feet. The workings consist of a shaft in the middle of the gulch and two adits that extend due east and due west. Each adit is 100 to 150 feet in length. Much underhand and a little overhand stoping has been done in the west adit; the east adit has much overhead stoping, some of it reaching the surface.

The sedimentary rocks at the head of Lightner Creek are part of the Cutler formation and are but slightly metamorphosed. The beds dip in general toward the south, but there is no uniformity in their attitude, because of the disturbances caused by the intrusion of the Silver Mountain stock and the complex network of dikes and sills that characterize the head of Lightner Creek.

The workings on the Daisy, Joe Graff, Hibernia, and Nellie Bly claims are all on a single vein zone, which trends a few degrees north of east. The zone can be traced in discontinuous exposures from a point west of the Daisy mine nearly to the divide between Lightner Creek and Chicago Gulch, a distance of about 1 mile. A vein in Chicago Gulch, several thousand feet farther east, is apparently on the continuation of the same zone. The Lida May and Bluff claims are on closely parallel fractures that are similar to the main vein. There are probably several other eastward-trending veins in the general vicinity of the Daisy.

The Daisy-Hibernia zone is composed essentially of two nearly parallel veins from 20 to 50 feet apart. Only the north, or Daisy, vein is well-explored at the Daisy workings. Farther east, both veins contain some ore, but the southern one, or Hibernia, is the stronger and has received the most attention from prospectors. The vein zone is nearly vertical but locally dips toward the north. In the Daisy mine its dip is 63°; in the Hibernia it is vertical at the surface but swings to a 70° northerly dip a few feet below.

More of the workings were accessible to Purington in 1896 than were seen in 1937. In his field notes he states that the veins he saw averaged 18 inches in width and consisted of sets of stringers or veinlets with an average width of 3 inches. They were composed of quartz that contained various quantities of galena, chalcopyrite, pyrite, free gold, and some polybasite and possibly other silver minerals. The average yield of the veins was reported to Purington to be about $35 a ton in gold and silver.

DAISY MINE

In and near the Daisy mine the red beds strike N. 80° W. and dip 19° S. A 20-foot porphyry dike, which strikes N. 60° to 70° E., crosses the east adit about 75 feet from its portal.

As shown in figure 21, the vein zone consists of veins of intrusive breccia and of ore-bearing quartz that traverse a shear zone in the country rocks. The shear zone is 4 to 5 feet in width and consists of strongly fractured and sheared country rocks, which are lightened in color and partly silicified. The intrusive breccia is irregular and somewhat discontinuous and ranges from 1 inch to 18 inches in thickness. It contains angular to subrounded fragments of shale, sandstone, and porphyry, set in a matrix of more finely comminuted rock. The variety of materials in the breccia, which are different from the immediately adjacent wall rock, show that it was forced in along openings in the fracture zone and was not formed in place. The breccia vein is thoroughly silicified and contains much disseminated pyrite.

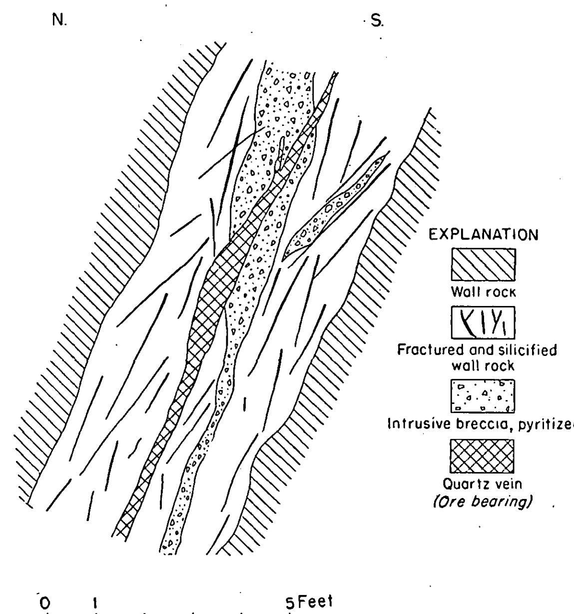

FIGURE 21.—Diagrammatic cross section of Daisy vein, showing relation of vein to intrustive breccia and to shear zone.

The quartz vein, which contains the ore minerals and ranges from 1 inch to 12 inches in thickness, traverses the central part of the fracture zone. In places it cuts the intrusive breccia. The most abundant mineral is rudely banded and crustified white to clear quartz. Most of it is coarse-grained, but some is so fine as to resemble chalcedony. Some bands are almost black, owing to abundantly disseminated pyrite. Pink carbonate and a little barite, most of which occurs as late vug-filling, are the other gangue minerals. The most prominent ore mineral is coarse-grained galena, which forms irregular masses an eighth to three-quarters of an inch in diameter throughout the quartz. Minor amounts of dark-brown sphalerite, tetrahedtite, pyrite, argentite, and one or more of the ruby silver minerals are intimately associated with the galena. Free gold was found in several specimens on the dump and is said to have been visible in ore from several parts of the mine. That seen was partly in the form of hackly teeth and partly in irregular veinlets cutting both quartz and galena. Some masses of galena are bordered with narrow shells of anglesite and cerussite.

DARBY (5?)

Several adits, now caved, explored a vein on Darby Creek, east of the La Plata River. There are no patented claims along the creek, and hence the name of the property is not known; it is here called the Darby for convenience. There are three adits between altitudes of 10,500 and 10,750 feet, the longest probably not much more than 50 feet in length. The northernmost of them is probably a crosscut to the Darby vein or to a closely parallel fracture; the other two are drift adits. Fine-grained to coarse-grained sandstone and shale of the Cutler formation make up the country rock. South of Darby Creek the rocks are only slightly altered, but in the vicinity of the prospect, and northward, the sandstone has been metamorphosed to quartzite and the shale to hornfels. Two thin sills of porphyry are exposed near the workings, and a very thick sill occurs several hundred feet above them. The vein follows a fracture zone 18 inches to 20 feet in width. It trends toward the southeast and dips steeply north. The amount of displacement along the fracture zone is undetermined but it probably small. The vein filling, which forms narrow streaks in brecciated country rock, consists of massive quartz, comb quartz, and a little pyrite, which is the only metallic mineral seen. Below the thick porphyry sill the whole fracture zone narrows to 18 inches and contains a 2-inch to 4-inch vein of barren quartz. In the porphyry the fracture zone is wider but contains no quartz. The vein is parallel to the Euclid vein, and it seems to be a continuation of the general fracture zone that is occupied in part by the Good Hope and Ashland-Ten Broeck veins farther southeast. The showings on Darby Creek, however, cannot be regarded as encouraging.

DIXIE QUEEN (3)

By E. N. Goddard

The Dixie Queen mine is on the south side of the Dolores River, half a mile east of Robinson's Ranch, along the same dike as that of the Missouri Girl. According to Jess Robinson, who worked the mine for several years, it was first opened in 1905 or 1906, and 2 or 3 tons of sorted ore containing 30 percent of copper were shipped.

The workings consist of two tunnels on the east side of the dike, about 150 feet apart vertically and 300 feet horizontally. Only the upper tunnel was accessible at the time of the writer's visit. The geology of the tunnel is shown in figure 22.

The lower tunnel explores the upper part of the Cutler formation. Red and gray sandstone are on the dump, but no plant material and no evidences of mineralization were seen. The upper tunnel explores the same plant-bearing horizon as that exposed in the Missouri Girl mine. The drifts expose three nearly vertical fracture zones, which trend northwest, parallel to the dike, and are 15 to 20 feet apart, as well as two small fracture zones that are nearly at right angles to the dike. (See fig. 22.) Chalcocite forms veinlets and lenses in seams of fractured coaly material in or bordering the northwest-striking fracture zones. (See fig. 5.) Chalcocite is not concentrated at the junctions of fracture zones; its distribution seems rather to be controlled by that of the carbonaceous material. Chalcocite does not appear to be abundant enough to form minable ore, though possibly a small amount of ore could be produced by sorting.

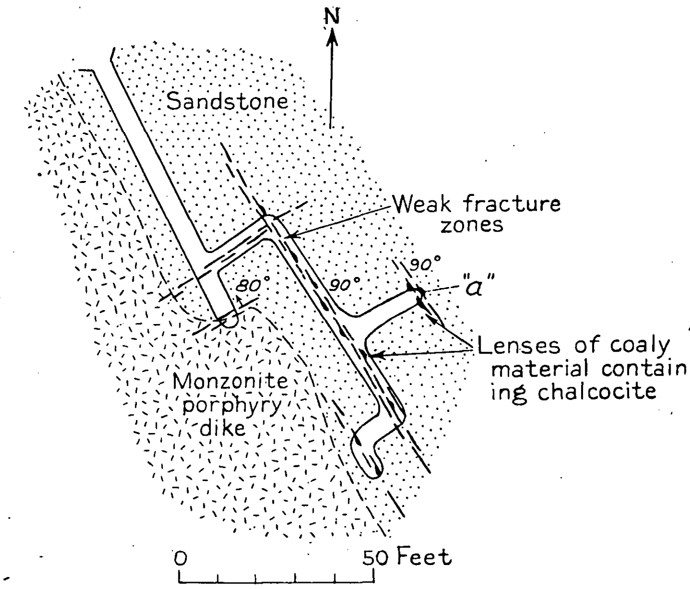

Figure 22.—Plan of the Dixie Queen upper tunnel, showing the distribution of chalcocite

DOYLE GROUP (2b)

LOCATION AND HISTORY

The Doyle, or Hesperus group, which comprises a large number of claims and mine workings on both sides of Jackson Ridge (pls. 14 and 19) is typical of those deposits which consist of gold-bearing pyrite in veins and replacement bodies. Except that the ore contains pyrite rather than tellurides, they are similar in most respects to those of the Incas mine. The deposits have been known for many years, and several attempts have been made to exploit them. Most of these attempts were unsuccessful, partly because of metallurgical difficulties.

The property is 8 miles southwest of Jackson Ridge. It is connected with Mancos, 12 miles distant, by a good county road which is open most of the year. The nearest railroad connection is at Brayton switch, near the place where the Rio Grande Southern line crosses the East Mancos River. All the mine workings are above timber line, at altitudes of 11,000 to 12,000 feet. The water supply is limited and is drawn from a small snow-fed lake in a natural depression near the head of Rush Basin.

The Hobo claim, the first claim in the East Mancos area to be recorded, was located about 1888, and the Timberline group of claims was located in 1890. In 1890, also, George A. Jackson began development of the "Jackson contact" along the West Mancos River, the available information on which is given below in the description of the Peerless mine.

During the nineties the pyritic replacement body at the Pony Express limestone horizon was discovered. About 1896 or 1897 James Doyle, a former Cripple

Creek operator, formed the Mancos Consolidated Gold Mines & Development Co., which began extensive development and exploratory work and consolidated most of the properties. A 10-stamp amalgamation and concentration mill was erected and ran for several years, producing a considerable amount of gold. Between 1902 and 1934 various other attempts were made to operate the property, and two or more successors to the original stamp mill were built. At least one of them was designed for roasting and cyanidation of the ore. In 1934 the Hesperus Mining Co. was formed and acquired control of nearly all the land on Jackson Ridge. A small pilot mill was erected and produced a small quantity of ore. It was replaced in 1935 by a larger flotation mill, and much development work, principally on the surface, was done. Early in 1936 most of the new buildings and equipment were carried away by a snowslide with a loss of eight lives. The property was idle in 1936 and 1937, but plans were under way to resume development. An affiliated company, the San Juan Milling & Refining Co., was organized in 1937 and began erection of a 200-ton flotation mill near Brayton switch. It planned to handle custom ore as well as that from the Doyle mine.

PRODUCTION

The production prior to 1902 is unknown, but from various published figures it seems possible that the Doyle group produced $40,000 or more between 1890 and 1901.[5] Most of the ore came from the North Star and Sundown mines. According to Lee,[6] the group produced $22,500 in 1902. The production included 300 tons of crude ore, containing $40 in gold to the ton, and $10,500 in bullion, 900-fine, recovered by milling 700 tons of $15 ore. The following figures include all the recorded production since 1902:

Recorded production of Doyle group, 1902–43 [1]

Year	Producer	Ore milled (tons)	Ore sold (tons)	Gold	Silver (fine ounces)	Copper (pounds)
1907	Mancos Consolidated Gold Mines & Development Co.	--------	4	13.69	3	--------
1910	Doyle Consolidated Mines	--------	445	423.10	178	97
1934	Hesperus Mining Co.	500	82	31.24	--------	--------
1934	Sasser mine (E. C. Sasser)	--------	94	65.30	--------	--------

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production 1903–43 for years not listed; no authentic records for production 1890–1902.

DEVELOPMENT

The south slope of Jackson Ridge has been prospected by means of dozens of adits, from a few feet to several hundred feet in length, and a few adits were driven on the north side of Jackson Ridge and on the slope south of the East Mancos River. A few shafts, also, from 10 to 80 feet deep, have been sunk, mostly in Rush Basin. Only the more important mine openings are shown in plate 19, and comparatively few of these were accessible in 1935–37. The two most important mines, the Timberline and the North Star-Sundown, are shown in figure 23 and plate 20.

GEOLOGIC FEATURES

GENERAL GEOLOGY

Sedimentary rocks.—As shown in plate 19, the sedimentary rocks exposed in the vicinity of Jackson Ridge range from the Dolores formation through the Dakota(?) sandstone. Except in small areas along the West Mancos River and near the Georgia Girl mine, in the extreme southwest corner of the area shown in plate 19, all the rocks are rather thoroughly metamorphosed. The Entrada sandstone, the Junction Creek sandstone (upper La Plata sandstone of former reports) and the Dakota(?) which is represented only by a few small outliers, have been converted in most places into hard, relatively coarse grained quartzite. The Dolores, the marl member of the Wanakah, and the shale of the Morrison formation consist largely of dense light-colored fine-grained quartzite and hornfels. Despite the general similarity of the metamorphosed rocks, the different members have not been equally resistant to erosion; the two thick sandstone layers stand out as prominent cliffs, whereas the other beds form benches or steep but nearly uniform slopes (pl. 7).

The Pony Express limestone member of the Wanakah formation (La Plata limestone of former reports) is poorly exposed on the slope south of Rush Basin, where it is probably about 2 feet thick and is largely if not completely replaced by sugary quartz, intergrown with a little pyrite. On the south side of Jackson Ridge this limestone is exposed in numerous mine openings and ranges from 4 inches to more than 5 feet in observed thickness. Its average thickness in the North Star-Sundown mine is 2 feet, and it is certainly no greater for the entire south side of Jackson Ridge. There the limestone is almost completely replaced by massive gold-bearing pyrite in most places, but locally it contains much sugary quartz. The pyrite is largely altered to limonite near the surface and where it is exposed in the Narrow Gauge shaft in Rush Basin. A little unreplaced limestone was seen at one place in the North Star-Sundown mine.

On the west side of Jackson Ridge the limestone appears to be absent in most places, or at best very thin; it was seen in only two places. Where the West Mancos River crosses it, at an altitude of 10,900 feet, it is exposed in outcrops and in several prospect cuts. Here the bed, which is almost entirely replaced by pyrite and quartz, ranges from 5 to 14 inches thick. A 5-inch to 6-inch bed of black soft shaly material, probably altered limestone, is exposed at the breast of a short adit

[5] Petre, R. W., Mines of the La Plata Mountains, Colo.: Eng. and Min. Jour., vol. 66, pp. 667–668 (1898). Anonymous Min. and Sci. Press, vol. 79, p. 581, 1899, and vol. 84, p. 209, 1902. Lee, H. A., Colorado Bur. of Mines Ann. Rept. for 1901–2, p. 130, 1902. Toll, R. H., La Plata Mountains, Colo.: Min. and Sci. Press, vol. 97, pp. 741–744, 1908.

[6] Lee, H. A., op. cit., p. 130.

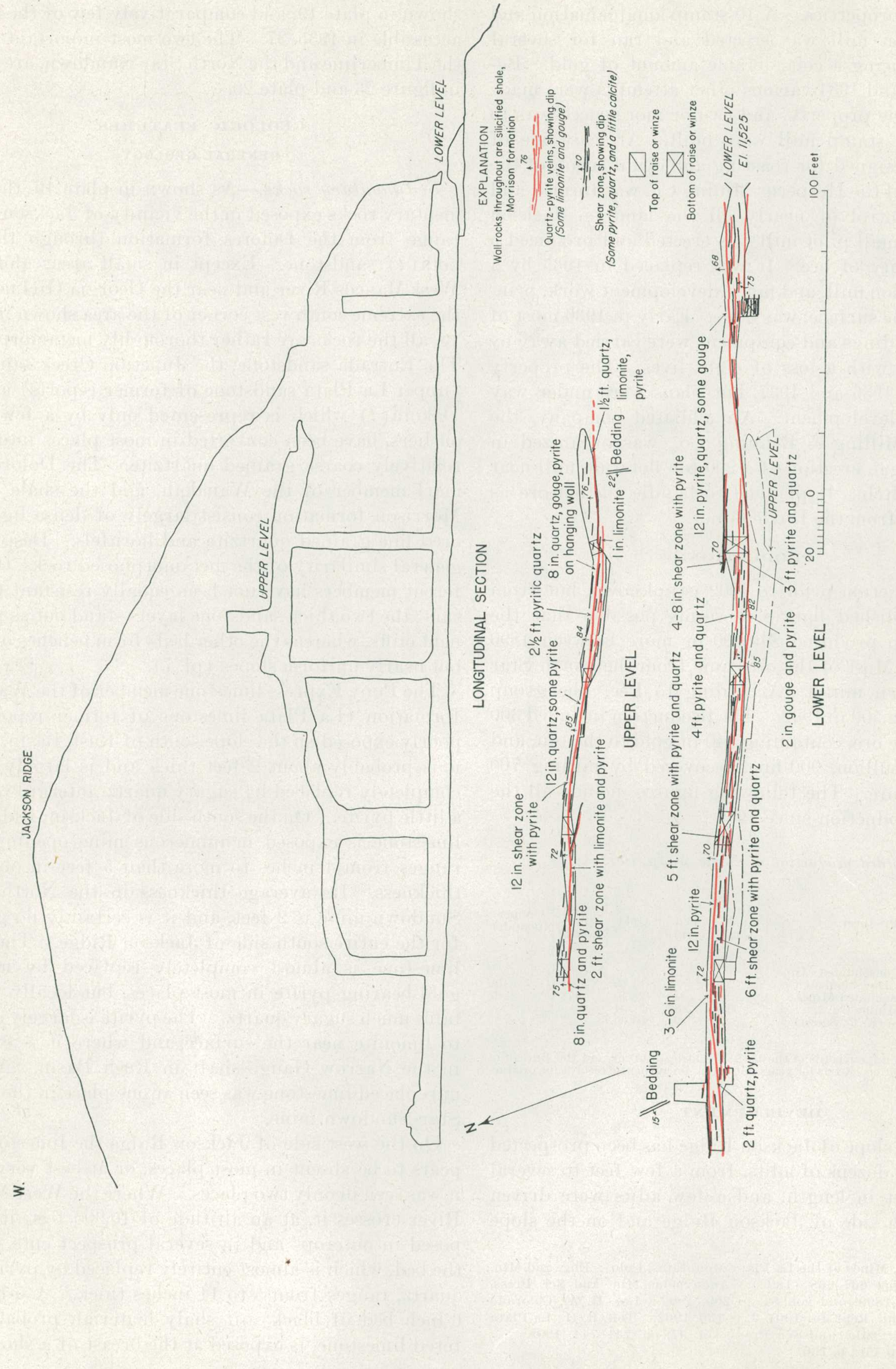

FIGURE 23.—Plan of upper and lower levels, Timberline mine, Doyle group.

1,500 feet to the southwest. Along the north slope of Jackson Ridge are several prospect openings, all of them caved, which were evidently driven in search of the blanket vein. None of their dumps contain pyrite or limestone, and, as these openings are all at or near the Pony Express limestone horizon, there is a strong presumption that the limestone bed is not present on this slope. There is indeed a widely held local belief that the main ore bed underlies all of Jackson Ridge and crops out on the West Mancos River, where it is said to be 5 feet thick; this belief, however, is thought to be based on a misinterpretation of the stratigraphic relations, for the ore bed at the base of the Entrada sandstone, exposed in and near the Peerless mine, has been erroneously correlated with the ore body replacing the limestone at the top of the Entrada.

Igneous rocks.—Numerous dikes, sills, and irregular masses of porphyry (offshoots from the large bodies of Spiller and Gibbs Peaks) cut the sedimentary rocks. Some of the porphyry, particularly in the southwestern part of the area shown on plate 19, has a marked syenitic aspect, but most of it is diorite-monzonite porphyry. With two exceptions all the bodies of porphyry are short, irregular, and discontinuous, and range in trend from due north to due east. One of the exceptions is the sheet of syenite porphyry that caps the northwestern part of Jackson Ridge; the other is the northward-trending dike shown near the center of plate 19. This is exposed at only three places, but the correlation indicated is believed to be correct.

Structural geology.—Jackson Ridge lies just north of the steep hinge-fold which encircles the central part of the La Plata Mountains and which parallels the East Mancos River at this place. On the slope south of Rush Basin, between Spiller and Gibbs Peaks, the rocks dip 30° to 60° NE. Near the river they flatten abruptly, and on Jackson Ridge they dip 5° to 20° NW. (See pl. 7.) Where the beds are steeply tilted, they are strongly sheared and brecciated. Shear zones, which contain much varicolored chalcedony and some quartz and pyrite, trend in all directions, but the strongest system trends northeast, parallel to the axis of the fold. Throughout this area the breccia fragments are cemented with quartz and chalcedony and pyrite and some chalcopyrite are widely disseminated. The shaly beds of the Jurassic are less well exposed than the sandstones, but presumably they are less strongly brecciated.

North of the river, where the beds are more nearly horizontal, the rocks are not brecciated. Instead, they are cut by a large number of steeply dipping fractures, most of which strike northwest, normal to the strike of the hinge fold in this area. Most of these fractures are faults having displacements that range from a few inches to about 30 feet. There is no uniformity in direction of dip or of displacement. Most of the individual fractures can be traced only for a few hundred feet, but several fracture belts are continuous for a mile or more. The relation between dikes and fractures is clearly shown in plate 19.

ORE DEPOSITS

BRECCIA DEPOSITS

Ore deposits of three general types occur in the area covered by the Doyle group—breccia deposits, blanket-vein or bed-replacement deposits, and fissure veins. So far as could be learned, the brecciated and mineralized sandstone south of Rush Basin has received little attention from prospectors. It is in general more strongly mineralized than any of the shear zones near the Century mine, on Bear Creek, some of which contain appreciable quantities of gold. Hundreds of thousands of tons of breccia are available, and thorough sampling and examination appears to be justified on the chance that the material will be found to contain enough gold to be amenable to large-scale operations.

BLANKET-VEIN DEPOSITS

Most of the development work done on the Doyle properties has centered on the "Doyle blanket," or pyrite replacement deposit in the Pony Express limestone. The limestone has been almost completely replaced by fine to coarsely granular pyrite containing gold and a little chalcopyrite. Ore produced in the early days yielded from $15 to $50 to the ton in gold. Nearly if not quite all of this ore was oxidized. The whole bed of ore is reported by several engineers to have an average gold content of 0.20 to 0.35 ounce to the ton. The blanket-vein is exemplified by the deposit worked at the North Star-Sundown mine, described in detail below.

North Star-Sundown mine.—The North Star-Sundown mine, shown in plate 20, is the largest mine on Jackson Ridge and affords the best opportunity for study of the Doyle "blanket," a deposit of the bed-replacement type. The workings consist of a maze of interconnected drifts and flat stopes, or rooms, which penetrate the ridge to a maximum distance of 700 feet from the surface. Large parts of the stopes are backfilled. As nearly all the workings follow the northwestward-dipping replacement deposit, none of them is level. The altitudes of various points on the drift floors, as plotted in plate 20, indicate the irregularity of the floor and show that in general the workings slope downward toward the north, or away from the mine portals.

The top of the Entrada sandstone, here a hard quartzite, forms the floor of most of the workings. The Pony Express limestone member of the Wanakah, here represented by pyrite and quartz, is 4 inches to more than 5 feet thick. In this mine, and indeed in all the exposures on the south side of Jackson Ridge, the "limestone" bed is overlain by a 3-foot to 4-foot bed of medium-grained to fine-grained shaly sandstone representing the Bilk Creek sandstone member of the Wanakah formation. This bed, which is silicified, is overlain by a thin parting of soft and but slightly metamorphosed shale, which is overlain in turn by dense hornfels, the metamorphic equivalent of the marl member of the Wanakah. In a few places the shale parting is partly replaced by pyrite. The practical effect of this succession of beds is to allow subsidence of the sandstone bed soon after removal of the pyritic ore. The hornfels above the parting seems to stand well and forms the roof of most of the stopes. The beds dip in general 7° to 10° NW. A porphyry dike, which is about 20 feet wide and trends to the northwest, has been exposed by two crosscuts in the easternmost part of the mine. In one of the crosscuts both the dike walls are vertical; in the other, the southwest wall is vertical but the northeast wall is partly sill-like.

Two parallel northwestward-trending fault zones are exposed in the workings. One of them, called the North Star fault, is marked by a series of discontinuous fractures, which contain vein quartz, pyrite, and gouge. The zone ranges from 10 inches to 2 feet in width, and its dip ranges from vertical to 60° NE. It is a reverse fault, the beds on the southwest side of the fault having been faulted down from 1 foot to 4 feet. The Sundown fault zone, 400 feet west of the North Star fault and 1 foot to 10 feet wide, consists of a series of strong shear zones, filled in part with pyrite and quartz. Its dip, also, ranges from vertical to 60° NE. It is a normal fault, the beds on the northeast, or hanging wall, being faulted down from 9 to 13½ feet. Several other faults with slight displacement are shown in plate 20.

The main ore bed, or blanket vein, ranges from 4 to 62 inches in observed thickness. The 84 recorded measurements of thickness shown in plate 20 average almost exactly 24 inches. In most places the primary ore consists of massive pyrite, which locally contains enough chalcopyrite to produce green copper stains on oxidation. The pyrite is slightly schistose, with laminations parallel to the bedding. Locally the ore contains considerable quantities of white sugary quartz intergrown with the pyrite, and in a few places quartz makes up more than half the ore by volume. In one of the drifts that expose the porphyry dike mentioned above (section A′, pl. 20) the bed of pyrite continues through the porphyry. The relation indicates that after porphyry was intruded, but before the ore was deposited, there was some movement parallel to the bedding planes.

The gold contained in the primary ore is probably in the form of extremely fine, free particles intergrown with the pyrite. One specimen that was said to contain several ounces of gold to the ton was examined microscopically, but no gold was found under the reflecting microscope. Within 250 feet of the surface nearly all of the ore is oxidized to spongy limonite; oxidation is nowhere complete, however, and all the ore contains some residual pyrite. Farther from the surface the ore is largely primary pyrite, though no place was seen in the mine where limonite was entirely absent. Most of the ore found in the stopes was oxidized, and some of it yielded considerable fine, free gold when panned. The horizontal limits of the stopes were probably determined in part by diminution in gold content of the pyritic ore and in part by difficulties in treating the heavy sulfide ore. The uphill haul to the surface was doubtless also a factor.

The best ore is said to occur near the faults, but this statement is only partly borne out by the stope map (pl. 20). Furthermore, the unreplaced limestone at the breast of the North Star fault drift shows that in at least one place no ore was deposited close to a fault. The faults themselves have received little or no attention from the operators, although some high-grade ore occurs along them.

FISSURE VEINS

Only a few of the veins have been explored to any considerable extent. They contain pyritic vein matter which is similar to that in the limestone replacement body except in containing much more quartz. The vein zones range from less than 6 inches to more than 10 feet in width. The Timberline mine, the best developed of the group, is described here as a type example (fig. 23).

Timberline mine.—The walls of the Timberline vein consist of shale of the Morrison formation (McElmo of older reports) and are highly silicified. The shale dips about 15° W. The vein strikes N. 70° E. and dips 68° to 85° N. It can be traced for about 700 feet eastward from the mine, nearly to the point where it should intersect a strong northward-trending fault, but the actual intersection is not exposed, and the vein has not been identified east of the fault. Westward the vein can be traced several hundred feet past the crest of Jackson Ridge, where it has been prospected to some extent. As seen in the mine workings, the vein occupies part of a 5-foot to 10-foot shear zone, filled with a breccia that contains pyrite, quartz, and a little calcite. The vein itself is not continuous but forms a series of slightly overlapping fractures, from 3 inches to 4 feet thick, filled with white quartz intergrown with considerable pyrite. Gouge is locally abundant. Some of the pyrite is oxidized to limonite, and in places the whole vein is made up of limonite. The mine had not been adequately sampled when visited in 1935; the ore, however, is said to be comparable in tenor to that in the main bed-replacement deposit, containing 0.02 to 0.35 ounce of gold to the ton.

As the upper drift is less than 100 feet below the crest of Jackson Ridge, it would seem advisable to confine further development to lower levels, particularly in the Junction Creek sandstone. The probable intersection of the vein with the northward-trending fault mentioned above would appear to be a particularly favorable place for prospecting.

FUTURE OF THE DOYLE GROUP

A large aggregate tonnage of low-grade to medium-grade ore is unquestionably present in the Doyle "blanket vein." To extract this ore would be relatively difficult and expensive, however, because of variations in the thickness of the ore bed, its small average thickness, and its northwesterly dip, which would necessitate an uphill haul for ore from any of the present workings. Much further development work would be necessary to determine the average thickness and tenor of the blanket ore, the relation of tenor to the vertical fractures, and the distribution of ore beneath the whole of Jackson Ridge. The future of the property appears to depend somewhat on the finding of minable ore in the steeply dipping veins. Many of them deserve further exploration, particularly where they cut the thick sandstones. Adequate sampling might possibly show that the brecciated and silicified sandstone on the hill south of Rush Basin contains enough gold to justify large-scale mining and milling operations. Treatment of the pyritic ore, none of which is either entirely fresh or entirely oxidized, has been found difficult or impossible by various operators in the past, and further study of ore dressing and metallurgical practice may still be necessary.

DURANGO GIRL (5)

The Durango Girl mine, which has been briefly described by Emmons,[7] is on the north bank of Walls Gulch, 1½ miles above its junction with Junction Creek, at an altitude of 9,800 feet. It is best reached over the good Eagle Pass pack trail from the Junction Creek road. The property, which is owned by the Durango Girl Mining & Milling Co., comprises the Durango Girl, Durango Boy, and New Hope patented claims, together with several unpatented claims. The mine was discovered in 1893 and was intermittently active until 1926. It was idle throughout the period 1927–43 except for 1939. Most of the mining work was done by hand. Some of the ore produced in the first few years of the mine's history is said to have been concentrated in a small mill at the mouth of Walls Gulch, but by far the greater part of the output consisted of high-grade hand-sorted ore that was shipped direct to the smelter.

Since 1893 the mine has produced about $55,000 in gold and $8,000 in silver. The production figures for 1893–99, shown in the table below, are taken from the records of the Durango Girl Gold Mining & Milling Co., as reproduced in a prospectus issued in 1924. The company's figures for the period 1902–21 check closely with those of the United States Geological Survey and the Bureau of Mines, and it is believed that the earlier figures are essentially correct.

[7] Emmons, W. H., The Neglected mine and near-by properties, Durango quadrangle, Colorado: U. S. Geol. Survey Bull. 260, pp. 121–127, 1905.

Recorded production, Durango Girl mine, 1893–1943 [1]

Year	Ore (pounds)	Gold (fine ounces)	Silver (fine ounces)
1893	417	5. 57	91
1894	20, 010	96. 70	270
1895	14, 977	117. 89	376
1896	12, 282	29. 93	195
1897	12, 186	36. 59	546
1898	18, 490	54. 47	849
1899	1, 116	6. 05	17
1902	26, 500	652. 00	6, 000
1903	51, 076	403. 23	818
1904	33, 354	364. 54	1, 440
1906	188, 911	339. 01	2, 497
1907	6, 428	3. 43	44
1910	353	. 32	2
1911	442	2. 93	26
1912	980	3. 81	31
1914	11, 673	68. 81	561
1916	5, 348	58. 51	787
1918	2, 139	8. 06	32
1919	4, 578	11. 40	176
1920	1, 316	3. 90	43
1921	772	3. 60	24
1926	----------	. 50	32
1939	2, 000	. 30	18

[1] Figures for 1893–1901 from records of Durango Girl Gold Mining & Milling Co., those for 1902–43 compiled from mine records of U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The mine workings are shown in figure 24. The deepest work is less than 200 feet from the surface.

The sedimentary rocks in the vicinity of the Durango Girl mine are soft, relatively unaltered redbeds of the Cutler formation. The regional dip of the rocks is 10° to 15° east, but locally, as at the breast of the upper adit, the beds dip west. The sedimentary rocks are cut by a rather complex network of diorite-monzonite porphyry sills and dikes. A dike of dark-green porphyry, 5 to 10 feet wide, crops out near the mine workings. It strikes N. 70° W., parallel to the vein, and cuts all the rocks with which it comes in contact within the short distance it can be traced. It is doubtless an offshoot from the Lewis Mountain diorite stock.

The vein strikes N. 75° W. except near the breast of the upper adit, where it turns due west, and its course on the surface is about N. 70° W. It dips 54° to 78° N. It can be traced on the surface for several hundred feet west of the mine and is possibly the eastward extension of the Ashland-Ten Broeck vein system.

Slickensided surfaces in several places indicate that the fault followed by the vein is normal, with downthrow on the north. This view is borne out by the upper adit relations at the breast sketched in figure 24 where the porphyry is dragged down on the hanging wall, and by the tightness of the vein in places where the angle of dip is low. The amount of displacement is not known. The marked difference between the rocks on the walls of the vein (fig. 25) suggests a displacement of several hundred feet. Surface exposures, however, do not indicate a fault of this order of magnitude, and it therefore seems likely that here, as in the Gold King and Neglected mines, the fissures existed prior to the porphyry intrusion and controlled distribution of the

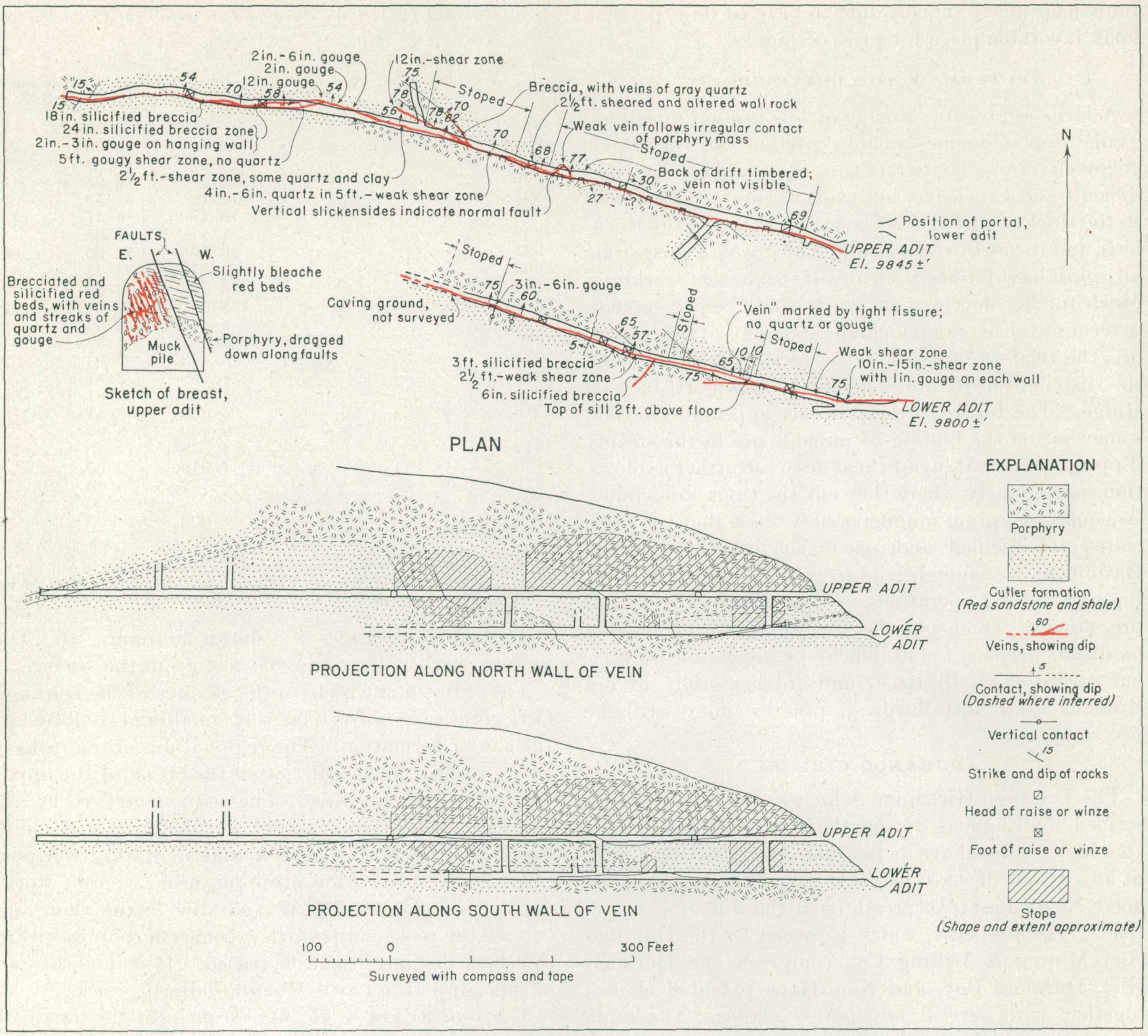

FIGURE 24.—Plan and sections, Durango Girl mine.

porphyry masses. If that is true, the displacement may amount to only a few feet.

As the richer parts of the vein have been removed and other parts are hidden by lagging, much of the following description of the vein is based on unpublished field notes by Purington and Emmons, and on Emmons' published summary.[8]

The vein zone varies in thickness from a fraction of an inch to 5 feet. In general it is wider in porphyry or sandstone than in other rocks. Where both its walls are shale, or where it follows the contact between shale and porphyry, the vein is tight. In places it is represented only by a tight fissure, with no gouge or vein matter; elsewhere it contains a foot or more of gouge. The gouge is most abundant near the breast of the upper adit, where the vein has a low dip. The wall rocks are altered from 2 inches to 6 feet on each side of the vein. They are lightened in color and partly silicified, and they contain much disseminated pyrite.

The vein matter consists of a belt of quartz stringers that traverse the fracture zone. Individual stringers are rarely more than half an inch wide; the belt as a whole is represented by a mere seam in some places, but attains a thickness of 3 feet; its average thickness is about 1 foot. Green roscoelite is more abundant in this vein than in any other seen in the district. Much of the quartz is colored in various shades of green by intergrown roscoelite and closely resembles the high-grade shipping ore of the Gold King mine. The only other nonmetallic minerals common in the vein are white dickite and opaline silica. Pyrite is relatively

[8] Emmons, W. H., op. cit. (Bull. 260), p. 126.

abundant in the vein zone but is rarely found in the high-grade vein quartz. The metallic minerals are intergrown with the quartz, and according to Emmons they make up in places as much as a quarter, by volume, of the pay streak. Tetrahedrite, the telluride minerals (hessite, coloradoite, and petzite) and free gold are most abundant. A mercury sulfide, probably cinnabar, was noted by Emmons.

The shoots that yielded the ore produced were clearly controlled in part by the character of the wall rock and in part by the steep dip of the vein. Both Purington and Emmons note that the richest ore mined lay between sandstone walls, but that by far the greater part of the shipping ore had walls of porphyry. The latter statement is amply demonstrated by the stope map (fig. 24 sections). Little or no ore has been found where the walls are shale. These relations contrast with those in the Neglected mine, where shale is far more favorable to ore than sandstone. The difference lies in the degree of silicification of the wall rocks in the two mines. Little or no pay ore was found where the vein has a low dip. Although the mine, as now developed, is obviously nearly "worked out" so far as high-grade ore is concerned, a large quantity of mill ore is said to remain in the stopes. Further exploration along the strike of the vein might reasonably be expected to reveal other ore shoots. Likewise, there is no indication that the bottoms of the ore shoots already exploited have been reached, and exploration at lower levels would appear to be justified.

EAGLE PASS (5)

The main adit of the Eagle Pass mine on the patented Eagle Pass claim is at the head of Lewis Creek, about 150 feet below Eagle Pass. The vein was found comparatively early in the history of the camp and was worked intermittently until 1922, but little is known of its history or early production. Local residents, some of whom have worked in the mine, estimate its total production as between $10,000 and $25,000. The recorded part of the production, amounting to about $8,800, is shown below:

Recorded production, Eagle Pass mine, 1887–1943

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1887	--------	209	1, 800	--------	--------
1888	--------	10	78	--------	--------
1911	9	9. 63	287	--------	--------
1913	4	2. 89	104	63	171
1914	10	7. 87	341	--------	--------
1917	20. 5	11. 56	476	--------	420
1919	12	5. 80	267	23	208
1922	10	6. 10	165	--------	--------

Figures for 1887–88 from reports of the Director of the Mint; those for 1902–43, compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed since 1902.

None of the workings were accessible in 1935–37. Unsuccessful efforts to reopen the main adit, which is about 200 feet long, were made in 1936 by the operators of the Gold King mine. Two short adits on Jennie Lind ground, on the east side of Eagle Pass, at altitudes of about 11,650 and 11,700 feet, are probably driven on the Eagle Pass vein. The upper one is estimated to be about 75 feet long; the lower is probably not more than 40 feet long.

The chief rocks near the mine are redbeds of the Cutler formation, which lie nearly horizontal and are moderately silicified. Several dikes and sills of porphyry cut the sedimentary rocks.

The vein strikes slightly north of east and dips 57° to 62° N. Although it can be traced only about 700 feet west of Eagle Pass, a vein that it probably its westward extension has been opened on the hill between French Gulch and Lewis Creek. Because of the northerly dip, the outcrop of the eastern part of the vein has a course of about N. 65° to 75° E. It is largely obscured by soil and talus and can be traced only about 500 feet from the top of the pass. The northwestward extension of the Jennie Lind vein appears to intersect the Eagle Pass vein a few feet below the workings on the east side of the pass, but the actual intersection, if it exists, has apparently not been explored. The eastward extension of the Good Hope vein intersects the Eagle Pass vein in or near the main adit on the west side of the pass. All these veins probably belong to the same fracture zone.

At Eagle Pass, the Eagle Pass vein consists of a 10-foot fracture zone containing a little quartz and barite but no visible metallic minerals. The ore on the dumps of the two eastern adits is much like that of the Gold King mine; it consists of gray to greenish-gray dense quartz, clearly formed by replacement of the brecciated wall rocks. Vugs in the fine-grained quartz are partly filled with white to clear crystals of quartz and a little barite. Galena, pyrite, coloradoite, and hessite, intergrown with free gold, are scattered through the quartz in small irregular masses and as veinlets. Some of the gold is primary, but some of it appears to be secondary. A representative sample of vein matter from the upper dump, with wall rock excluded, was assayed by E. T. Erickson and found to contain 0.72 ounce of gold and 3.82 ounces of silver to the ton. Neither the shape of the ore shoot nor the character of the ore exposed in the mine workings is known, but the ore was probably very similar to that just described. It seems likely that the ore shoot lay close to the intersection of the Good Hope and Eagle Pass veins. The intersection of the Jennie Lind and Eagle Pass vein also should have been favorable to ore deposition, but so far as could be determined no work has been done on it. Further prospecting of the vein near the two intersections, particularly in depth, would appear to be justified.

EUCLID (EUCLID GULCH)

The Euclid mine on Euclid Gulch, a westward flowing tributary of the La Plata River, was opened on the westward extension of the Ashland-Ten Broeck vein system early in the history of the district. The property comprises three patented claims, the Euclid, Euclid No. 2, and Sylvanite No. 2. It has not been worked for many years, and nothing is known of its production or history. It was worked through several adits at different altitudes, all of which were caved when the mine was visited. The vein is exposed at the portal of a caved adit at an altitude of 10,650 feet. It there strikes N. 70° W. and contains a 2-inch to 5-inch seam of white to green quartz in a 3-foot fracture zone. The vein as a whole is probably similar in character to the Ashland and Ten Broeck veins which are in the same vein system.

EUCLID (NEAR SHARKSTOOTH)

The Euclid group of nine unpatented claims is situated on a ridge north of the north fork of the West Mancos River. It is approximately half a mile west of the Sharkstooth and three-quarters of a mile north of Hesperus Peak (pl. 1). The mine was briefly examined by the writer in 1936 in company with the owner, Clay Q. Williams, of Cortez, Colo. Time was not available to remap the topography and geology in the vicinity of the mine, and much information essential to a complete picture of the geologic setting is lacking. As plotted in plate 2, the mine is at an altitude of about 11,000 feet, but aneroid observations indicate that its altitude is actually at 11,500 feet or more, the topographic base being inaccurate. The mine is 20 miles by road and trail from Mancos. A fork of the West Mancos road ends near an abandoned lumber camp, known as Spruce Mill, and from there a good pack trail, 4 miles long, leads to the mine.

The deposit was discovered in 1912, and exploratory work has been carried on intermittently since that time. A 5-ton mill, built of logs and equipped with grinding and flotation machinery, was constructed in 1929, but the machinery was sold two or three years later. No ore has been produced. The most extensive working is a 235-foot adit (fig. 25). There are also several short adits and shallow open-cuts.

The most prominent geologic feature in the vicinity of the mine is a strong east-striking fault, which passes through the gap between the Sharkstooth and Banded Mountain (pl. 1), and along which the beds on the north side are downthrown more than 100 feet. The contact between the Dakota (?) and Morrison beds is exposed just above the Euclid mine on the north side of the fault, whereas all the rocks on the south side belong to the Morrison (McElmo of former reports). The rocks, which are soft and unmetamorphosed, strike N. 20° W. and dip 25° W. A diorite-monzonite porphyry

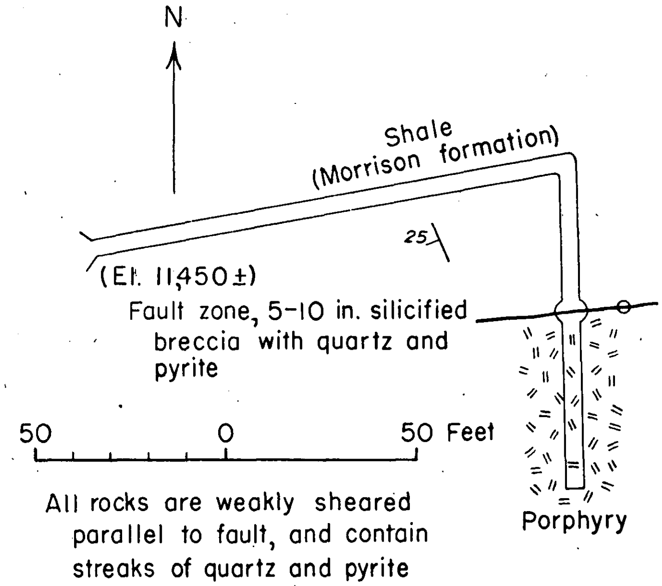

FIGURE 25.—Plan of main adit, Euclid mine, on North Fork West Mancos River.

dike at least 45 feet wide follows the south wall of the fault.

In the main adit the fault is marked by a 5-foot to 10-foot zone of strongly brecciated rock, which is partly silicified and contains veinlets of quartz and pyrite.

For at least 40 feet on each side of the fault the rocks are weakly sheared and contain scattered streaks and veinlets of pyrite and of quartz intergrown with pyrite and arsenopyrite. Most of the quartz, both in the main fault zone and in the sheared wall rocks, is white and coarse-grained. Some of it contains angular fragments of altered wall rock, and some has a rude comb structure and encloses a few small crystal-lined vugs. The pyrite, with which is intergrown a small quantity of arsenopyrite, is later than the quartz. The vein matter contains some gold. Representative samples from the entire width of weakly sheared rock are said to have contained 0.07 ounce and more of gold to the ton, and Mr. Williams states that he found one small specimen of gold-bearing telluride. A few minute specks of ruby silver and of galena occur in places.

Several hundred feet west of the mill, an 8-foot to 10-foot pyritized fracture zone is exposed in altered shale on the bank of a small stream. This zone, which is probably a split from the main fault, strikes N. 75° E. and dips 60° N. A porphyry dike follows the south wall.

The Euclid deposit is of interest chiefly because its ore is localized along one of the strong faults that characterize the northwestern part of the district. It seems possible that along this and other faults worth-while ore deposits might be found where the wall rocks are more favorable than the Morrison shales. At the Euclid mine, however, the top of the sandstone is more than 500 feet below the surface.

EUREKA-BULLDOZER (5)

The Eureka-Bulldozer mine, on Lewis Creek, was the first mine to develop what is now known as the Gold King vein. The patented Eureka claim adjoins the east end of the Gold King claim, which covers the ground that formerly fell within the unpatented Bulldozer claim (pl. 14). The vein was discovered early in the eighties and was worked intermittently until 1914.

In 1883 the Bulldozer was developed by two open-cuts, 20 and 25 feet long. The Eureka was worked by a 40-foot drift at the bottom of a 50-foot shaft.[9] When the mine was visited by Purington in 1896 the workings amounted to 700 or 800 feet.

The main Bulldozer workings, now part of the Gold King mine and known as the Davie and Water tunnels, are shown in plate 22. The Eureka shaft and adit are just east of the Bulldozer, near the bed of Lewis Creek. They were caved in 1935–37.

The mine is reported to have produced a comparatively large amount of high-grade ore during the first 20 years of its existence. The incomplete production shown in the following table amounts to about $14,000, but it may represent only a minor part of the total production:

Incomplete production, Eureka-Bulldozer mine, 1887–1943 [1]

Year	Mine	Ore (dry tons)	Gold (fine ounces[2])	Silver (fine ounces[3])
1887	Bulldozer		276.5	3,220
1887	Eureka		90	375
1888	do		27.8	132
1889	do		33	208
1890	do		30	370
1904	Eureka-Bulldozer	15	40	200
1913	do	1	1.14	7
1914[4]	do	20	8.62	63

[1] Figures for 1887–90 from annual reports of Director of the Mint; figures for 1904, 1913, and 1914 compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production records for 1891–1901; no production 1902–43 for years not listed.
[2] Computed from dollar value, using gold=$20 to the ounce.
[3] Computed from dollar value, using silver=$0.98, $0.94, $0.84, and $1.05 for 1887–88, 1889, and 1890, respectively.
[4] Also included 30 pounds of copper and 724 pounds of lead.

According to Burchard,[10] the near-surface part of the Bulldozer vein was 5 feet wide, with 4 feet of quartz vein matter. He also says that on the Eureka claim the vein was 5 feet wide and had a 12-inch streak of high-grade ore on one wall. Purington, who saw much more of the vein in 1896 than was exposed in 1883, noted that it ranged from almost nothing to 3 feet in thickness and averaged 18 inches. He also noted that the vein was nearly vertical in the Bulldozer tunnel but dipped 50° N. in the Eureka. The ore, like that of the Gold King vein, contained tellurides of gold and silver, galena, pyrite, and a little chalcopyrite, in a gangue consisting of quartz, chlorite (roscoelite?), and a little fluorite. Some of it contained visible free gold.

[9] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1883, p. 375, 1884.
[10] Burchard, H. C., op. cit (for 1883), p. 375, 1884.

FLORENCE W. (2c)

The Florence W. mine, on the Gold Dollar patented claim, is in a ravine on the west side of the East Mancos River, 1 mile north of Gold Run. The upper adit is less than 100 feet below the county road. Little is known of the mine's history except that it was worked from 1914 to 1916 and had been idle for some years when examined in 1936. It was probably discovered during the present century as it does not appear on claim maps prepared in 1903. The production shown in the following table amounts to about $3,700:

Production of Florence W. mine, 1902–43 [1]

Year	Mining company	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, dry assay)
1914	Gold Dollar Gold Mining Co.	103	79.27	105		422
1915	Florence W. Gold Mining Co.	14	23.94	105		
1916	do	60	67.34	146	85	116

[1] Compiled from mine production records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The main workings are shown in figure 26. A 100-foot inclined raise follows the vein from the lower drift and lacks only about 15 feet of connecting with the upper level. An underhand stope of unknown depth was opened from the upper drift. Most of the ore produced is said to have come from the discovery shaft, whose location is not known but which is presumably near the present workings.

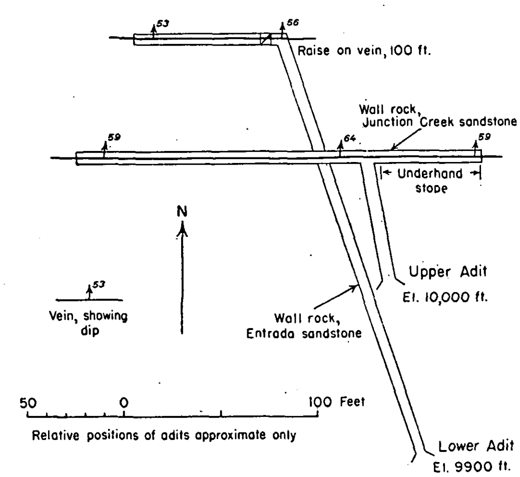

FIGURE 26.—Sketch map of Florence W. mine.

The vein strikes due east, but because of its northerly dip of 53° to 64° its outcrop has a course of about N. 80° E. The claim map (pl. 14), indicates that it intersects the Doctor-Jack Pot, or Kentucky vein, some distance west of the mine. The vein follows a normal fault with a downthrow on the north of between 20 to 30 feet. The lower adit is entirely in Entrada sandstone; the upper adit is in the Junction Creek sandstone (upper La Plata sandstone of former reports). At the top of the raise, according to G. W. Gilmore, Jr., the hanging wall is sandstone and the footwall is shale, so that on the footwall side of the fault the contact between the Wanakah formation and the Junction Creek sandstone must be less than 15 feet below the upper drift.

The vein zone consists of 2½ to 5 feet of brecciated country rock, and particularly near the east end of the present workings it contains much gouge. The vein proper, which is 6 inches to 3 feet in width, is very similar to the Red Arrow vein. It was formed partly by replacement of the breccia and partly by open-space filling. It consists of a coarse intergrowth of quartz, barite, and ankerite containing pyrite and a little tetrahedrite, chalcopyrite, and bornite. The gold in the ore is probably free, though none was seen in the specimens examined. The lead produced in 1914 and 1916 was probably derived from galena.

The tenor of the ore is not known. The production figures cited above indicate that the shipping ore contained from 0.8 ounce to 1.7 ounces of gold and 1 ounce to 7.5 ounces of silver to the ton. Although too little is known of the deposit to throw much light on its possible extent or value, its similarity to the Red Arrow vein would seem to justify thorough re-examination.

GEORGIA GIRL (2b)

The Georgia Girl mine is southwest of the Doyle mine, on the slope between Jackson Ridge and Helmet Peak (pl. 19). It was discovered between 1890 and 1895 and was worked for a few years. It produced little ore, however, and has been idle for many years. In addition to the main adit, which is now caved but which must have been less than 100 feet long, there are several shallow open-cuts and very short adits on the vein.

The main workings are in the Junction Creek sandstone, which is here interfingered with several lenses of shale. The vein follows a strongly sheared and kaolinized porphyry dike, from 5 to 10 feet in thickness. This dike is evidently an offshoot from the irregular mass of porphyry that crops out where the East Mancos River crosses the vein, and this mass in turn is probably connected in depth with the Gibbs Peak porphyry stock.

The Georgia Girl vein is part of one of the most persistent fracture zones in the vicinity of Jackson Ridge. This zone trends nearly due east and can be traced for more than a mile. It is probably not a single continous fracture but a series of closely spaced overlapping fractures. At the main adit the vein strikes N. 86° E. and the dip ranges from 70° SE. to vertical. According to Purington [11] the vein exposed in this adit was 5 feet wide and occupied the whole width of the dike. The sandstone walls were silicified and somewhat impregnated with pyrite. The vein itself consisted of a network of white quartz veinlets, whose interstices were filled with clay and pyrite. Although the ore is said to have been of high grade, it seems likely, from comparison with the better-known pyritic deposits of the Doyle group that the high-grade ore was oxidized and occurred relatively near the surface. Where it cuts the Entrada sandstone below the main county road, the vein trends due east and consists of a 4-foot breccia zone with considerable quartz and a little pyrite; and it is of like character as far east as it can be traced.

[11] Purington, C. W., unpublished field notes, 1896.

GOLD FARM (2a)

The Gold Farm prospect, at altitude 11,750 feet on the north spur of Deadwood Mountain, deserves notice only because it adds to the available knowledge of the distribution of replacement deposits in limy beds. The adit, which was caved in 1936 but is probably not more than 100 feet long, can be reached over the trail between the Bonnie Girl mine and the top of Deadwood Mountain. The workings are at the contact between the Dolores and Cutler formations, which dip toward the north. They expose a replacement deposit in the 7-foot limestone conglomerate bed at the base of the Dolores. In the vicinity of the mine this bed is largely replaced by chalcopyrite, specularite, and garnet. The ore is very similar to that of the Bay City mine. A strong northeastward-trending shear zone intersects a north-south vein near the workings, and this intersection may have been responsible for localization of ore in the limy bed. The northward-trending vein, which is explored by a 100-foot adit at an altitude of 11,910 feet, is a weak fracture zone, 2 to 4 feet wide, containing a 2-inch to 5-inch seam of pyrite-bearing quartz near the middle.

GOLD KING (5)

LOCATION AND HISTORY

The Gold King mine, which did not begin large-scale production until 1927, presents a good example of a telluride vein in altered redbeds and illustrates the relation of the ore deposits to the degree of silicification of the wall rocks, to porphyry sills, and to vein structure. It is situated on the north bank of Lewis Creek, at an altitude of about 10,500 feet. A fairly good road and an aerial tramline connect it with the Gold King mill on the La Plata River, less than 2 miles to the southwest.

The Gold King vein, which is an extension of the vein formerly worked by the Eureka and Bulldozer mines, was discovered by Basil Caramouzis in 1921. During the following five years he did much exploratory work and made several small shipments of high-grade ore. In 1927 the La Plata Mines Co. bought the property and began comparatively large-scale development and production. The old Bonnie Girl or Baker Contact mill, which had not been operated since 1908, was acquired and rebuilt, flotation machinery being added to the original stamp-mill equipment. Several water-power and steam-power plants were tried out unsuccessfully, and a power line carrying electricity

VIEW OF GOLD KING MILL

Shows tailings pile in left foreground and glacial cirques of Silver Mountain in the distance.

supplied by the Western Colorado Power Co. was finally installed. After several years of successful operation the company fell into difficulties, and from 1933 to the end of 1935 the mine was operated on a cooperative basis under a trusteeship. In 1936 it was taken over by the Fawn Mining Co., a Canadian corporation. This company worked it under several managements until the autumn of 1937, when, the developed ore having been exhausted, mine and mill were shut down.

The Gold King mill (pl. 21) was first used in 1928, the ore shipped in 1927 having been hand-sorted crude ore. From 1928 on, both sorted crude-ore and concentrates were shipped. The original mill had been equipped with fifty 1,000-pound stamps, supplemented by six Wilfley tables. The operators of the Gold King added jaw crushers at mine and mill, tube and ball mills, classifier, thickener, and flotation cells. Various combinations of these machines were tried by successive mill superintendents. The mill has a rated capacity of 250 tons, but it was seldom operated at more than one-third capacity. Most of the tailings were retained in five small ponds, two near the mill and three near the mouth of Boren Creek.

The Gold King production is given in the following table:

Production of Gold King mine, 1921–43 [1]

Year	Crude ore produced, short tons	Crude ore and concentrates sold (short tons)	Gold (fine ounces)	Silver (fine ounces)	Lead (pounds, wet assay)	Zinc [2] (pounds, wet assay)
1921		2	5.60	3		
1924		(3)	16.09	30		
1925		9	16.90	87	500	(4)
1927		59	529.14	1,550		
1928	7,000	339.4	1,390.26	12,813	69,630	46,288
1929	19,824	763	5,523.14	81,364	71,000	99,298
1930	(4)	160	48.31	887	721	1,081
1932	2,303	70.2	320.00	3,166	8,283	9,126
1933	457	162	564.61	4,516	7,000	(4)
1934	339	155	582.80	2,884	6,461	(4)
1935	3,436	254	1,034.10	4,756	22,900	(4)
1936	2,866	89	219.30	1,883		(4)
1937	11,900	744	1,529.80	25,395	250,000	(4)
1939	83		225.90	1,351	4,393	(4)
1940	47		117.70	544		(4)
1941	8		13.80	90	12	(4)
Total through 1943			12,137.45	141,349	440,900	

[1] Compiled from mine records of the Bureau of Mines. No production for years not listed.
[2] No payment made for zinc.
[3] 222 pounds.
[4] Not recorded.

The mine workings, including the Davie and Water tunnels of the old Eureka-Bulldozer mine, are shown in plate 22. The mine is worked through a 600-foot crosscut adit, which connects with the east-west Main level about 350 feet below the surface. There are two long drifts above the Main level, known as the Intermediate and Second levels. Four shorter drifts below the Main level were worked through a 400-foot winze. Including principal raises and winzes there are about 6,000 feet of workings in the mine. At the time of examination the two lowest levels were under water, and the Water tunnel and most of the 100-foot level were inaccessible because of caved ground.

GEOLOGIC RELATIONS

Rocks.—The sedimentary rocks exposed in the mine are interbedded shales, mudstones, sandstones, and grits, which dip 2° to 20° W. As shown in plate 2, the main adit of the mine lies above the base of the Rico formation. Although the contact of the Rico and Hermosa formations must lie not far below the Main level, it has not been recognized in the lower workings. One small exposure of red sandy and shaly limestone containing Rico fossils was found on the footwall of the No. 2 level, 130 feet east of the Big winze, but no fossils were found in the hanging wall, and the top of the Rico formation has not been accurately located either underground or in the immediate vicinity of the mine. All available evidence indicates that most of the ore came from the Rico formation, though some was found in the lower Cutler and some almost certainly in the uppermost Hermosa beds. Along most of the vein the rocks are relatively unaltered.

Several porphyry sills, from 1 foot to nearly 200 feet in thickness, are exposed. As shown in plate 22, most of them are very irregular in shape and swell out or cut across the sedimentary strata in many places.

Geologic structure.—A body of breccia, the shape and character of which are not entirely clear, is exposed near the latitude of the main adit on all accessible levels but the No. 2. The breccia is composed of angular fragments of sedimentary rocks. It is thoroughly silicified, and pyrite is abundant in the interstices between the breccia fragments. Its contacts with the adjacent sedimentary strata are gradational in some places, but elsewhere they are marked by fairly well defined fractures. The breccia mass is 75 to 230 feet wide and appears to trend north, at right angles to the course of the Gold King vein. Its walls are nearly vertical, and according to miners who worked in the lower parts of the mine it extends at least as far down as the 300-foot level. Whether it is a pipelike body or represents a northward-trending crushed zone is unknown. The porphyry sills appear to be later than the breccia and to cut through it. This explains the absence of the breccia on the Intermediate level and the presence in several places of intrusive contacts between porphyry and breccia.

The Gold King vein follows a fault that strikes nearly due east and dips 35° to 85° N., its average dip being about 60°. The outcrop has been traced northwestward from Lewis Creek as far west as Amethyst Creek, the first above Ashland Gulch. It should be noted that the Lucky Strike vein, on the west side of the La Plata River, follows the same course. The Sadie vein is almost certainly the eastward extension of the Gold King.

In and near the breccia mass the fracture zone takes an irregular course and is much split up; elsewhere its course is regular, and only a few minor fractures split off into the walls. The main fracture consists of a zone of crushed and brecciated country rock, thoroughly cemented and more or less completely replaced by dense to finely crystalline quartz. In and near the breccia the zone may attain a width of more than 10 feet, though it locally pinches down to 2 inches; away from the breccia its width rarely exceeds 6 inches.

On each side of the breccia mass the wall rocks are lightened in color and silicified for 2 to 10 feet away from the fracture plane, but in other places the silicified zone is less than a foot wide or is entirely absent.

The amount and even the direction of displacement along the Gold King fault have not been determined, because the only recognizable marker bed, the one containing fossils, could not be found on the hanging wall. The difference in form of the porphyry masses exposed in the two walls is such as to suggest a possible vertical displacement of 400 feet or more. But, as there is no other evidence of such a displacement, the writer believes that the fault is probably a small one and that the difference in the shapes of the porphyry masses was governed in part by an older, or preporphyry, fault zone which guided the porphyry magma to some extent.

In summary, the sequence leading to the formation of the vein seems to have been about as follows: Formation of the breccia mass and of an eastward-trending fracture zone; silicification of the wall rocks, particularly of the breccia; intrusion of porphyry; renewed movement along the east-west fault zone; deposition of ore and silica.

ORE DEPOSITS

Ore minerals.—The principal ore minerals of the Gold King mine are tellurides of gold and silver and native gold. The rather high ratio of gold to silver in most of the ore mined suggests that gold-bearing tellurides (krennerite, calaverite, and perhaps sylvanite and petzite) are more abundant than in the specimens examined. In them hessite is by far the most abundant, but one large specimen is rich in krennerite, and small quantities of calaverite and coloradoite are widespread.

Other metallic minerals are native tellurium, pyrite, sphalerite, tetrahedrite, galena, chalcopyrite, myargyrite, pyrargyrite, and cerussite. The gangue is largely white to dark green or gray quartz, accompanied by small quantities of barite, calcite, ankerite, and fluorite. The ore minerals form small irregular masses scattered through the gangue; only in exceptionally rich specimens do they make up more than a small proportion of the ore. Sulfides are the most abundant, the tellurides are next in abundance, and the silver sulfosalts are scarce. Small veinlets and irregular masses of free gold have been found even on the lower levels. Galena is abundant in places, particularly in the flat ore shoot above the No. 2 level.

Ore shoots.—Most of the ore that has been produced was found in an ore shoot closely associated with the breccia mass (pl. 22). Above the Main level this shoot was 250 to 350 feet long and at least 200 feet high. Stope and company assay maps suggest that below the Main level it pitches a little toward the east, but little is known as to its downward extent. No reliable method of predicting where ore is likely to be found within the shoot is known. Wide places in the vein appear to be more favorable than narrow ones. The vein splits and encloses large wedges or horses of wall rock in several places, and thus far minable ore has been found along only one of these splits at any one place. It displays no consistent preference for either the footwall or hanging-wall splits but nearly always follows the steeper of the two.

A smaller ore shoot, which has yielded ore containing more lead and somewhat less gold than the one described, has been exploited above the No. 2 level, east of the breccia mass. This shoot was only 60 to 150 feet high but was about 900 feet long. In and near this shoot the vein is narrower than in the larger shoot, and the wall rocks, which include porphyry, shale, and sandstone, are only slightly metamorphosed. The available evidence indicates that a sharp steepening of the dip of the vein has been a controlling factor in causing localization of ore. This dip ranges from 40° to 60° below the No. 2 level and from 65° to 80° above it.

Tenor.—Few detailed records of the tenor of the ore produced are available. The average gross value of all the ore mined to the end of May 1935 was $13.46 to the ton (gold valued at $35 to the ounce). Some of the ore was much richer than this; for example, one 25-ton carload of sorted crude ore shipped in the spring of 1935 yielded a net smelter return of $9,952. The mill record for 1935 shows that 3,284 tons of ore milled contained 0.11 ounce of gold and 1.00 ounce of silver to the ton, 0.44 percent lead, 0.40 percent zinc, 0.85 percent iron, and 85.0 percent insoluble. This ore yielded 103 tons of concentrates containing 2.95 ounces of gold and 25.40 ounces of silver to the ton, 12.1 percent of lead, 12.0 percent of zinc, 23.0 percent of iron, and 15.9 percent of insoluble. The tails contained 0.016 ounce of gold and 0.20 ounce of silver to the ton. Ore from the smaller shoot that was being milled toward the close of operations in 1937 had a gross value of $5 to $10 per ton. The great increase in lead production for that year probably reflected an improvement in milling methods, as well as a difference in the mined ore. The unmined portions of the vein have not been thoroughly sampled, and the results that have been obtained at different times have been conflicting. One set of records available to the writer and believed to be fairly reliable show that 24 samples taken below the 100-foot level contained from 0.08 ounce to 5.31 ounces of gold to the ton over widths of 8 to 30 inches, and averaged 0.92 ounce of gold over about 20 inches.

SUGGESTIONS FOR FURTHER PROSPECTING

The ore developed by the present workings is evidently almost exhausted, but in view of the relatively large production per foot of development work, search for other ore shoots is tempting. The two ore shoots that have already been discovered and worked occurred at places where the wall rocks were brittle and the vein was steep, and it is reasonable to suppose that other shoots, if they exist, will be found at similar places. Unless geophysical methods can be brought to bear on the problem, it will be difficult, if not impossible, to foretell the location of the most likely places in advance of actual development.

The breccia mass described above is the most brittle and hence the most favorable wall rock known in the mine. Exploration in this breccia in search of other possible splits of the Gold King vein would seem to be justified. Further exploration in depth, particularly within and near the breccia, would also seem to be justified. The Hermosa beds should certainly prove to be at least as favorable as the overlying Rico beds which have yielded most of the ore produced in the past. It is not known positively that the vein is continuous between the productive Eureka-Bulldozer and the Sadie mines, but available information justifies a search for this part of the vein. The possibility of finding ore at the junction of the westward extension of the Eagle Pass and the Gold King veins should be investigated, and so should the probable westward extension of the Gold King vein itself. If any such exploratory campaign is undertaken, it should be done with the full realization that it is highly speculative and that ore shoots, if they exist at all, may be small and therefore likely to be missed entirely.

GOLD KING-SWAMP ANGEL

The Gold King-Swamp Angel group of claims is between Fassbinder and Leavenworth Gulches. Its relation to the Wheel of Fortune group is shown in figure 49. The Gold King, Swamp Angel, and Bobtail claims, which make up the group, were among the first claims to be patented in the district. According to Dan Cason, of Durango, the mine produced some native gold and copper and a little native mercury, but in what quantity is not recorded. In 1902, shortly after the discovery of the Neglected mine, the Gold King was reopened and somewhat developed but produced no ore.[12] The country rocks in the vicinity of the mine are unmetamorphosed redbeds of the Cutler formation, with which several thin sills of porphyry are associated. The vein was developed by several adits, but all of them were caved in 1936, so that the vein could not be examined. Its course, according to the claim map (pl. 14), is about N. 80° E., and it is apparently an extension of the Oro Fino vein.

[12] Min. and Sci. Press, vol. 85, p. 136, 1902.

GOLD WEDGE (5)

The Gold Wedge vein, on the patented Gold Wedge and St. John claims, is apparently the northeastward extension of the Aurora vein. The workings are on the north slope of the ridge between the Bessie G. and Aurora mines, at an altitude of 11,475 feet. They can be reached over a branch from the Bessie G.-Columbus Basin trail. The vein was discovered early in the history of the district and produced an unknown quantity or ore. Purington does not mention it in his notes for 1896, and it had been idle for many years when visited in 1937. It was worked by at least two adits, both of which are caved.

On the north slope of the ridge near the mine, the outcrop of the vein trends N. 55° E. At the top of the ridge its course swings to S. 80° W., but how much of the swing is due to dip and how much to actual change in direction is not known. The continuation of the vein west of the ridge is known as the Aurora vein.

According to Burchard,[13] the mine was worked in 1883 by two drifts, 60 and 70 feet long. He states that the vein contained 11 inches of ore that yielded from $75 to $190 gold and silver to the ton in carload lots, 80 percent of the value being in gold. Blocks of ore now on the dumps show that parts of the vein are at least a foot wide. The vein matter consists of white to greenish-gray granular quartz containing specks of galena, pyrite, arsenopyrite, and telluride minerals. A few tiny vugs are lined with clear quartz crystals and with minute crystals of light-brown ankerite. A representative sample of vein matter from the dumps was collected for assay. It yielded 0.90 ounce of gold and 7.28 ounces of silver to the ton.

GOOD HOPE (5)

The Good Hope mine, on the patented Good Hope claim, is about 1,200 feet west of Eagle Pass, on French Gulch, a tributary to Lewis Creek. The principal workings are 50 feet below the Eagle Pass trail, at an altitude of 10,400 feet. These, or other workings on the westward extension of the vein, have been known at various times as the Excelsior, Yankee Boy, and Jessie May. The Good Hope is an old mine, and almost nothing is known of its production except that it produced $183 in gold and $187 in silver in 1887 [14] and produced nothing from 1902 through 1940. In 1941 it produced 3 tons of ore that yielded 4.90 ounces of gold, 164 ounces of silver, and 68 pounds of copper. There was

[13] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1883, p. 370, 1884.

[14] Munson, G. C., in Kimball, J. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1887, p. 172, 1888.

an open-cut on the vein, and a short crosscut adit from which drifts were probably opened on the vein.

The country rock is largely sandstone and shale of the Cutler formation, but a porphyry sill is exposed just north of the open-cut. The rocks are unaltered except close to the vein, where they are silicified. The vein strikes N. 80° W. and dips steeply north. As was noted in describing the Eagle Pass vein, the Good Hope is probably on the extension of the Jennie Lind vein system. In the open-cut it occupies a fracture zone 10 feet wide. The country rocks in the fracture zone are iron-stained, indicating the former presence of pyrite, and the vein matter consists of a few streaks of quartz and barite. According to Purington, the vein exposed in 1896 consisted of four stringers of quartz in the sandstone, thought to be of promising width. He states that the ore was similar to that from the Durango Girl and other mines in Walls Gulch, consisting largely of gold telluride in quartz and containing a little sulfide.

GRAND VIEW (2b)

According to Purington,[15] the Grand View prospect was situated on Bragdon Ridge at an altitude of 11,250 feet. It was 1,500 feet east of the Tip Top claim of the present Monarch group, and occupied part of the area that is more fully described here as the May Rose mine. Purington states that the prospect explored a northeastward-trending zone of pyritized and decomposed porphyry, which was referred to as a "vein." According to information given to him by local miners, the altered porphyry as a whole was said to average $0.05 to the pan in gold.

GRAVES (2c)

The Graves mine is east of and above the Southern Boy, on the east side of the La Plata River and south of Burnt Timber Creek. Much work has been done on the property over a period of several years, but very little ore has been produced.

Two veins have been explored. One of them strikes N. 10° to 20° E. and is nearly vertical. It is developed by a series of adits and open-cuts on the south side of Burnt Timber Creek that expose the vein at several places between altitudes of 9,200 and 9,700 feet. None of these openings is more than 200 feet long. The vein occupies part of a 3-foot to 10-foot silicified fracture zone. The main zone sends off several branches that strike about N. 30° E. In some places the vein is a mere film but parts of it are as much as 12 inches thick. It consists of dense quartz, much pyrite, some chalcopyrite, galena, tetrahedrite, and large quantities of ankerite, which weathers dark brown or black. Crystals of quartz and calcite line vugs. In places the quartz, ankerite, and sulfides occur in alternate bands; elsewhere the sulfides and ankerite form irregular masses in the quartz.

[15] Purington, C. W., unpublished field notes, 1896.

The second vein strikes N. 38° E. and dips steeply northwest. It probably intersects the first about 1,500 feet south of Burnt Timber Creek. It is either the northeastward extension of the Little La Plata-Red Cloud vein, developed by the Lady Eleanora mine, or a closely parallel one. It lies within a 5-foot fracture zone and is 1 foot to 2 feet wide. It is made up of strongly sheared country rock, traversed by streaks and veinlets of cream to light-brown dense quartz intergrown with coarsely crystallized barite. Galena, pyrite, and ankerite fill interstices in the barite. Some of the ore is oxidized and contains free gold.

GREENHORN

The Greenhorn prospect is close to the La Plata River and about 500 feet north of the mouth of Darby Creek. It has been inactive for many years and apparently never produced any ore. It was developed by two short adits, one on each side of the river. The country rocks, believed to belong to the upper part of the Hermosa formation, are strongly silicified. Several eastward-trending dikes of diorite and of diorite-monzonite porphyry are exposed near the prospect. The vein is vertical and strikes N. 81° E. According to Purington, it consists of a 6-inch to 18-inch belt of stringers of dark-gray quartz, associated with calcite and barite. Purington noted very small crystals of what he took to be realgar enclosed in the calcite. The vein matter was reported to contain $19 worth of silver to the ton. Several other parallel veins and fracture zones occur near the Greenhorn, but none of them have been prospected to any extent, and none appear to be particularly promising.

HIDDEN TREASURE

One of the mines called the Hidden Treasure is believed to have been near the Daisy-Hibernia group of mines, already described. According to the report of the Director of the Mint for 1883, it was on the center fork of Lightner Creek and was worked along a 5-foot vein in a porphyry dike. The ore-bearing part of the vein, said to have been 4 feet wide, consisted of white quartz enclosing galena, sphalerite, pyrite, and argentite. The deposit was worked through a 25-foot shaft and a 12-foot adit, and the ore is reported to have yielded from 20 to 300 ounces of silver and 0.1 to 0.6 ounce of gold to the ton.

HIDDEN TREASURE (TIRBIRCIO CREEK) (5?)

The Hidden Treasure mine on Tirbircio Creek, near the mouth of Schurman Creek, can be reached by a trail which follows that stream from the Gold King mill. This is believed to be what Burchard,[16] in the report of the Director of the Mint for 1883, called the Heck mine. The deposit was worked by two adits on the north bank of Tirbircio Creek. Both adits are now

[16] Burchard, H. C., op. cit. (for 1883), p. 375, 1884.

caved, but they must have had a total length of several hundred feet.

The lower adit is near the top of the thick porphyry sill that is exposed near the mouth of Tirbircio Creek, and the upper adit is in silicified redbeds of the Cutler formation that overlie the porphyry. The vein follows a strong, eastward-trending fracture zone that is probably an eastward continuation of the Honeydew zone. All the rock on the dumps is brecciated and iron-stained, and there is much soft gouge. White to gray quartz with pyrite and a little galena can be seen in places. According to V. H. Steele, of Hesperus, the workings followed irregular courses through a broad breccia zone in search of the vein, which was never found. He states that only the gouge contained values. A large sample of the gouge, taken by Mr. Steele was concentrated 10:1 by panning, and this concentrate yielded 170 ounces of gold to the ton; that is, the original sample must have contained about 17 ounces of gold to the ton. These figures are in accord with those reported by Burchard for the Heck mine. He says that the mine worked a 3-foot pay streak rich in tellurides. Shipments in several-ton lots are said by Burchard to have yielded $537 to the ton for first-class ore and $135 for second-class ore. There are several other veins between Schurman Creek and the mouth of Tirbircio Creek. They all trend nearly due east and probably are similar in character to the Hidden Treasure, but the little prospecting that has been done on them has apparently been disappointing.

HONEYDEW (2c)

The Honeydew prospect, originally known as the Del Rey, is in some respects one of the best situated in the district for exploration of possible replacement deposits in the Hermosa formation. It is on the west bank of the La Plata River, opposite the mouth of Boren Creek and just north of the town of La Plata. It has been worked several times since its discovery in the early nineties but has produced only a few dollars worth of ore.

The deposit has been explored by means of several short adits and by two shafts, 60 and 100 feet in depth. A 100-foot crosscut was run from the bottom of the 100-foot shaft. Both shafts were full of water in 1935–37.

The country rock near the mine is diorite-monzonite porphyry, part of the thick crosscutting body that is exposed along the La Plata River from La Plata to a point above the Gold King mill. A thin wedge of silicified shale, believed to belong to the lower part of the Cutler formation, is exposed near the mine. The thickness of the porphyry is not known. It is an irregular crosscutting body in places and may indeed be stocklike in the vicinity of the Honeydew. (See pl. 2.) Even if the base is sill-like, there is no reliable information regarding the depth to the Hermosa formation, which, however, must be at least 500 feet below the surface.

Above the mine, on the ridge between Spencer Gulch and Schurman Creek, there are several porphyry sills, interlayered with metamorphosed rocks of the Cutler formation.

The Honeydew is in a broad eastward-trending fracture zone. Most of the fracture strike N. 70° E. to due east and are nearly vertical. The rock is thoroughly brecciated along some of the major fractures, a few of which give evidence of minor faulting with downthrow on the south. Throughout a belt several hundred feet wide the porphyry is strongly sericitized and contains innumerable fractures, many of them filled with veinlets of pyrite-bearing quartz enclosing a little galena and chalcopyrite in places. The stronger fissures, which are from 6 inches to 2 feet in width, contain quartz veins comparatively rich in pyrite, "steel" galena, chalcopyrite, sphalerite, and tetrahedrite. The quartz is cut by veinlets and veins of pink to buff ankerite up to 1 inch in width. Most of the quartz is white like the quartz typical of pegmatites, but some is clear and some is mixed with dense chalcedony. In places irregular masses of white to pink orthoclase as much as 2 inches in diameter are intergrown with the quartz and give the vein matter a pegmatitic aspect. Locally, sulfides make up more than 50 percent of the vein matter.

The 60-foot shaft was sunk on one of the veins mentioned above. This vein is said to have been 2 feet wide near the bottom of the shaft and to have yielded a small lot of sorted ore that contained copper, lead, silver, and a little gold. A nearly horizontal fault was cut near the bottom of the shaft, and the vein was lost. The 100-foot crosscut from the 100-foot shaft traversed a complex series of fault fractures and found little or no ore.

Too little is known of the Honeydew deposit or of its general geologic relations to justify predictions as to the possibility of finding workable ore bodies in depth. The presence of base-metal deposits in a strong fracture zone in rocks not far above the Hermosa formation indicates, however, that replacement bodies may have been formed in the Hermosa limestone, and cautious exploration, either by shaft or by diamond drilling, seems justifiable. It should be clearly understood, however, that there is at least an even chance that the porphyry body is stocklike in character and may extend to great depths. Whether or not there are replacement bodies in the limestone, it is possible that workable deposits of base-metal ore might be found at favorable places along some of the vertical veins.

INCAS (5)

HISTORY AND PRODUCTION

The Incas mine, known also as the Van Emmett property, is on the southeastern slope of Ohlwiler

Ridge, most of the workings being between 10,500 and 11,000 feet in altitude. The mine can be reached over a good pack trail from the May Day mine. Although it has been one of the heaviest producers in the district, the mine was not discovered until 1909. The greater part of its total production of more than $250,000 was taken out before 1913, and no ore has been produced since 1922. During 1936 and 1937 a 500-foot crosscut adit was driven by the Nugget Gold Mines Co., of Denver, in an effort to develop the Incas veins at lower levels.

None of the productive workings were accessible in 1936, and the following account is based in part on a private report by C. A. Chase and on conversation with Dan Cason, who made the first discovery. Cason's work was confined to a shaft sunk at the intersection of a northward-trending vein with the north wall of an east-west porphyry dike. The results were encouraging, but none of the bonanza ore that characterized the Incas deposit was uncovered. Later a Mr. Avery, working on a lease from Cason, drove an adit on the south side of the dike and discovered a rich "blanket" deposit in the Pony Express limestone in a raise above the adit. At the height of the mine's activity, 100 head of horses and mules were used to transport ore and supplies. The total production is shown in the following table:

Production of Incas mine, 1909–43 [1]

Year	Ore sold or treated (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)	Average tenor in gold (ounces to the ton)
1909	9	11.92	32	148		1.32
1910	1,579	2,350.66	3,320	79		1.49
1911 [2]	4,008	6,441.51	5,969			1.60
1912	1,109	1,697.77	2,186			1.53
1913	28	22.58	1,139	66	688	.8
1914	519	744.47	917			1.43
1916	7	33.62	45			4.8
1917	84	94.79	102			1.13
1921	395	576.50	569			1.46
1922	236	242.10	225			1.03
Total	7,974	12,205.92	14,804	293	688	

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.
[2] Includes a small production from Gold Coin claim.

The main workings are shown in figure 27. In addition to them, the whole southeast slope of Ohlwiler Ridge is dotted with the dumps of caved prospect adits

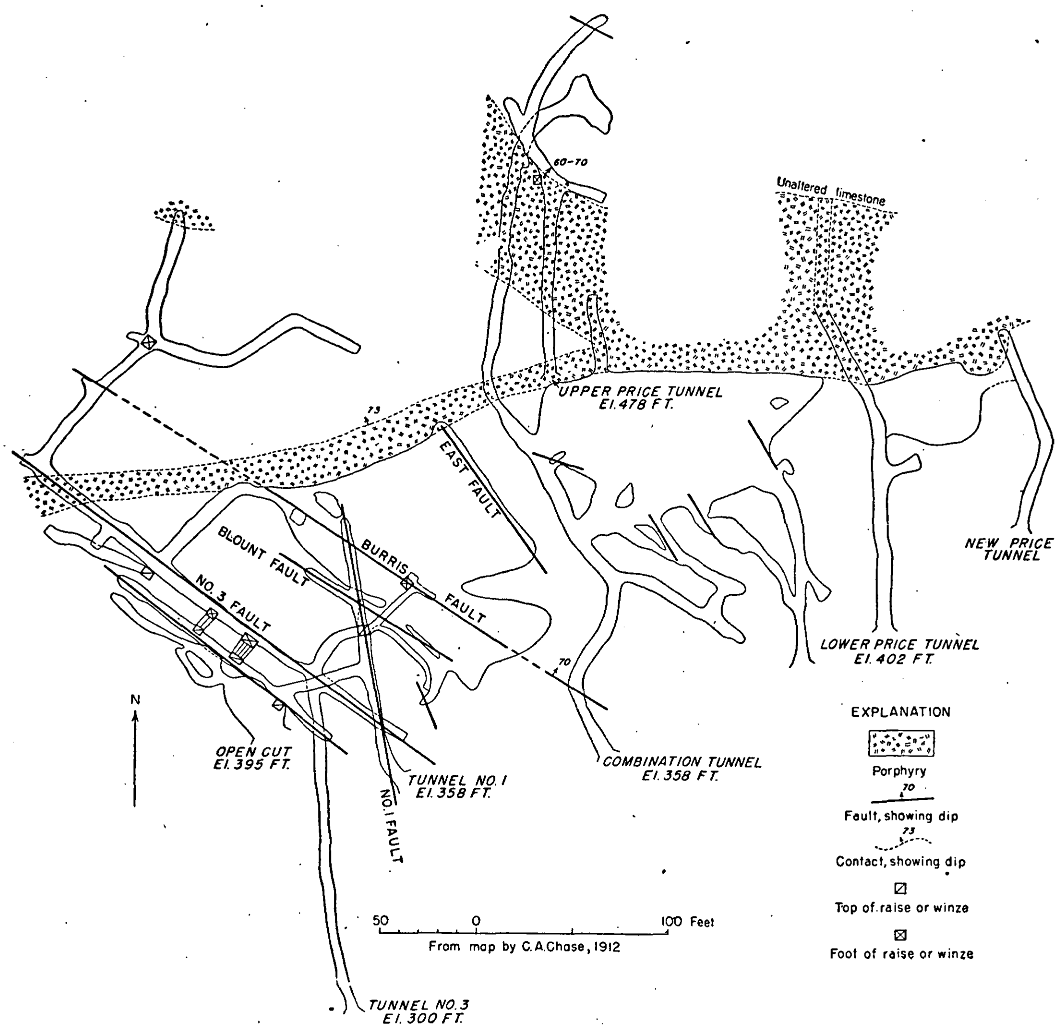

FIGURE 27.—Plan of principal workings, Incas mine.

and shafts, which are especially numerous along and near the outcrop of the Pony Express limestone. The only old adit that was accessible in 1936, known as the Miller tunnel, is shown in figure 28. The adit recently driven by the Nugget Co. is at an altitude of 10,700 feet. It was 500 feet long in 1937 and trends N. 5° W.

GENERAL GEOLOGIC RELATIONS

As the smooth, grass-covered slope of Ohlwiler Ridge reveals but little as to the underlying geologic relations, those shown in plate 2 are highly generalized. In essence, it may be said that the normal succession of beds ranges from the upper part of the Dolores formation

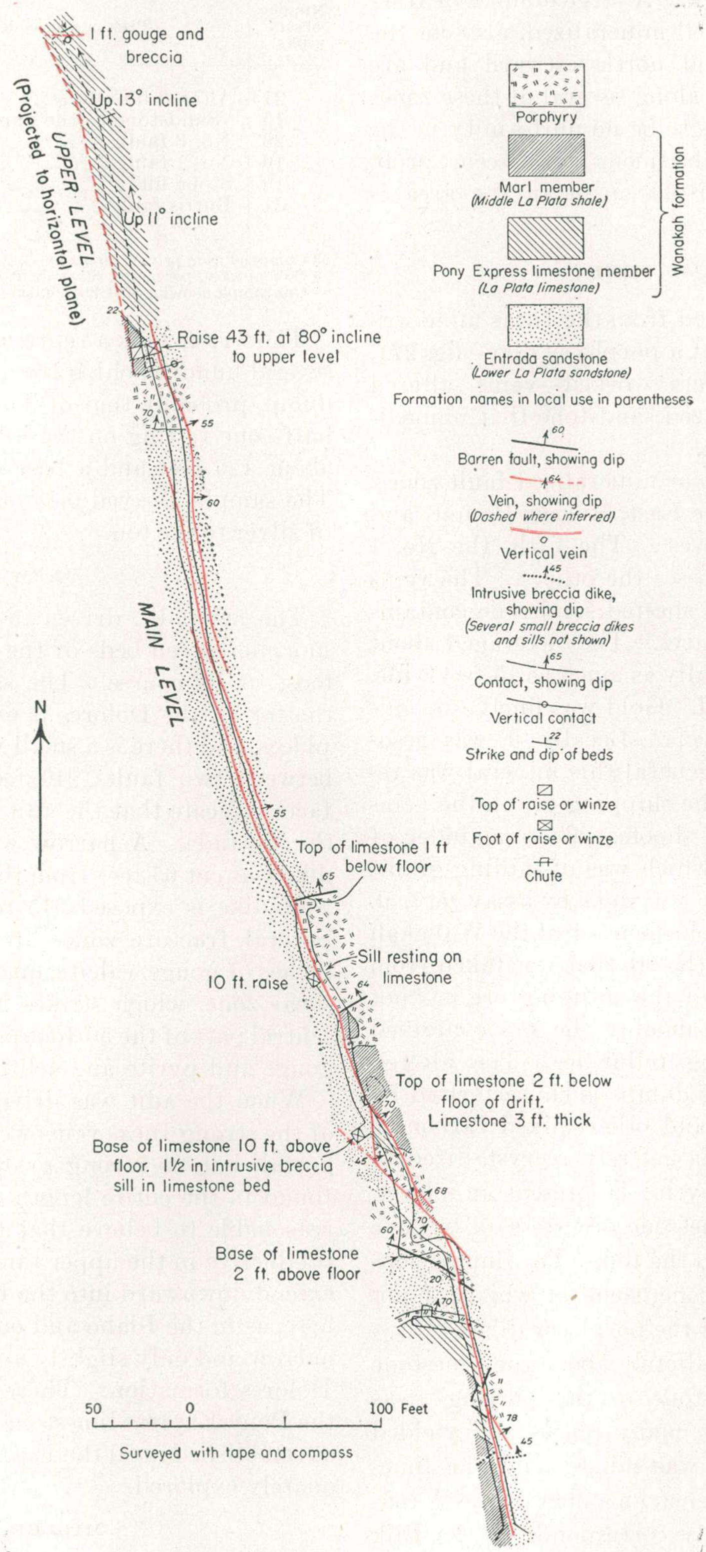

FIGURE 28.—Plan of Miller tunnel, Incas mine. The complex geologic regulations shown on the map are probably typical of a large part of Ohlwiler Ridge.

through the Junction Creek sandstone. The beds dip about 20° SW. A series of porphyry dikes, from 5 to 100 feet in thickness and having a general northwesterly trend, cut the sedimentary rocks. At least 10 such dikes are exposed in the bed of Little Deadwood Gulch, but, as other exposures are largely lacking, most of them are not shown on plate 2. A large number of fracture zones, some of them well mineralized, also cut the rocks. Most of them trend northwestward and are nearly vertical. The rocks along several of these zones are faulted, but there seems to be no uniformity in the direction or amount of displacement and it seems probable that the net fault displacement in the area is negligible.

MAIN INCAS MINE

Nearly all the ore produced from the Incas mine was taken from the south side of a porphyry dike (fig. 27). Three types of deposit were worked—veins, altered limestone, and the mineralized sandstone that immediately overlies the limestone.

There are five main veins or mineralized fault zones. Four of them, known as the East, Burris, Blount, and No. 3 faults, strike northwest. The fifth, the No. 1 fault, strikes north and crosses the others. The veins consisted of brecciated and sheeted sandstone containing a few seams of vein quartz. They averaged about 3 feet in width but were locally as much as 15 feet wide. The walls were well-defined. Gold was finely disseminated throughout the breccia. Locally it was associated with pyrite, but in general this mineral was regarded as unfavorable. The shipping ore in the veins was found in short vertical shoots. The remainder of the vein material, most of which was of milling grade, was not mined. All mining was done by assay control.

The Pony Express limestone member of the Wanakah formation yielded much of the ore that was taken from the Incas. The character of the shipping ore has not been recorded, though presumably the ore contained free gold and gold-bearing tellurides. The altered limestone seen on the Incas dumps is characterized by an abundance of ankerite and other mixed carbonate minerals, and much of it is entirely recrystallized to brown marble. A little pyrite is present in places. Several carloads of the limestone ore are said to have yielded 10 ounces of gold to the ton. The dumps contain much unaltered limestone, some of which, if not all, was taken from north of the porphyry dike.

A bed of sandstone immediately above the limestone and known as the "sandstone to the parting" was crushed and mineralized in many places and yielded much ore. Presumably it was mined with the limestone. It is overlain by the marl member of the Wanakah formation and probably corresponds to the Bilk Creek sandstone member as defined by Goldman and Spencer (pp. 28–29).

The following table shows average assay of samples taken by C. A. Chase in 1912 from the different deposits. Some of the ore represented by these samples was doubtless removed between 1912 and 1922.

Average results of sampling, Incas mine [1]

Number of samples	Place or type of deposit	Thickness (feet)	Value [2]
21	Altered limestone	1. 8	$9. 75
15	"Sandstone to the parting"	3. 0	5. 60
26	No. 3 fault	3. 5	[3] 9. 60
10	No. 1 fault	3. 7	18. 00
19	Stope fill	--------	10. 40
31	Burris fault	3. 2	15. 00

[1] Compiled from private report by C. A. Chase, 1912.
[2] Gold at $20.67 per ounce, silver about $0.61.
[3] One sample showing $164.40 excluded from average.

The writer took a representative sample consisting of several hundred chips from various parts of the largest dump, probably that of Tunnel No. 3. The dump is a half-cone resting on the hill slope and has a height of about 125 feet and a base diameter of about 100 feet. The sample assayed 0.43 ounce of gold and 0.29 ounce of silver to the ton.

NEW ADIT

The new adit, driven in 1936–37, traverses unmetamorphosed red beds of the Dolores formation through most of its course. The salmon-colored sandstone at the top of the Dolores is exposed in the roof in a few places, and there is a small wedge of Entrada sandstone between two faults 240 feet from the portal. These facts indicate that the adit is not far below the base of the Entrada. A narrow westward-trending porphyry dike was cut 65 feet from the portal, and a 50-foot east-west dike is exposed 315 to 365 feet from the portal. Several fracture zones are marked by 1/8 inch to 10 inches of gouge, calcite, quartz and pyrite; and a 5-foot shear zone, which strikes N. 75° E. and traverses the central part of the 50-foot porphyry dike, contains much gouge and pyrite and a little quartz.

When the adit was driven, it was believed that one of the strong Incas veins would be cut 370 feet from the portal, but no strong or well-mineralized veins were found in the entire length of 500 feet. Although it is reasonable to believe that the various veins that were productive in the upper sandstone (Bilk Creek) should extend downward into the Entrada, it seems likely that here, as in the Idaho and other mines, the fractures are narrow and only slightly mineralized in the underlying Dolores formation. Therefore the lack of ore beneath the Pony Express limestone member cannot be regarded as established until the Entrada sandstone has been adequately explored.

MILLER TUNNEL

The geologic map of the Miller tunnel (fig. 30), which is several hundred feet southwest of the main Incas workings, indicates the complexity of the relations that is believed to exist beneath much of Ohlwiler Ridge.

The adit follows a strong northward-trending fault zone, along which the rocks are more or less crushed and which contains much gouge and some calcite, quartz, and pyrite. The fault is down thrown on the east, or hanging wall, but as several cross faults complicate the picture, the total displacement is not known. In a large part of the adit, the upper part of the Entrada forms the wall rock. The Pony Express limestone member of the Wanakah, here about 3 feet thick, is exposed in a few places on the main level and is more extensively exposed on the short inclined upper level. In places it is unmetamorphosed, but elsewhere it is recrystallized to coarse-grained mixed carbonate similar to that described above as occurring in the main Incas workings. The marl member of the Wanakah is exposed in a few places. Several irregular dikes and sills of porphyry are present. Many small dikes and sill-like bodies of intrusive breccia, most of them less than 2 inches thick, cut the country rocks. They are made up of angular fragments of country rock in a strongly sericitized and kaolinized matrix. Most of the fragments came from the adjacent wall rocks, but the breccias include some foreign material that must have been intruded from some distance. Apparently no workable ore was found along the fault zone or in the limestone bed.

SUMMARY

Most of the ore taken from the Incas mine in the past came from near the common intersection of vertical veins with an eastward-trending dike and the Pony Express limestone member of the Wanakah formation. Several similar intersections that have been prospected on Ohlwiler Ridge do not contain workable ore deposits, however, and the cause of ore localization in the area is still unknown. In spite of this, and of the fact that there are already many prospect openings on the ridge, further exploration appears to be justified, both along the limestone horizon and along veins that cut the sandstone beds. Even if no deposits of high-grade ore are found, considerable tonnages of milling-grade ore may be discovered. The dumps of the old workings seem to deserve thorough sampling.

IRIDOS (5)

Except for a brief description by Burchard [17] nothing is known of the Iridos mine, which was situated on the southeast slope of Chicago Gulch. It is said to have explored partly a large vein, striking N. 75° E., of which only the footwall was exposed. A shaft exposed a 4-inch to 8-inch vein throughout its depth of 70 feet. The ore contained gold amalgam and native mercury in considerable quantity.

IRON KING (2c)

The Iron King prospect is on the south bank of Burnt Timber Creek, 2,300 feet above its mouth. It is on the Iron King claim, which is part of the Lucky Four group. It has produced little or no ore.

As shown in figure 29, the property is developed by a 300-foot crosscut adit from which a 300-foot drift was turned on the vein. There are two short side drifts and three raises, none more than 20 feet in height.

[17] Burchard, H. C., Rept. of the Director of the Mint upon the production of the precious metals in the United States, 1883, pp. 370, 371, 1884.

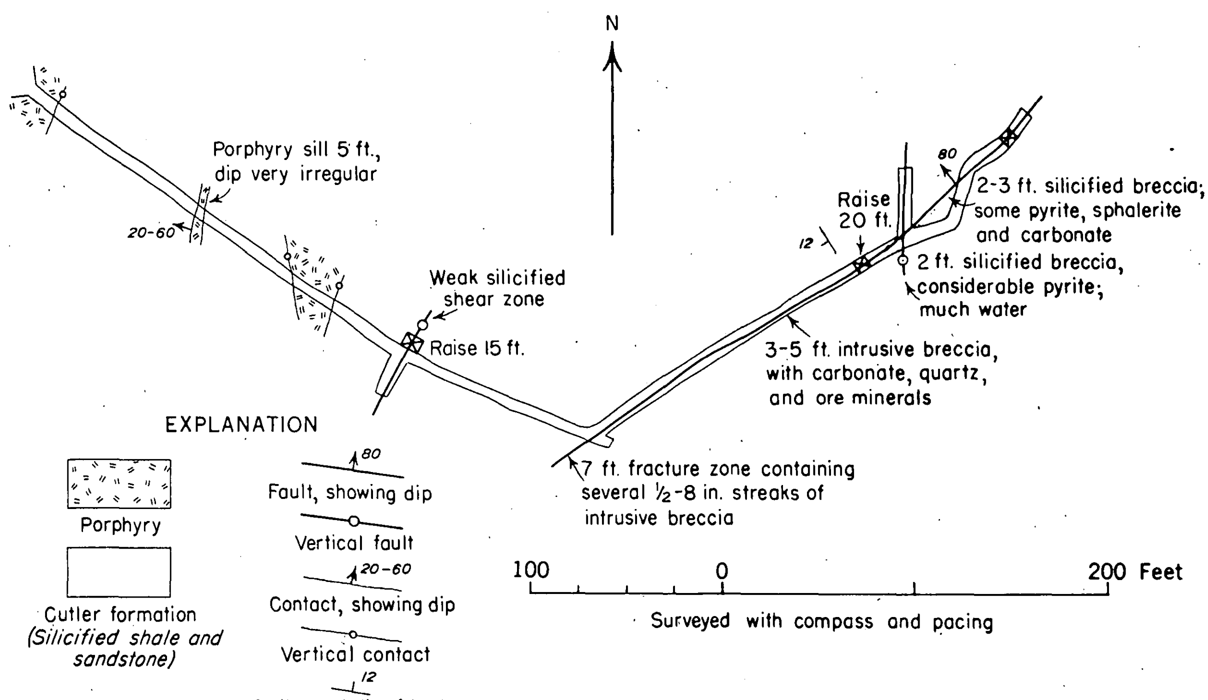

FIGURE 29.—Plan of Iron King prospect.

With the exception of two vertical dikes and a thin irregular sill of coarse-grained porphyry, shown in figure 29, all the country rocks are silicified shale and sandstone of the Cutler formation. The beds dip southwest and at low angles. The drift exposes a strong fracture zone 2 to 7 feet wide, that strikes N. 40° to 56° E. and 80° to 90° NW. The country rocks are strongly brecciated throughout the zone. In most places fragments of the adjacent rock make up the breccia, but locally, as near the west end of the drift, fractures ½ inch to 8 inches in width are filled with intrusive breccia. This material is composed of angular to subrounded fragments of shale and sandstone, set in a matrix of finely comminuted material of the same type. Variations in color and texture of the constituents leave no doubt that the breccia contains material from several different beds and that it was intruded. Both kinds of breccia are thoroughly silicified and are veined with quartz. Pyrite is widespread as veinlets, small irregular masses, and disseminated crystals.

In places the breccia contains irregular lenses of vein matter that range from less than ½ inch to more than 6 inches in thickness. They are made up in large part of white to clear quartz. White bladed barite is intimately intergrown in places with the quartz. Fine crystals of pink to brown ankerite coat fracture planes and breccia fragments and impart a dark-brown to black color to the weathered ore on the dump. Pyrite is associated with the quartz but is no more abundant in the quartz than in the enclosing breccia. Clear, light yellowish-green sphalerite is the most abundant sulfide mineral in the ore. It forms irregular masses as much as 6 inches across in the quartz, many of them surrounded by thin aureoles of galena. Galena also occurs alone as tiny blebs in the quartz and barite. The ore has a consistently low proportion of sulfide to gangue, and probably would not pay to work unless it contained appreciable quantities of gold or silver. The lack of previous production and of stoping strongly indicates that the gold and silver contents were low.

JENNIE LIND (5)

The Jennie Lind mine, on the patented claim of the same name, is near the head of Walls Gulch, a few hundred feet southeast of Eagle Pass. It was discovered in the late eighties or early nineties, and parts of the vein have since been worked from time to time. There is no record of its production prior to 1901, but as the ore was unusually rich, the early production was presumably several times as great as the $4,000 or so that has been taken out since 1901.

The principal mine workings consist of three drift adits, each 200 feet or more in length, about 100 feet apart vertically. The lower adit (fig. 30), at an elevation of 11,225 feet, was the only one accessible in 1937. It was apparently driven after 1896, as Purington mentions only the two upper adits in his notes. There is only one small stope above the lower adit, and the vein there is decidedly weak. It seems likely, therefore, that most of the ore produced came from the upper levels. Several short adits and shallow open cuts provide discontinuous exposures of the southeastward extension of the vein as far as the divide between Foin and Walls Gulches.

Production of Jennie Lind mine, 1901–43 [1]

	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1901	49.6	83.41	559
1904	.75	6.28	71
1909	.75	4.61	43
1912	.5	.79	8
1913	17.0	39.98	[2] 295
1914	1.0	1.42	12
1922	.5	14.50	223

[1] Production for 1901 from Report of Colorado State Bureau of Mines for 1901, p 264, 1902. Production for 1902–43 compiled from mine records of the U. S. Geologica Survey and the Bureau of Mines. No production for years not listed.
[2] Also produced 102 pounds of copper and 465 pounds of lead.

Exposures are poor in the upper part of Walls Gulch, and little definite information can be obtained about the general geology or the character of the ore deposit. The country rocks are southward-dipping redbeds of the Cutler formation cut by several dikes and sills of igneous rock. The igneous rocks range from typical diorite-monzonite porphyry through dense dark-colored porphyry to equigranular diorite. The different types grade into one another in places, and it was necessary to class all the igneous rocks as diorite-monzonite porphyry on the maps (pl. 2 and fig. 30). The country rocks are relatively unaltered except near the vein, where they have been silicified and pyritized. In the lower adit the relations between porphyry and sedimentary rocks, which are here largely arkosic sandstone, are not clear. The few surface exposures make it seem likely, however, that the porphyry is in the form of an irregular dike enclosing lenses of sandstone.

East of the mine the Jennie Lind vein strikes about N. 82° W., but it swings to a N. 60° W. trend near the mine from which it can be traced nearly to its intersection with the Eagle Pass vein. As pointed out in the description of the Eagle Pass mine, the intersection is probably just below the caved adits on the east side of Eagle Pass. The Good Hope vein appears to be the westward extension of the Jennie Lind vein zone. This interpretation of the vein relations is based on scanty information and may be subject to correction. The dip of the vein is irregular. In the lower adit it ranges from 85° S. to 70° N.; farther east it is steep and everywhere to the south. Purington notes that in the upper adit the vein dips 70° S. but that in the middle adit the dip was 30° N. He believed that the two adits were on different veins.

The lower adit exposes a continuous fracture zone from 2 to 7 feet wide. Two weak splits occur at places where the vein changes direction, and two parallel,

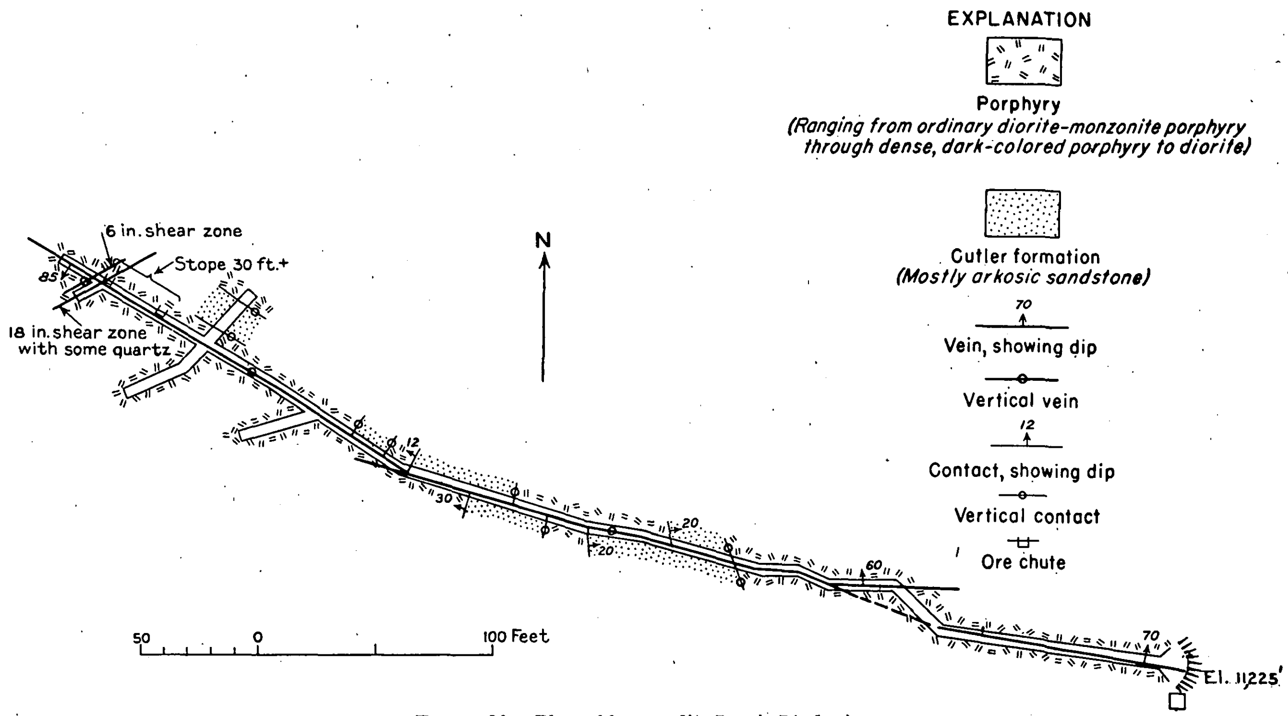

FIGURE 30.—Plan of lower adit, Jennie Lind mine.

northeastward-trending shear zones containing a little vein quartz cross the vein near the breast of the adit. The rocks within the fracture zone are thoroughly silicified and contain a little disseminated pyrite. Narrow streaks of clear to white granular quartz are present here and there throughout the zone, but no ore minerals were seen at any place on the adit level. On the dump, however, there are several tons of good ore, undoubtedly taken from the small stope near the breast. The ore seen is an intergrowth of gray granular quartz with white, bladed barite. Some of the quartz is vuggy and has a greenish cast, like the telluride-bearing quartz of the Gold King and other mines. The only metallic minerals seen in the specimens examined are galena and a little pyrite and light-brown sphalerite. The galena, which is rather coarsely crystallized, forms discontinuous streaks and blebs in the quartz and barite. It seems to favor the quartz but may occur anywhere within the vein matter. The width of the vein is not known. The ore shoot worked in this stope was almost certainly controlled by the northeastward-trending cross fractures.

The ore seen by Purington in the upper levels in 1896 consisted of dark-gray quartz that contained two species of telluride minerals. The pay streak was nowhere more than 3 inches wide.

In a 50-foot adit at 11,000 feet, below the lower adit of the main workings, the vein consists of 6 to 18 inches of pyrite-bearing quartz in a 15-foot shear zone. Eight hundred feet east of the lower adit portal the Jennie Lind vein crosses a strong northeastward-trending vein, which is rather extensively opened up farther to the southwest. The latter vein contains 4 feet of quartz at the intersection, but the Jennie Lind vein is very weak. One hundred feet east of this crossing a small cut exposes a 6-inch to 10-inch quartz vein that contains, by volume, 20 to 40 percent of galena. Three hundred feet farther east there are two small cuts on the vein. Two-thirds of the 3-inch to 9-inch vein is made up of moderately coarse grained mottled green and white quartz, similar to the high-grade "shipping" ore from the Gold King except that it contains somewhat more roscoelite. The remaining third of the vein matter is white sugary quartz with blebs and lenses of coarsely crystallized galena. The appearance of the ore suggests that it is of high grade, but its tenor is not known.

There are indications that pockets and small shoots of ore, rich in tellurides or galena or both, may possibly be found along the Jennie Lind vein. Intersections with cross fractures are probably the most promising places for prospecting. The probable intersection with the Eagle Pass vein, not far east of Eagle Pass, seems to deserve special attention.

J. L. RUSSELL-JIM SMITH (5)

The J. L. Russell vein is about 250 feet southeast of the Aurora-Gold Wedge vein and nearly parallel to it. In the report of the Director of the Mint for 1883, Burchard [18] states that it contained a 3-inch pay streak rich in tellurides and free gold. There is no record of production. The mine workings, none of them extensive, were inaccessible in 1937. The vein crops out prominently on the ridge between Ruby and Heffernan Gulches where it occupies a 2-foot to 3-foot iron-stained

[18] Burchard, H. C., op. cit. (for 1883), p. 371, 1884.

fracture zone in porphyry. Very little vein quartz and no ore minerals were seen in the outcrops examined.

JUMBO-MOROVORATZ (2c)

The Jumbo-Morovoratz mine is on the west bank of the La Plata River, opposite the Idaho mine, at the mouth of the La Plata canyon. The property consists of the Jumbo and two Morovoratz claims, all of which are patented, and seven unpatented claims. The Morovoratz was one of the first veins discovered in the district. Fossett,[19] writing in 1876, notes a rich 3-foot vein that contained sulfurets of silver and carbonates of copper. The mine was worked at least until 1883 but probably not much later, for Toll [20] writes that it had been idle for 30 years before its revival in 1907. He states that the deposit consisted of a bed of black limestone impregnated with galena and containing some silver.

As shown in the following table, the mine has produced less than $20,000 worth of ore since 1902. The early production is unknown but probably small. The mine was last worked in 1932.

Production of Jumbo-Morovoratz mine, 1902–43 [1]

Year	Mine	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pound wet assay)
1912	Morovoratz	1	10.01	199	----------	----------
1914	Morovoratz [2]	24	2.09	702	138	386
1915	Jumbo	102	10.90	3,316	----------	510
1917	do	24	----------	1,250	----------	----------
1918	do	3	.10	194	11	183
1919	do	105	5.40	2,645	----------	1,952
1920	do	407	18.89	7,658	----------	664
1922	Jumbo-Morovoratz	29	1.50	460	----------	----------
1923	do	22	1.70	806	----------	1,524
1924	do	32	1.40	574	----------	233
1925	do	89	4.90	2,123	----------	1,100
1929	do	3	.60	473	----------	----------
1932	do	11	1.01	352	----------	----------

[1] Compiled from mine production records of the Bureau of Mines. No production for years not listed.
[2] Includes 8 tons of ore from the Jumbo that contained 0.50 ounce gold, 271 ounces silver, 39 pounds copper, and 170 pounds lead.

As shown in plate 23, the mine workings consist of two long crosscut adits, known as the Cunningham and Morovoratz tunnels, and a shorter drift adit, the Ruby tunnel, on the Jumbo vein. Several drifts have been opened on veins that were intersected by the crosscut adits. About four-fifths of the workings were accessible in 1937.

The rocks exposed in and near the mine workings range from the Entrada sandstone through the Junction Creek sandstone. The beds, which are essentially unaltered in most places, dip 15° to 25° SW. Several irregular dikes and sills of porphyry cut the sedimentary rocks.

The mine workings explore an area of relatively complex faulting, of which neither surface nor underground exposures are adequate to yield a clean-cut picture. Several faults, dipping steeply and trending from N. 20° E. to N. 70° E., are recognizable. Two of them, the Jumbo vein and the Morovoratz fault, have been extensively explored. As shown in plate 23, several of the northeastward-trending faults are reverse, but the displacement does not amount to more than a few feet on any of them. A westward-trending fault, believed to be the westward extension of the Idaho fault, is exposed on the surface between the Cunningham and Morovoratz tunnel portals. The rocks south of this fault have dropped less than 25 feet. The fault is not exposed underground, but it appears to die out toward the west. One bedding-plane fault, with unknown displacement, is exposed in the north drift on the Cunningham level.

The fault planes are marked by fracture zones 3 inches to 5 feet in width. They contain much breccia in some places; gouge predominates in others. Brown and pink carbonate and a little quartz are virtually the only vein minerals seen in any of the underground exposures.

The location and geologic setting of the Morovoratz deposit, from which ore was taken early in the mine's history and again in 1912–14, is not known. Presumably most of the ore ascribed to the Jumbo claim came from the Jumbo vein in the Ruby and Upper Nona tunnels, and the ore deposit was in all probability similar to that described under the Little Nona mine.

Too little is known of the Jumbo-Morovoratz property to justify any opinion as to its future, and many of the data that might give a clue to the structural control of possible ore deposits are lacking. It seems highly probable that most of the ore produced in the past was found close to the surface and was oxidized. Whether the property still contains other deposits of this type, or workable deposits of primary ore, can be determined only by further extensive exploration.

KENNEBEC (4)

The Kennebec mine, on the east side of Kennebec Pass, was discovered about 1880 and was active at least until the end of 1883. According to mine records of the United States Bureau of Mines, P. W. Pittman, a lessee, shipped 4 tons of ore from the mine in 1919 that yielded 0.30 ounce of gold and 167 ounces of silver. There are no other available records of production.

The vein is on the Tippecanoe-Mineral Wonder fracture zone. It trends due east and dips to the north. Burchard [21] states that a 90-foot shaft exposed a continuous pay streak, averaging 10 inches in width for its entire depth. A drift was run eastward from the shaft. At 130 feet it intersected a crosscut adit, near which the vein was 3 feet wide and consisted of white quartz impregnated with ruby silver and silver sulfide. Burchard

[19] Fossett, Frank, Colorado: A historical, descriptive, and statistical work on the Rocky Mountain gold and silver mining region, pp. 428–429, Denver, 1876.

[20] Toll, R. H., La Plata Mountains, Colo., Min. and Sci. Press, vol. 97, p. 743, 1908.

[21] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1883, p. 370, 1884.

states that $15,000 had been spent on the property but that no ore had yet been produced.

KENTUCKY (2c)

The Kentucky mine, formerly known as the Jack Pot, is on one of the branches of Gold Run, at an altitude of 9,800 feet, and is half a mile north of the Red Arrow mine. The property includes the Doctor, Jack Pot, and Fair View claims. It was discovered about 1900 and was worked intermittently until 1910 or later but has been inactive in recent years. In 1908, according to mine production records of the Geological Survey, it produced 8 tons of ore that yielded, in all, 13.74 ounces of gold and 106 ounces of silver. In 1910 it produced 3 tons of ore, which yielded 0.37 ounce of gold, 37 ounces of silver, and 123 pounds of copper. No other production is recorded. The workings (fig. 31) comprise a 500-foot drift adit, three raises, a winze of unknown extent, and a small overhand stope about halfway between the portal and the breast.

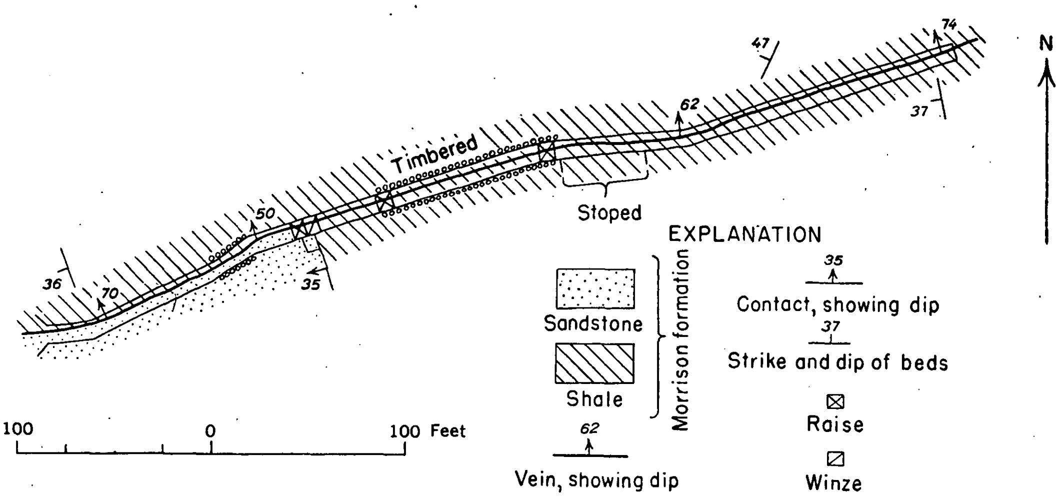

FIGURE 31.—Plan of Kentucky mine.

The adit is near the top of the shale of the Morrison formation. The conglomerate near the top of the Morrison appears near the portal on the south side of the vein, but all the other rock exposed in the mine is soft greenish-gray shale. Since there is no means of distinguishing between the shale above and below the conglomerate layer, the stratigraphic relation of the rocks on the north wall of the vein to those on the south wall is not known. The beds dip rather steeply to the west.

The vein follows a fault that strikes about N. 75° E. and dips 50° to 74° N. It cannot be traced on the surface, but it probably intersects the Florence W. vein not far east of the Kentucky mine. The amount and direction of displacement along the fault are not known. The fault zone is marked by much greenish-gray gouge, which is only 2 to 6 inches thick near the breast of the adit, but is 10 feet thick in several places near the stope. Near both ends of the adit the vein consists of a 1-inch to 14-inch zone of partly silicified wall rock along the footwall side of the gouge. It contains considerable pyrite, but no vein quartz was seen. The vein is lagged and inaccessible in the vicinity of the stope, but presumably it was wider there than elsewhere.

Considering the softness of the country rocks, the Kentucky vein is strong. In the more brittle Junction Creek sandstone, or in the Dakota (?) sandstone, the vein should be even wider and might contain minable ore.

KIABAB (2c)

The Kiabab property includes a group of unpatented claims that cover both sides of the upper end of the ridge between Starvation Creek and the East Mancos River. Most of the workings are above 10,900 feet altitude and lie 2,500 to 4,000 feet west of Madden Peak. Several relatively short adits have been driven at various places in search of ore, but none of them was accessible in 1936. No ore has been produced.

The Kiabab property lies within the complex Parrott fault system. The country rocks range from the Entrada sandstone through Junction Creek sandstone. Most of the workings explore the Pony Express limestone member of the Wanakah and the two thick sandstones. The two or more splits of the fault system were apparently the chief objectives. The vein matter seen on the dumps is an iron-stained intergrowth of quartz and coarsely crystalline barite, similar in most respects to the high-grade gold-bearing ore of the Red Arrow mine. Black manganese oxide, probably derived from ankerite, is fairly abundant in some specimens. Some of the ore is reliably reported to contained visible free gold, but no gold was seen in the specimens examined. The Pony Express limestone, which is here about 2 feet thick, is pyritized and silicified in some places, and in others it contains innumerable calcite-filled fractures.

KIMBALL

The Kimball prospect is near the county road on the west side of the East Mancos River, at an altitude of 11,000 feet. It is 500 feet north of the Lady Stafford and 4,000 feet northeast of Helmet Peak. Situated on an unpatented claim held by a Mr. Kimball, of Mancos, the workings consist of a 50-foot adit that trends N. 70° W. No production has been recorded.

The country rock is unmetamorphosed Junction Creek sandstone, which here contains flakes and small lenses of green and pink shale. The vein strikes N. 70° W. Near the portal it dips steeply to the north, but near the breast it splits. The southwest split is vertical; the other dips 55° to the northeast. The rocks between the splits are fractured and contain disseminated pyrite and a little chalcopyrite. At the breast, which is the only place where the vein is well-exposed, the vertical split contains half an inch or less of quartz, chalcopyrite, and pyrite. The northeastward-dipping split is marked by a little gouge but contains little or no vein matter.

LADY ELEANORA (2a, 2c)

The Lady Eleanora mine, formerly known as the Little La Plata, is operated by the Lady Eleanora Consolidated Gold Mines Co. It is on the east side of the La Plata River, about 1,000 feet downstream from the mouth of Bay City Gulch. The property includes the Red Cloud, Little La Plata, and Little La Plata Mill Site claims, patented in 1884, and four unpatented claims. A small flotation concentration mill was erected in 1936 and produced about 1 ton of concentrates, but both mine and mill were idle in 1937. The ore deposits have been known for many years, and some high-grade ore is said to have been recovered in the early shallow workings. The production since 1902, as shown in the following table, has been small:

Production of Lady Eleanora (Little La Plata) mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)
1906	7	1. 36	336	--------	930
1908	5	2. 08	34. 5	--------	--------
1911	10	3. 37	31	32	--------
1912	8	1. 97	23	51	--------
1917	2	. 88	20	--------	--------
1919	4	2. 30	85	27	--------
1923	2	1. 80	3	--------	--------

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The main mine workings are shown on figure 32. A 450-foot crosscut adit, extending southeast from its portal near the mill, provides access to the upper levels. The principal development is on the second level, which is 67 feet above the adit and connected with it by a 185-foot, two-compartment raise. On this a 400-foot drift that follows the Little La Plata vein northeastward from the raise, and a 500-foot crosscut. A raise near the breast of the main crosscut is said to be 100 feet high and on the "Idaho" vein. Several open-cuts and short adits are scattered over the hill above the main workings, but none of them is extensive.

With the exception of an eastward-trending porphyry dike that is exposed near the portal of the main adit, all the country rock belongs to the Dolores formation, whose base is not far below the lower crosscut. The beds dip 10° to 20° SW. Near the lower part of the workings the shale and sandstone beds are silicified and the limestone conglomerate beds are metamorphosed, containing much andradite and epidote and some specular hematite and chalcopyrite. Where these metamorphosed beds have been oxidized they locally contain workable pockets of free gold ore. Higher on the hill the rocks are only slightly altered.

Three principal veins are exposed on the property. Two of them, believed by the operators to be extensions of the Idaho and Valley View veins and called by those names, strike nearly due north. The Little La Plata vein, said to be an extension of the Jumbo, strikes about N. 25° E. and thus crosses the so-called Idaho and Valley View veins. The correlations noted are possible, but cannot be regarded as established.

The Little La Plata vein, where exposed in the main workings, dips from 65° to 80° NW. and consists of 3 inches to 3 feet of quartz and other minerals in a 1-foot to 5-foot fracture zone. Toward the northeast the quartz pinches out and the vein zone is represented by a thin film of gouge. The vein matter consists of gray granular quartz containing relatively abundant siderite and various quantities of pyrite, arsenopyrite, chalcopyrite, tetahedrite, galena, and sphalerite.

The "Idaho" vein, which dips steeply to the east in general but is vertical in places, ranges from 6 inches to 3½ feet in width. In most places it consists of an open breccia with little or no visible vein matter; elsewhere it contains quartz and sulfides and is similar to the Little La Plata vein. The "Valley View" vein is similar in most respects to the "Idaho."

The most logical places for further exploration seem to be the intersections of the Little La Plata vein with the northward-trending veins. The ore is complex and probably would have to be concentrated by selective flotation. Furthermore, the tenor of the unoxidized ore should be determined accurately before very extensive development is begun.

LADY MAURINE (2c)

Several unpatented claims on Lightner Creek, not far above the mouth of the South Fork, were held in 1937 by A. S. Butell, of Durango. The most promising is the Lady Maurine, 1 mile above the South Fork Lightner Creek, at an altitude of about 8,320 feet. Development is confined to a small open-cut on the west bank of the stream. The rocks are red shale and sand-

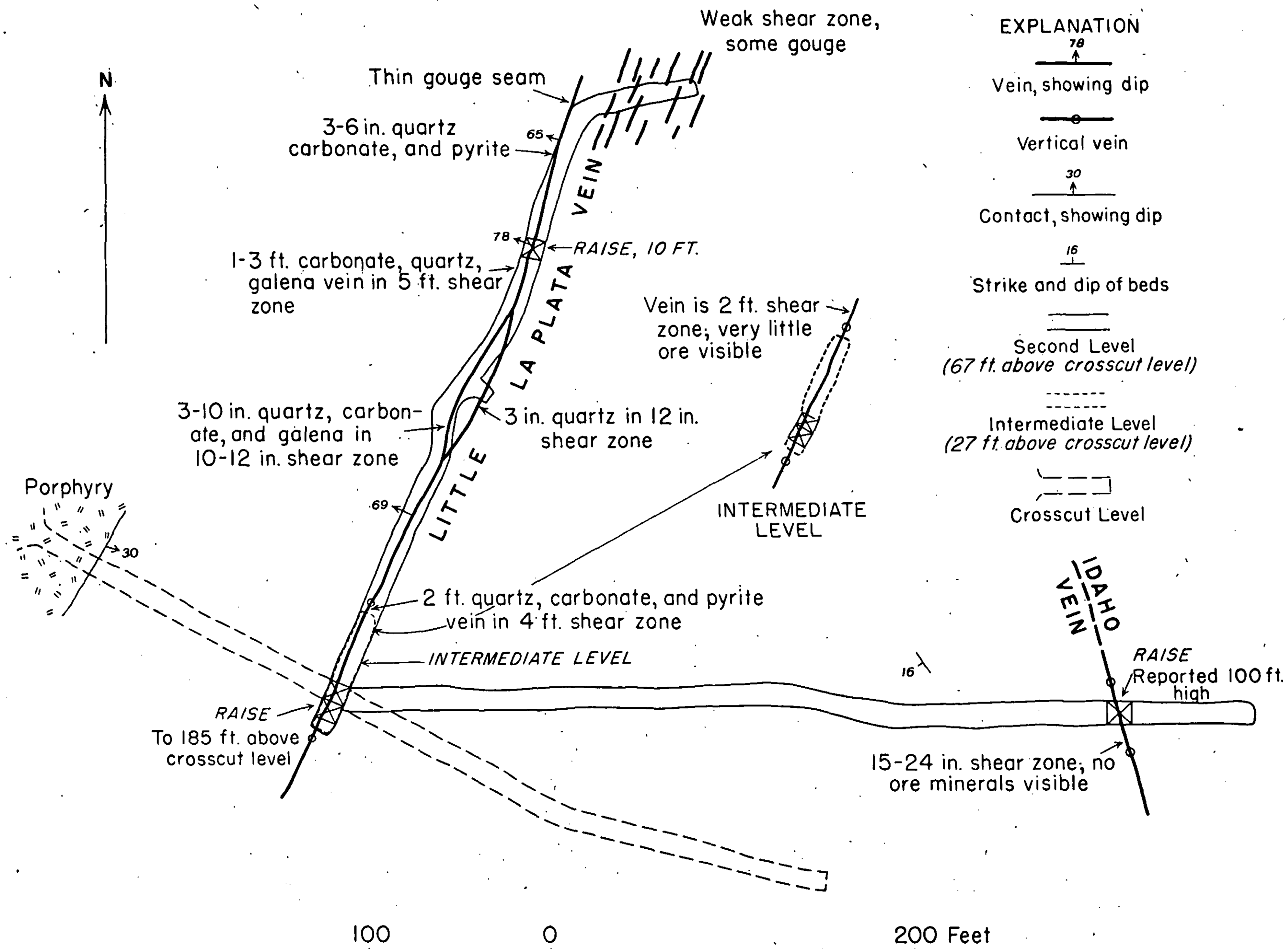

FIGURE 32.—Plan of principal workings, Lady Eleanora mine.

stone belonging to the upper part of the Cutler formation. They dip 29° SW. The deposit consists of a breccia zone that is 50 feet in width and whose well-defined walls strike N. 82° W. and dip 80° to 85° N. The rocks in the southernmost 10 feet of the zone are only slightly fractured and altered; those in the remaining 40 feet are thoroughly brecciated, bleached, and partly silicified. Small specks and blebs of pyrite, tetrahedrite, and a little galena are disseminated throughout the breccia. They are especially abundant along and near the north wall, but the south wall is marked by a thin seam of pyrite and galena. According to Mr. Butell, a sample taken from the entire width of the breccia zone yielded 0.25 ounce of gold, 3.5 ounces of silver, and 4 percent copper to the ton.

Four hundred feet north of the Lady Maurine breccia zone, a 10-foot porphyry dike, which strikes nearly due east, is exposed. It can be traced to a point several hundred feet east of Lightner Creek, where it probably intersects a northward-trending fracture zone. Exposures are so poor that it is impossible to tell whether the dike continues past the fracture zone. A 2-foot breccia zone striking due east and dipping steeply north lies 250 feet north of the porphyry dike. Unlike the main breccia zone described above, it contains fragments of several different kinds of sedimentary rocks and is thus analagous to the intrusive breccia dikes that have been noted elsewhere in the district.

Seven hundred and fifty feet south of the Lady Maurine prospect, and on the same side of the stream, there is an 80-foot adit, which is said by Mr. Butell to have been dug in 1894 and to have produced a little ore from near the surface. The country rock is the flaggy sandstone that in many places marks the base of the Dolores formation. The adit follows a strong vertical breccia zone, striking N. 65° W., which is from 6 inches to 4 feet wide and contains many veinlets of fine-grained quartz and calcite. Comb quartz partly fills interstices in the breccia. Copper-stained material is abundant. The mine water contains much calcium carbonate, derived from the vein calcite, and deposits it on the adit floor as travertine. Some of this material is in the form of irregular spherulites, or "cave pearls," that reach a maximum observed diameter of 1 inch. At 75 feet from the adit portal the vein is cut off by a fault that strikes N. 55° E. and dips 85° SE. From 1 foot to 2 feet of gouge occurs along the fault plane, beyond which soft, unaltered red shale is exposed. The faulted segment of the vein has not been found.

The chief interest of the deposits just described lies in their indication that the strong eastward-trending dike and vein system, which characterize the area between the May Day mine and Deadwood Creek, continue eastward at least as far as Lightner Creek. Further cautious prospecting appears to be justified in places where the wall rocks are favorable to ore deposits.

LADY STAFFORD (5)

The Lady Stafford mine is 200 feet above the county road on the west side of the East Mancos River. The workings are 3,500 feet N. 60° E. of Helmet Peak, at an altitude of 11,000 feet. The property, which is covered by the unpatented Lady Stafford claim, has been owned for several years by Miss Jessie A. Stafford, of Phoenix, Ariz. It is locally reputed to contain one of the richest ore deposits along the East Mancos. A small shipment of good ore was made in 1928 by Will Harvey, a lessee, but there was no other production between 1902 and 1937. In 1937 the Barr-Menefee Mining Co. secured a lease on the property and did some exploratory work. Previous development, consisting of a 40-foot adit, half of which was open-cut, was supplemented by a short new adit 150 feet below the old workings.

As in the nearby Kimball prospect, the country rock is shaly Junction Creek sandstone. The beds dip toward the southwest, and the upper adit, if it were extended, would undoubtedly enter the overlying shales of the Morrison at no great distance from the present face.

The vein strikes N. 52° W. and dips 67° SW. According to local reports it can be traced for more than a mile toward the northwest. The walls of the fissure are marked by slickensided surfaces and by broad grooves pitching 45° to 65° NW. in the plane of the vein. The character of the surfaces and the drag of the wall rocks both indicate a normal fault, with downthrust on the southwest, but the displacement is probably not great. At the breast of the upper adit a ½-inch to 2-inch streak of black fine-grained quartz with much pyrite and some chalcopyrite occurs along the hanging wall. On the footwall side of this streak there is a 3-foot fracture zone with disseminated pyrite and chalcopyrite. Chalcanthite is crusted on the walls in places. The vein is wider in the floor of the drift than in the breast. The Barr-Menefee Co.'s work in 1937 exposed a 6 to 8 inch high-grade streak near the mouth of the open-cut. A 1-foot zone on the footwall side of this streak also contained some gold, at least part of which was in the form of tellurides. In the lower adit the ore is completely oxidized. There its thickness ranges from a thin film to 18 inches, and it is reported to contain gold. Further exploration of the vein, particularly where the wall rocks are of sandstone, seems to be justified.

LALLA ROOKH (2b)

The Lalla Rookh is described in Purington's notes as being on the south side of the Burnt Timber Creek, 1 mile east of the La Plata River. It has not been worked for many years and there is no record of its ever having produced ore. The vein explored by this prospect was probably the northwestward-trending vein that is shown in plate 2 as crossing the gulch along Burnt Timber Creek at an altitude of 10,100 feet. At the workings, which are not described by Purington, the strike of the vein was due north and the dip was vertical. It traversed both porphyry and sandstone but was stronger and better-defined in the porphyry. It was not well-exposed in the workings examined by Purington, but he was told that it had a 14-inch pay streak containing an average of $70 to the ton in gold. This estimate was probably much too high. The ore consisted of pyrite, chalcopyrite, and black sphalerite in a quartz gangue.

LILLIE BELLE (5)

The Lillie Belle vein, covered by the Lillie Belle and Summit patented claims, lies between the Bessie G. and Aurora veins, on the ridge between Heffernan and Ruby Gulches. It was discovered early in the eighties but was never extensively developed. There is no record of its production except for 1904, when 2 tons of ore that yielded 0.51 ounce of gold and 5 ounces of silver were shipped. None of the workings were accessible in 1937, and the vein is poorly exposed. It trends east and is similar in general to other veins in the vicinity. Burchard, in his report for 1883, states that a 20-foot adit on the Summit claim exposed a 2-foot vein of gold-bearing and silver-bearing white quartz, with galena, pyrite, and chalcopyrite in a 4-foot fracture zone. Evidently the ore shoot was small, but the vein is apparently continuous for nearly 2,000 feet, and further exploration might possibly uncover other ore shoots.

LITTE KATE (2b)

The Little Kate mine, on Basin Creek at an altitude of 11,000 feet, explores a body of gold-bearing pyritic breccia that is of a kind apparently unique in the district. In the following description, the writer's observations have been supplemented by data taken from Purington's 1896 field notes, from a private report on the Tomahawk-Black Diamond properties by R. D. McCausland, and from conversation with Mr. August Ekburg, of La Plata, who has been acquainted with the property since its discovery.

The Little Kate claim was the first to be located on Basin Creek, having been staked in the early nineties. The mine reached a peak of activity in 1895 and 1896 but was virtually abandoned by 1900. A 20-stamp mill, operated by water power from the falls above the mine, ran for several years and is said to have produced several thousand dollars in bullion. Purington noted that the mill saved $3 in gold to the ton, though this represented a recovery of only 50 percent. The tailings were dumped directly into Basin Creek. Most of the ore was taken from open cuts and other near-surface workings. The only underground opening accessible in 1935 is shown in figure 33.

The breccia is cut by a great number of veins, only the strongest of which are shown in figure 47. The veins strike in all directions, but their dominant trend is east to northeast. Most of them occupy silicified fracture zones, which are from 6 inches to more than 10 feet wide but rarely more than 1 foot wide.

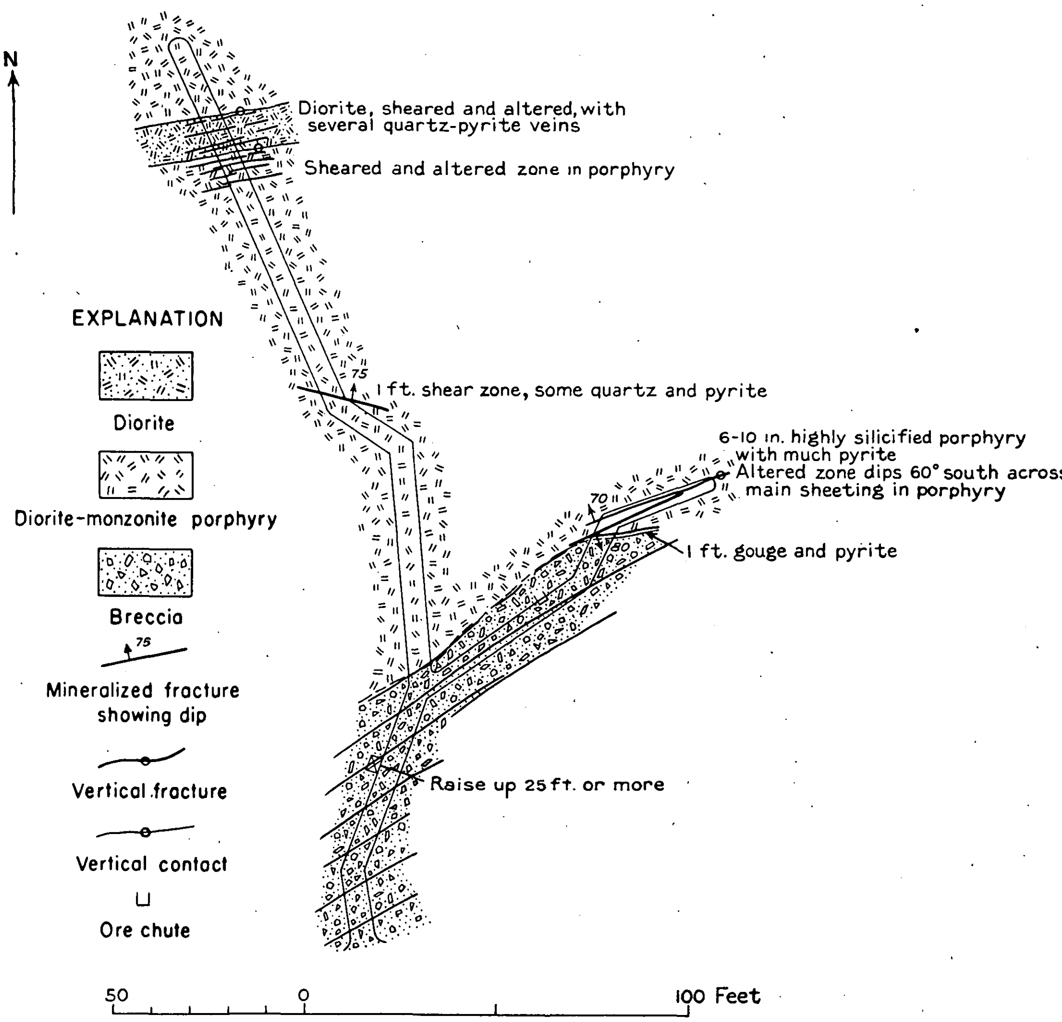

FIGURE 33.—Plan of main adit, Little Kate mine.

The general geologic relations in the vicinity of the Little Kate mine are shown in figure 47, which is based on a plane-table survey. The contacts are largely obscured by talus where they are represented by dotted lines, but the mapping is believed to be essentially correct.

The diorite, the porphyry, and the Cutler formation all have their usual characteristics. The sedimentary rocks are metamorphosed to quartzite and hornfels, and original limy nodules and lenses are represented by andradite, epidote, and other contact-metamorphic minerals. By far the most important geologic feature in the area shown in figure 47 is an irregular mass of breccia extending along the southwest side of the diorite stock. (See pp. 39–40 and pl. 8*C*). The breccia is 2,200 feet long and 200 to 650 feet wide and has a known vertical range of more than 600 feet.

They contain quartz, pyrite, chalcopyrite, and some calcite.

All the breccia contains a little gold, which probably is closely associated with the sulfide minerals. The veins contain considerably more gold than the breccia, and samples of some of them are reliably reported to have yielded as much as 1.5 ounces of gold to the ton. The Little Kate mine explored a belt of narrow quartz stringers, which contain much pyrite. Although single veins up to 18 inches in width were cut, most of the veins were narrow and lenticular. Most of the ore produced was oxidized and consisted largely of limonite with free gold, but Purington saw fine free gold panned from unaltered pyrite. The unoxidized ore gave way to primary ore within 10 or 12 feet of the surface.

Although numerous samples have been taken by interested persons, the average tenor of the breccia is not certainly known. Several investigators have sampled the dumps, outcrops, and underground exposures at the Little Kate mine itself. Their results indicate a range of 0.034 to 0.38 ounce of gold to the ton, and different men have reached averages of 0.12 to 0.22 ounce. General samples of the main breccia body, exclusive of obvious vein material, have been reported to assay from 0.02 to 0.11 ounce to the ton and to average 0.04 to 0.06 ounce. The writer took samples from the lower, middle, and upper parts of the breccia zone. After the outlines of the breccia had been mapped, the three parts were divided on the map into 100-foot squares. A 1-pound to 2-pound sample was then taken at the center of each of the areas represented by these squares, the location of the sample points being controlled with the plane table. Each sample was composed of many small chips broken from the exposed rocks within a 10-foot radius of the square's center. No chips were taken from actual veins. Each of the three main samples was thus a composite of several hundred chips and was believed to be fairly representative of the exposed surface of the breccia exclusive of the veins. The three samples, when assayed by E. T. Erickson in the Geological Survey Chemical Laboratory, yielded 0.01, 0.01, and 0.04 ounce of gold to the ton and 0.05, 0.05 ounce and a trace of silver, respectively. It appears to have been proved that gold is sparsely distributed throughout an immense volume of breccia, which, moreover, is cut by many veins that contain more gold than the body of the breccia. Little is known regarding the effects of surface (supergene) enrichment, but except near the Little Kate mine, erosion has been rapid and sulfides are exposed at the surface.

LITTE NONA (2c)

The Little Nona vein, on the unpatented Little Nona claim, is a northeastward extension of the Jumbo vein, explored by the Jumbo-Morovoratz. The date of discovery is not known, but the mine has been worked at intervals by various owners and lessees since 1912. The following table shows that about $13,000, largely in silver, has been produced. The figures for 1931 are probably in error.

Production of Little Nona mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)
1912	39	4.04	1,378	291	204
1913	25	1.39	861	156	447
1914	55	6.83	2,171	419	244
1916	306	30.64	11,646	----	----
1917	20	2.01	745	180	74
1922	13	.70	291	----	----
1924	5	.50	419	----	----
1925	31	2.40	1,106	----	----
1931	20	41.69	175	----	----

[1] Compiled from mine production records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The Nona workings, shown in plate 23, consists of an upper adit 400 feet long and a lower one 150 feet long. The vein has been stoped to the surface from the upper adit, which was inaccessible in 1937; the stopes above the lower adit are small. The lower workings are in Entrada (lower La Plata) sandstone. The basal Pony Express limestone member of the Wanakah (La Plata limestone), cut near the portal of the upper adit, is said to have yielded much of the ore produced. The vein lies along the footwall of a fracture zone that strikes northeast and dips southeast. In the Entrada sandstone the fracture zone is 2 to 4½ feet wide. Where seen in the lower level the vein is ¼ inch to 6 inches wide and consists of soft dark-brown earthy material, with some quartz and barite. Limonite, black manganese oxide, and green copper stains are prominent in the ore and in places a little residual pyrite is found. Much of the contained silver is probably in the form of cerargyrite and argentiferous cerussite. The ore in the inclined raise above the lower level contains about 40 ounces of silver to the ton, but there the vein is very narrow.

LOST (5)

The Lost mine explores the westward extension of the vein worked by the Mason mine. Neither mine was visited during the present survey. The following data are taken from a brief report and sketch map of the claims by F. D. Aller, in the files of the State Planning Commission's Mineral Resources Project.

The main workings are on the Lost claim, on the northeast side of Falls Creek, at an altitude of 9,600 feet, a mile southeast of Slide Rock Mountain and 3.75 miles northwest of Trimble. The small Fraction claim lies east of the Lost claim and adjoins the west end line of the Lucky Strike claim in the Mason group. West of the Lost claim are the Katydid and Hillside claims. Porphyry claims Nos. 1 and 2 are parallel to and 300 feet north of the Lost claim, and their name suggests that the porphyry dike noted near the Mason mine continues as far west as Falls Creek. The chief development on the Lost claim is a 25-foot open cut, from whose face an adit extends 35 feet underground. There are several other small open cuts.

The country rocks are unmetamorphosed red shale and mudstone of the Dolores formation. The vein, or lode, strikes N. 78° W. and dips steeply north along the hanging wall of a fracture zone believed to be more than 30 feet wide. It is apparently a network of white veinlets, consisting mainly of fine-grained quartz but containing some calcite, in soft red shale or clay. Aller notes that the best ore is in clay. He makes no mention of the character of the ore minerals, but presumably the vein matter is similar to that of the Mason mine. According to records of the Bureau of Mines, the Lost mine produced 18.99 ounces of gold from 23 tons of ore in 1931 and 8.33 ounces from 15 tons in 1933.

LUCKY DISCOVERY (5)

INTRODUCTION

The Lucky Discovery deposit differs from the May Day and other deposits associated with strong east-west faults in that ore occurs along the fault, as well as in veins that intersect it. The mine, formerly known as the Lucky Moon, is on the south side of Root Creek and about 2,800 feet east of Parrott Peak. It can be reached by a good pack trail from the La Plata River. The deposit was discovered in 1909 and was worked almost every year until 1917. Thereafter it was worked intermittently until 1934, when the mine was taken over and renamed by Lucky Discovery Gold, Inc. This company operated until 1936, when it transferred its interests to another mining district. As shown in the following table, the mine has produced more than $30,000 worth of ore:

Production of Lucky Discovery (Lucky Moon) mine, 1909–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1909	34	127. 75	[2] 104
1910	10	42. 94	24
1911	21	12. 25	15
1912	70	138. 62	371
1913	48	47. 23	252
1914	10	3. 07	19
1916	60	60. 00	200
1917	22	50. 86	75
1921	11	9. 90	60
1923	58	132. 40	[3] 310
1929	1	3. 00	7
1934	124	423. 90	1, 453
1935	54	164. 91	1, 390
1936	5	10. 30	64

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.
[2] Also produced 88 pounds of copper.
[3] Also produced 734 pounds of copper and 125 pounds of lead

More than 4,000 feet of workings are shown in plate 24. They include two long and three shorter adits, which are connected in several places by raises. Together with sublevels and numerous surface openings, these workings show that a comparatively large block of ground has been more or less thoroughly explored.

GEOLOGIC RELATIONS

The Jurassic formations are typically represented in the vicinity of the mine. In general they are but slightly metamorphosed, but here and there they are moderately silicified. The basal Pony Express limestone member of the Wanakah ranges from 2 to 5 feet in thickness. Where exposed at the surface it is somewhat brecciated and silicified, but where seen underground it is extensively altered to black earthy material that contains much manganese oxide. No explanation of this difference in alteration is apparent.

The beds dip 3° to 20° SE. They are cut by several bodies of porphyry; most of these bodies are irregular dikes that show no dominant trend, but one is a thick sill cropping out on the hill above the mine. Small irregular dikes of intrusive breccia are associated with the porphyry in several places.

All the ground explored by the mine workings lies south of the main splits of the Parrott fault. The Nettie fault, so named because of its supposed correlation with the American Nettie vein farther east (pl. 14), is one of the main structural features in the mine. It strikes a few degrees south of east and is considered to be a minor split of the Parrott fault system. It dips 80° to 85° S. in most places, but locally it appears to dip steeply north. The walls are so poorly defined, however, that it is difficult to determine the true direction and amount of dip. Since the fault was not cut by the Trails End tunnel, it may die out in depth, but it seems more likely that the southerly dip flattens markedly below the No. 1 level (pl. 24 *E*).

The history of the movements along the fault is not clear. The rocks on the south wall of the fault are dropped a vertical distance of 10 feet. In a few places well-formed slickensides indicate that the south wall moved downward to the east on a pitch of less than 15°. But the drag on the Lucky Discovery vein, as exposed on the No. 1 level, and the displacement of porphyry dikes cut by the Trails End tunnel, are not consistent with this observation.

Two main veins, the Pioneer and the Lucky Discovery, and several minor shear zones, some of which are mineralized in places, trend northeastward. The Trails End tunnel follows the Pioneer vein for several hundred feet, but as the latter does not appear at the place where it should intersect the Nettie fault, it is very likely cut off by one of the more northward-trending shear zones shown in plate 24. The main parts of the Lucky Discovery vein, which is apparently discontinuous, are not displaced by the Nettie fault, but the vein is clearly older than the last movement on the fault, for it is broken and dragged a short distance along the fault zone.

An interesting feature of all the vein zones, and of the Nettie fault, is that they are almost invariably narrow and poorly defined where the walls are of porphyry but are strong between walls of sedimentary rock. This relation has not been observed elsewhere in the district. It means either that porphyry bodies were intruded after the major period of vein formation but before the close of mineralization, or that the moderately strong sericitization of the porphyry rendered it less competent than the sedimentary rocks and hence less able to support open fractures. The latter explanation is probably the true one. The controlling factors for the spotty silicification of the sedimentary rocks are not known, but in general the veins are stronger where the walls are silicified.

ORE DEPOSITS

Veins.—All the ore so far produced by the Lucky Discovery has been taken from the Nettie fault and from the Lucky Discovery and Pioneer veins. The Nettie fault is marked by a fairly tight breccia zone 6 inches to 4 feet wide. In some places it contains little or no vein matter, but in others it contains from 1 inch to 2 feet of copper-stained quartz, intergrown with ankerite, pyrite, arsenopyrite, dark-brown sphalerite, and the ore minerals. The most productive ore shoot so far discovered in the mine was on the Nettie fault, between the No. 3 tunnel level and the surface. It was probably nowhere more than 50 feet long and pitched steeply west. The stope, which was largely caved in 1936, ranged from 1 foot to 4 feet in width and it is said to have averaged 2 feet. The shoot seems to occur at a point where the vein swings from its normal southerly dip on the west end to a vertical or even a northerly dip at the east end.

The Lucky Discovery vein occupies a strong shear zone 6 inches to 6 feet wide. Where exposed on the No. 1 level it is tight and contains only a few small streaks of high-grade ore. Between this level and the No. 2 tunnel, however, an ore shoot was opened from which most of the ore produced by the Lucky Discovery company was taken. The lower part of the shoot lay between walls of shale, but the greater part of the production came from between walls of sandstone. The shoot is probably more or less continuous to the surface, for part of the ore produced by the Lucky Moon came from near the outcrop of this vein. No ore has been found south of the Nettie fault. A 135-foot raise was run up on the vein a few feet away from the fault, but the vein was so weak at that place that no drifting was done.

The Pioneer vein zone, which consists of moderately brecciated sandstone and a little copper-stained quartz and pyrite, is 2 to 5 feet wide on the Trails End level. One small pocket of good ore was found in a raise above this level. The pocket was about 35 feet above the tunnel and only a short distance below the limestone.

The limestone member of the Wanakah has been rather extensively explored on the Trails End level and in a winze below it. So far as known it contains no ore, but it has not been explored at its intersection with either of the productive veins.

Character of ore.—Minerals present in polished sections of ore from the Lucky Discovery comprise pyrite, sphalerite, galena tetrahedrite, hessite, petzite, coloradoite, sylvanite, gold, and a little supergene covellite and cerussite. The gangue is largely quartz with a little barite. As elsewhere the metallic minerals are scattered in small masses throughout the gangue.

Summary.—Despite the large amount of development work that has been done, the Lucky Discovery deposits do not appear to have been adequately explored. The intersection of the Nettie fault with the Lucky Discovery vein has been actually exposed at only one place. This is in the No. 1 tunnel, where the wall rocks belong to the marl member of the Wanakah which is generally unfavorable to ore. Neither of the fracture zones has been completely tested in the usually more favorable Pony Express limestone member of the Wanakah and Junction Creek sandstone, and except in the Trails End tunnel, which follows the Pioneer vein, the Entrada sandstone is virtually unexplored. The two main splits of the Parrott fault, which lie north of the present workings, have not been tested. It should be noted, however, that near the mine the rock between and north of the faults is the Dolores formation, which is unfavorable to ore in most places.

Pockets of high-grade ore may be found at any of the localities mentioned in the foregoing paragraph, and some ore may even be found in the shaly beds. But the mine's comparatively small production in comparison to its development raises a doubt as to whether sufficient high-grade ore can be uncovered to support large operations. The reserves of low-grade to medium-grade milling ore are quite unknown.

LUCKY FOUR (2c, 5?)

The Lucky Four group of claims is on the northwest slope of Ohlwiler Ridge. The mine has been inactive for some years, and little is known of its history or its ore deposits. In 1907 it produced 231.72 ounces of gold and 459 ounces of silver from 15 tons of ore. The only other year in which ore was produced was 1914, when 467 tons yielded 586.43 ounces of gold, 6,356 ounces of silver, 10,462 pounds of copper, and 4,840 pounds of lead.

The ore produced in 1914 is said to have been taken from the Pony Express limestone. Most of the rather extensive development work on the group was probably confined to this horizon or to veins in the underlying Entrada sandstone. The lead and copper content of the 1914 ore is considerably higher than that produced by other mines from deposits in the limestone. In 1936 the only accessible opening on Lucky Four ground was a short adit at 9,850 feet altitude in the ravine opposite the mouth of Bay City Gulch. As shown in figure 34, this adit follows the contact between a porphyry dike and slightly silicified redbeds of the Dolores formation eastward to a point a little more than 100 feet from the portal, where a short drift explores a vertical vein that strikes due north. The vein is also exposed in an open-cut north of the adit. It consists of 1 foot to 2 feet of quartz and coarsely crystalline barite, enclosing more or less galena, sphalerite, and pyrite. The galena is extensively altered to anglesite in some places along its contact with quartz.

LUCKY STRIKE (2c)

The Lucky Strike prospect is on the west side of the La Plata River, in the first gulch south of Basin Creek. It is worthy of note chiefly because it provides an excellent example, in small compass, of the dependence

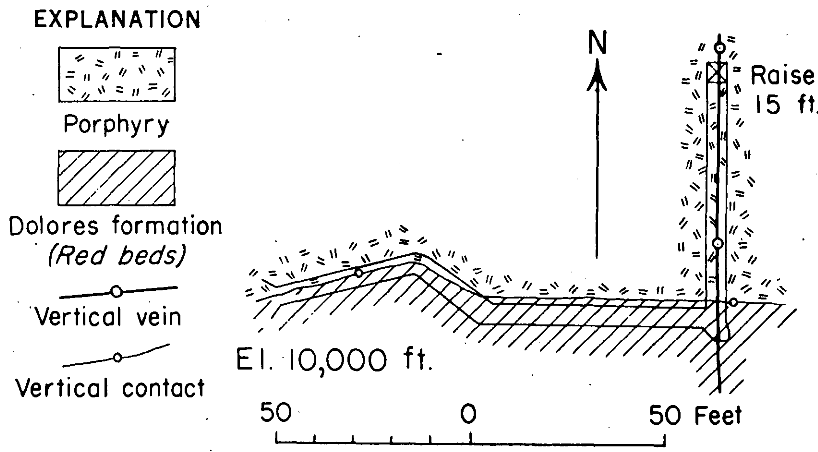

FIGURE 34.—Plan of lower adit, Lucky Four mine.

of ore deposits on character of wall rock. The prospect was opened in 1934 by a small group of partners. Several small lots of hand-sorted ore were produced, but the smelter returns were disappointing and the property was abandoned late in 1935.

The main adit, at an altitude of 9,850 feet, is 120 feet long and has a course of N. 78° W. A 42-foot open-cut is 70 feet below the adit. A thick porphyry sill extends from the La Plata River to a point midway between the open-cut and the adit. It is overlain by a 30-foot bed of arkosic conglomerate, overlain in turn by silicified shale and mudstone. The sedimentary rocks, which dip 6° to 13° SW., belong to the lower part of the Rico formation. Part of a thick porphyry dike, striking northeast and dipping 42° NW., is exposed near the breast of the adit.

The vein follows a fault that strikes a few degrees north of west and dips steeply south. The south or hanging wall of the fault dropped downward 15 feet. In the open-cut the fault is marked by a 15-foot fracture zone, which contains four 1-inch to 8-inch copper-stained veins of silicified breccia, black quartz, white clay (dickite), and pyrite. The black quartz, whose color is due to finely divided pyrite, is slickensided and indicates that part of the movement along the fault took place after the ore was formed. In the adit the vein is weak where the walls are of sedimentary rock, the fracture zone being only about 2 feet wide and the vein quartz not more than 4 inches thick. On the portal side of the porphyry dike the vein splits, one split extending into the wall for a short distance and then converging with the other split at the porphyry contact. The rock between the splits is shattered and contains many veinlets of quartz and ore. In the porphyry dike the vein is strong and ranges from 2 to 18 inches in thickness. It there consists of clear granular quartz, intergrown with pink to white barite and with granular pyrite. Next to pyrite, the most abundant metallic minerals are chalcopyrite and tetrahedrite. White powdery dickite fills cavities in the ore. A little coarsely crystalline galena occurs in places, and a small piece of free gold was seen in one specimen.

MAMMOTH (2b)

The Mammoth prospect is situated on Burnt Timber Creek, half a mile above its mouth, at an altitude of 9,300 feet. It was in operation when visited by Purington in 1896, but there is no other record of its history, and it apparently produced little or no ore. Purington says that the deposit being worked replaced a sandstone bed in the Cutler formation. A 6-foot bed of sandstone contained layers and lenses of pyrite intercalated between layers of unreplaced sandstone. The pyrite, said to contain some gold, made up about half the volume of the bed. The lateral extent of the deposit was not known.

MANCOS VIEW (2b)

The Mancos View claim, was patented before 1900, is on the southwest side of Helmet Peak. This and the adjoining Snowblind workings explore a pyritic replacement body in a wedge of metamorphosed Mancos shale in the syenite porphyry of Helmet Peak. Development on the Mancos View claim is confined to a 50-foot northeastward-trending adit at 11,600 feet altitude. The Snowblind adit, which is 40 feet long and extends eastward, is about 200 feet east of and 100 feet above the Mancos View adit. No production has been recorded from either property.

In the Mancos View adit the strata dip 40° W.; in the Snowblind they dip 15° N. Each adit exposes a 1½-foot to 3-foot bed of pyrite intergrown with magnetite and a little specular hematite, but whether the two workings explore the same bed or different beds is unknown. According to John Bauer of Mancos, the owner of the properties, the smallest assay returns on samples of the ore have been 0.06 ounce of gold to the ton.

MASON (5)

The Mason mine is on the south side of a gulch midway between Tripp Gulch and Falls Creek, 2½ miles west of Trimble on the Animas River. This and the adjoining Lost mine are outside the area covered by the present survey, and neither of them was examined by the writer. They have some bearing, however, on the distribution of ore deposits in the district, and it seems well to summarize what is known concerning them. Figure 35, which represents the mine workings approximately to scale, is taken from a brief report by J. R. Reed, in the files of the State Planning Commission's Mineral Resources Project; and the following description is taken chiefly from that report but partly from other sources.

According to Reed, the vein was discovered in 1921 by E. N. Mason of Durango, who located the Poverty Hill claim (fig. 35). It seems probable, however, that Mason rediscovered a vein from which ore was produced in 1912 and 1914 and that this same vein was described in 1906 by Lakes.[22]

Mason worked the property intermittently until 1931, when he formed the Mason Mining & Milling Co. This company was succeeded in 1933 by the Amalgam Gold Mines. The production of the mine is tabulated below. Most of the recent shipments were made in the form of bullion or of cyanide precipitate, and the tonnages given presumably refer to the amount of crude ore treated.

Production of Mason mine, 1912–43 [1]

Year	Claim and owner	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)
1912	Red Rock [2]	42	14.03	1,446	82	2,884
1914	Last Chance [2]	14	.69	95	--------	303
1921	Poverty Hill, E. N. Mason	--------	15.70	38	--------	--------
1924	Last Chance, E. N. Mason	3	3.12	28	--------	--------
1931	Mason Mining & Milling Co	1	10.47	--------	--------	--------
1932	Last Chance, Mining & Milling Co	44	120.03	--------	--------	--------
1933	Last Chance, Amalgam Gold Mines Co	23	63.21	--------	--------	--------
1934	Amalgam Gold Mines Co	--------	3.95	--------	--------	--------
1935	do	--------	2.07	--------	--------	--------
1936	do	15	40.77	--------	--------	--------
1937	do	14	24.80	--------	--------	--------
	Total	--------	298.84	--------	--------	--------

[1] Compiled from mine records of U. S. Bureau of Mines. No production for years not listed.
[2] Identity of these claims in relation to those in present Mason group uncertain.

The country rocks are unmetamorphosed redbeds of the Cutler and Dolores formations. As shown on figure 35, there is an 8-foot porphyry dike parallel to and 300 feet north of the vein. The vein, which dips 65° N., follows the north wall of a fracture zone that strikes a few degrees north of west and is 4 to 22 feet wide. Within this zone the rocks are partly bleached and silicified and contain veinlets of calcite.

The vein is 10 to 14 inches thick. Reed's description of the vein matter is obscure, but apparently the gangue is a mixture of finely crystalline quartz, barite, and calcite. Free gold, sylvanite, cinnabar, native mercury, native amalgam, and iron and copper sulfates and oxides are reported to have been found.

This description agrees with Lakes' description of what appears to be the same vein. He says that the vein occupies a series of small fissures in red sandstone and that workable ore is confined to depths within 100 feet of the surface. Free gold is irregularly distributed through narrow seams and cracks. With the gold are numerous bright shining crystals of telluride, said to be sylvanite. Locally the seams contain native mercury and amalgam, associated with the gold and sylvanite. Lakes also mentions a little fluorite and copper carbonate. It may be said in passing that Lakes' estimate of the lower limit of workable ore does not appear to be based on actual observation, for it seems quite certain that none of the workings on this vein have ever approached 100 feet in depth.

The vein is said by Reed to be about equally strong throughout the five claims of the group. Its continuation on the adjoining Lost claim indicates a total length

[22] Lakes, Arthur, A peculiar occurrence of native mercury, free gold, and telluride minerals near Trimble Springs, Durango; Mining Reporter, vol. 54, pp. 389–390, 1906.

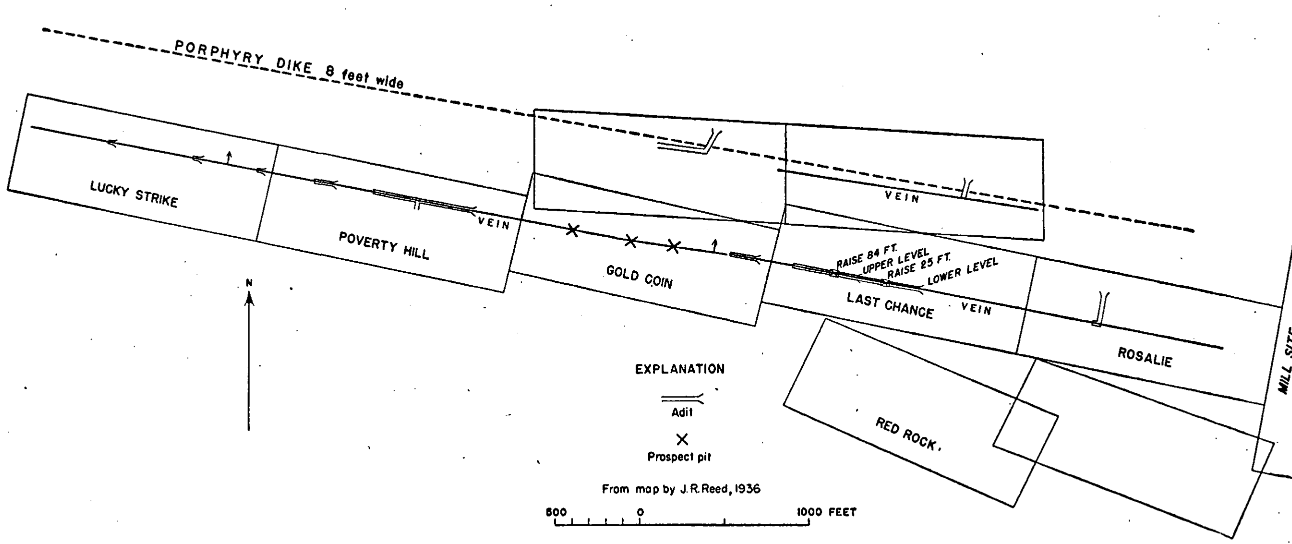

FIGURE 35.—Sketch map of claims and workings of Mason mine.

of at least 8,500 feet. The Mason mine, which has produced more gold than many of the mines in the district in which there has been extensive exploration, is 8 miles from the center of the district and more than 2 miles from the Neglected, the nearest producing mine. That fact should lend encouragement to further exploration not only of the Mason vein but of the hitherto nonproductive area that lies between it and the La Plata district proper.

MAY DAY AND IDAHO (5)

HISTORY AND PRODUCTION

The Idaho, or Valley View mine, and the adjoining May Day, at the mouth of the La Plata canyon, are together responsible for more than half the total production of the district. As they form a geologic unit the two mines are treated together here.

Most of the following description is based on the writer's observations, but these are supplemented in part by the work of R. D. McCausland, I. E. Goodner, and others who have examined the deposits on behalf of mine operators. The conclusions expressed here differ in important respects from those reached by several of the geologists and engineers who have reported on the properties, but it is believed these conclusions are correct, in their broad essentials, though many details are still lacking. The clarity of the descriptions is unavoidably impaired by the confusion that exists in the local terminology, especially by the use of the same names for different geologic and cultural features.

The Valley View claim, now part of the Idaho group, was located May 9, 1902, on a showing of ore near a trail that had been used by prospectors for many years. The rich outcrop of the May Day vein was discovered in 1903, and ore was produced from the vein in the same year. The Idaho did not begin to produce ore on a large scale until 1907. In 1910 a dispute over apex rights arose between the May Day and Valley View managements, both parties claiming mineral rights on a patented homestead. Litigation continued until 1912, when a United States District Court order imposed heavy damages upon the Valley View Co. and transferred part of its claims to the May Day. The mines were later operated by various groups of lessees for many years.

Until 1933 all the ore produced by both mines was either shipped crude or merely washed and hand-sorted to bring it up to shipping grade. The May Day Milling Co. was organized in 1933 by Durango businessmen and took over the May Day on a 15-year lease from its owner, the May Day Gold Mining Co. A 40-ton flotation mill was built, and was operated in a small way on ore from the mine and the dump until the end of 1936. The mine and mill were idle in 1937 and 1938.

The Idaho was acquired in 1933 by the La Plata Mountains Gold Mines Co., a subsidiary of the Consolidated Gold Fields of New Mexico, Inc. In 1936 the Pioneer Gold Producers, Inc., another subsidiary of the same company, was formed with the intention of building a custom mill near the Idaho mine. A small pilot mill was erected, and was operated successfully during 1936 and 1937. Early in 1938 the three companies were reorganized as the Consolidated Gold Producers, Inc., with authorized capitalization of $1,500,000.

These mines are more favorably situated for economical operation than most in the district. They are on the south border of the mountains and at comparatively low altitudes. The climate is therefore mild, there is no danger of snowslides, and outside work can generally be carried on the year round. A high-voltage power line serves the properties, which, moreover, are only 3 miles distant from the coal mine at Hesperus. The May Day railway spur, though now in disuse, could easily be placed in service if there were sufficient demand for railroad facilities.

As shown in the tables on page 144 at the end of 1943 the Idaho had produced 47,962.23 ounces of gold and 383,004 ounces of silver since its discovery, and the May Day had produced 74,914.92 ounces of gold and 758,984 ounces of silver. It is generally believed locally that both mines should also be credited with large quantities of gold that were "high-graded" from time to time, but the total production shown here is thought to be correct within a very few thousand dollars.

DEVELOPMENT

The principal workings, which total well over 5 miles in length, are shown in plate 25. Except for their lower parts, which were caved or filled with water, and for the stopes, most of the workings were open for examination in 1935–37. As indicated on the maps, most of the ore deposits have been worked through four long crosscut adits, connected by drifts, raises, and winzes. Much of the development work has been done in barren ground. This condition has necessarily raised the cost of mining, but at least it has yielded a far clearer picture of the structural relations than would have been possible if development had been confined more closely to the ore deposits.

GEOLOGIC RELATIONS

Nearly all the rocks in the vicinity of the mines are poorly exposed, and most of the relations shown in plate 2 are based on projections from the underground workings. The southward-dipping sedimentary rocks in this area are cut by a series of barren east-west faults, which drop the beds to the south and apparently also displace them eastward on the south side of the faults. Several northward-trending ore-bearing veins follow faults of small displacement, and these veins, together with closely associated replacement bodies in limestone, constitute the ore deposits of the two mines. It is be-

Production of May Day mine, 1903–43 [1]

Year	Operator	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Lead (pounds, wet assay)
1903	May Day Gold Mining & Milling Co	200	500.0	2,500	----------
1904	do	1,677	3,199.3	23,720	----------
1905	do	5,603	12,040.03	89,333	----------
1906	do	6,791	14,021.0	114,306	----------
1907	do	5,538	17,237.03	193,626	----------
1908	do	1,199	2,623.0	46,158	----------
1909	do	1,658	2,810.88	45,755	----------
1910	do	2,571	3,210.12	32,268	----------
1911	do	1,704	1,194.38	20,873	----------
1912	do	802	1,853.91	18,038	----------
1913	do	850	2,445.82	15,463	----------
1914	do	620	583.24	6,049	----------
1915	do	793	701.50	15,493	93
1920	do	123	115.50	1,121	795
1921	do	590	1,078.40	13,044	----------
1922	do	377	958.20	6,871	----------
1923	Cumberland Mines Co	669	554.50	13,660	----------
1924	do	1,220	1,045.40	9,761	----------
1925	do	700	1,015.00	18,216	----------
1926	do	21	38.60	658	----------
1927	May Day Development Co	554	588.47	7,362	----------
1928	do	1,112	852.00	10,977	----------
1929	May Day Gold Mining Co	61	56.20	888	----------
1930	Houser Leasing Co	43	87.60	706	----------
1931	do	315	462.12	1,763	----------
1932	do	630	931.01	3,387	----------
1933	May Day Milling Co	([2])	1,076.70	9,492	1,000
1934	do	[3] 230	1,364.90	12,299	2,381
1935	do	[4] 138	864.60	8,746	516
1936	do	[5] 179	851.60	8,758	----------
1938	do	[6] 27	98.11	1,191	----------
1939	do	[7] 62	331.4	4,353	639
1940	do	19	83.4	1,037	1,116
1941	Rowe Leasing Co	[8] 46	40.10	1,071	611
1942	do	4	.90	41	----------
	Total	--------	74,914.92	758,984	7,151

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.
[2] Includes 45 tons of crude ore and 110 tons of concentrate from 7,045 tons milled.
[3] From 13,123 tons milled.
[4] From 8,000 tons milled.
[5] From 10,200 tons milled.
[6] From 800 tons milled and 7 tons shipped crude.
[7] From 2,500 tons milled.
[8] From 25 tons milled and 41 tons shipped crude.

Production of Idaho mine, 1903–43 [1]

Year	Claim or operator	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)
1903	Chief Mining & Milling Co	4	5.75	154	----------	----------
1904	do	65	36.00	1,330	----------	----------
1906	Valley View	62	181.07	2,512	----------	----------
1907	do	2,184	2,394.90	22,356	----------	----------
1908	do	1,095	2,088.70	24,123	----------	----------
1909	do	1,272	2,987.44	25,138	----------	2
1910	do	1,859	13,061.67	105,536	79	----------
1911	Idaho	628	5,397.21	3,448	----------	----------
1912	Valley View	518	2,117.73	21,669	----------	----------
1913	do	4,987	12,293.92	98,393	----------	----------
1914	Valley View Consolidated Gold Mining Co	2,738	3,707.74	39,501	----------	----------
1916	----------	546	546.00	5,460	----------	----------
1917	Idaho Mining & Leasing Co	1,010	880.52	9,386	280	----------
1918	do	191	143.20	2,972	----------	----------
1919	do	228	190.50	2,201	101	123
1920	Valley View Consolidated Gold Mining Co	177	268.20	1,518	----------	49
1921	Geo. W. Gilmore	131	322.70	2,939	----------	----------
1922	do	70	140.30	1,511	----------	----------
1923	----------	86	51.50	2,317	44	144
1924	Valley View Consolidated Gold Mining Co	12	11.70	260	----------	----------
1925	F. A. Aller	43	92.20	634	----------	----------
1926	do	88	126.70	648	----------	----------
1929	do	19	34.88	362	----------	----------
1930	Geo. W. Gilmore	33	59.60	633	----------	----------
1931	do	33	24.10	183	----------	----------
1933	La Plata Mountains Gold Mines Co	19	67.17	523	----------	----------
1935	do	10	30.30	----------	----------	----------
1936	do	1	2.53	73	----------	65
1937	do	6,036	592.00	6,450	----------	7,000
1938	do	2,180	106.00	774	----------	1,900
	Total	26,325	47,962.23	383,004	504	7,383

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed. Figures for 1916 probably inaccurate.

lieved that the barren faults are pre-ore and that the heavy gouge zones that characterize them guided the ore solutions as they rose along the veins. Post-ore movements along the barren faults complicated the structural picture to some extent.

SEDIMENTARY ROCKS

The sedimentary rocks, none of which exhibit any unusual features, range from the Dolores formation through the Morrison (McElmo of former reports). The thicknesses of the different units, as determined from the mine maps, are as follows: Entrada sandstone, 180 to 225 feet; Pony Express limestone member of Wanakah formation, 1 foot to 10 feet; marl member of Wanakah 65 to 100 feet; Junction Creek sandstone, 250 to 350 feet; shale of Morrison formation about 500 feet. The rocks are unaltered in most places, but near porphyry dikes and along some of the veins and faults the sandstone and shales are silicified and the Pony Express limestone is locally replaced by ore minerals.

IGNEOUS ROCKS

Several irregular dikes and sills of porphyry are exposed in the mine workings and on the surface. They are shown in plate 25 but not in plate 26. The most continuous of these bodies follows the Idaho fault for at least half the length of the fault; it is made up of typical diorite-monzonite porphyry, but it is nearly everywhere sheared and strongly altered. Though known as the Idaho dike, it is highly irregular in form, and most of its exposed contacts are faults marked by more or less abundant gouge. Other porphyry bodies exposed in the mines are similar to this one, but none of them are as closely associated with the ore deposits.

STRUCTURE

May Day-Idaho fault system.—The sedimentary rocks dip 10° to 55° S., their average dip being between 20° and 30°. The most important structural feature is the May Day-Idaho fault system, whose regional relations are described on pages 45–46 and illustrated in plate 2. This system, which is most strongly developed in and near the mines under discussion, strikes nearly due east along the southern base of the La Plata dome. Most of the individual faults are barren of ore deposits, but for reasons explained below, they are believed to have played an important part in the localization of ore.

The block diagram in plate 26 represents in generalized form the major aspects of the system as exposed in the mine workings. Many details of the structure are also shown in the structure sections in plate 26 and on the geologic maps of the mine levels (pl. 25). As shown in these illustrations and described on pages 45–46, the system at its type locality comprises two strong eastward-trending reverse faults, the Idaho and the May Day, each with downthrow on the south.

The total vertical displacement along the two faults is 350 to 475 feet; and marker horizons, such as the Pony Express limestone, show an apparent horizontal displacement of 1,000 to 2,000 feet to the east on the south side of the fault system.

Locally the displacement follows a single fracture plane; elsewhere it is distributed through several splits. Near the junction of the May Day vein with the faults, where the latter are very close together, the rocks between them are so much broken and jumbled that it seems impossible to decipher the relations. At other places the fault planes are more distinct and are marked by zones of heavy gouge or breccia from less than an inch to many feet in width. Bedding-plane slips complicate the structure in places, but their distribution and relative importance could not always be determined. A good example of such a slip is exposed near the portal of the Idaho No. 1 tunnel (pl. 25, insert sketch).

The two named faults can be traced only a few hundred feet east of the May Day workings. They may extend farther east in the underlying, more competent rocks, pinching out or passing into a local fold in the shale beds of the Morrison that are exposed at the surface. It seems more probable, however, that the displacement is transferred to a parallel fault a short distance to the north, two mineralized branches of which are exposed in the Lamb tunnel (pl. 25).

Vein systems.—Besides the strong eastward-trending faults of the May Day-Idaho system, there is also a series of normal faults that trend northward and dip steeply eastward. These faults, which have displacements of 10 to 30 feet, contain the principal ore deposits of the mines. They are described individually in the succeeding paragraphs on ore deposits. They are represented on the geologic maps (pls. 25, 26) as being discontinuous, and as stopping abruptly, in most places, at their junctions with the major faults. Whether or not this representation is essentially true is not quite certain; the evidence bearing on the matter will now be considered.

Interpretation of structure.—No complete solution of the May Day-Idaho structural problem seems possible on the basis of the available information. For reasons outlined below, the writer believes that the main movement along the May Day-Idaho fault system took place before the introduction of the ore deposits, and that it was nearly contemporaneous with the porphyry intrusions and the formation of the La Plata dome. The Idaho dike is certainly older than the last period of movement along the Idaho fault, and it seems to have been intruded during the main period of east-west faulting; if so, its irregular shape might be due in part to movements that took place while the magma was still plastic.

Later earth movements that followed the formation of the barren faults and the intrusion of the porphyry resulted in the formation of northward-trending fractures, which gave access to ore-bearing solutions. These solutions rose close to the tight gouge dams along the barren faults, and deposited ore in places where the country rocks were favorable to the formation and survival of strong breccia zones, or where they were easily replaceable. Still later, slight movements along the east-west faults obscured the relations to some extent but had no other appreciable effects.

The beliefs just outlined differ from those held by several geologists and engineers who have examined the mines. It is held by them, and by some of the miners, that the May Day and Idaho faults are post-ore and that they displaced the ore-bearing veins horizontally. The Idaho, Valley View, and "810-foot" veins are thus regarded as segments of the same vein. The May Day and Brooklyn veins are supposed to be similarly related. If these correlations are correct, the horizontal displacement along the system is more than 1,000 feet. Whether or not the fault displacement was chiefly horizontal, this hypothesis that the faults are post-ore fails to explain the concentration of ore at intersections of veins with the "barren" faults, the absence of "drag" ore in the fault planes, and the mutual relations of the Idaho dike and fault. The fact that the segments of the east-west fault system exposed in the Lamb tunnel have yielded some ore and contain large quantities of calcite east of the May Day area is also evidence that the main period of movement was preore, for these segments at least were in existence before the introduction of the ores. In addition, the strong east-west faults appear to be closely related to the hinge fold that encircles the central part of the district, which was formed early in the structural history of the La Plata dome.

The direction and amount of movement on the May Day-Idaho fault system cannot be determined from the data now available. If, as is believed by several engineers and mining men who have had good opportunity to observe the geologic relations underground, the Brooklyn and May Day veins on the one hand and the Idaho, Valley View, and "810-foot" veins on the other, are segments of two veins that have been dislocated, it can be shown that the displacement along the barren fault system was essentially horizontal, the south wall having moved east somewhat more than 1,000 feet. If that is not so, an infinite number of solutions is possible. And, except for the fact that the supposed segments of both the principal veins are "displaced" almost equal distances, and that most of the slickensides seen are horizontal, there is no evidence known to the writer that supports this correlation. There are no known means of either proving or disproving the correlation between the various segments, and there are no correlatable bodies of igneous rock in the different fault blocks. The horizontal slickensides indicate that the last movement along the system was horizontal, but they prove nothing as to the direction of the main displacement. The very fact that the fault system appears to die out within a short distance east of the mines, itself suggests that the horizontal displacement was not great.

The distribution of the sedimentary rocks shown on the maps and diagrams does not, in itself, prove large horizontal movement. Vertical or dip-slip movement on a fault that nearly parallels the bedding of gently dipping rocks will cause jogs in the boundaries of marker beds that are several times as great as the amount of vertical or dip-slip displacement. In the May Day and Idaho mine area, the boundaries of the sedimentary layers are shifted 1,000 to 2,000 feet along the south side of the major fault system. If the principal vein fissures on the two sides of the fault are not equivalent, vertical as well as horizontal components of movement are necessary to satisfy the observed facts. The minimum displacement that will fulfill the conditions is one of 300 to 400 feet, pitching steeply to the east. At any rate, some rotation of the fault block, or more probably, warping of the beds, is required to account for variations in the horizontal offset of key beds from place to place.

Clearly then no clean-cut solution is possible at this time. The barren east-west faults are almost certainly older than the ore deposits. The principal northward-trending veins may represent segments of two main fissures that were displaced horizontally by the May Day and Idaho faults. It seems equally possible that most of the movement on the barren faults was more nearly vertical and that the ore-bearing fissures never extended beyond their present limits. The writer is inclined to favor a third hypothesis that each of the veins may be more extensive than is now apparent, and that unrecognized segments of any or all of them may exist. Failure to recognize these segments may have been due in part to the weakness of all the veins where they cut certain country rocks and in part to the fact that several of the development drifts have followed gouge zones so closely that the actual fault walls are unexposed for long distances.

ORE DEPOSITS

Classification.—Two related classes of ore deposits are known in these mines—veins and limestone replacement bodies. Both of them yield telluride ores of gold and silver. A third class, which consists of altered and mineralized porphyry, is known but has not yet been exploited. Production from the different kinds of deposits has not been recorded separately, but even though the replacement bodies have yielded richer ore than the veins, the veins are probably responsible for the greater part of the total production.

Veins.—Three veins, the May Day, the Valley View, and the Idaho, have yielded most of the ore that has been produced, but some ore has also been taken from the Brooklyn, Gertrude, "810-foot," and other veins. The distance between vein walls ranges from a few inches to about 10 feet. The walls are well-defined in places, but elsewhere they are gradational, the stope widths, which average 3 to 4 feet, being determined by assay control. Ore streaks, separated by wedges of nearly barren rock, range from narrow seams that fill interstices of brecciated rock to solid masses of ore up to 2 feet wide.

The veins are described below in order of position, from west to east. Much of the description of the relations between the veins and the barren faults is necessarily colored by the writer's interpretation of the structure, discussed in preceding paragraphs.

The Idaho vein, the most westerly of the group, is known only to the north of the Idaho fault. It strikes a few degrees west of north and in most places dips eastward. Several splits have been discovered, each of which locally contains ore. The main ore shoot is clearly related to the Idaho fault (pl. 26). Toward the north the vein narrows and becomes lower in tenor, even where the wall rocks are of kinds that are elsewhere favorable to ore deposits. Some if not all of the high-grade shoots within the main shoot are controlled by abrupt local changes in the dip or strike of the vein. As shown in plate 26, some of the ore taken from this vein came from between walls of the Dolores formation (redbeds) or from the Pony Express limestone, but by far the greater part of the ore produced was found where one or both walls were of Entrada sandstone.

The Valley View vein, 300 feet east of the Idaho, was the first one of the group to be discovered. It has yielded much of the ore credited to the Idaho mine and some of that credited to the May Day mine. Only a small part of the workings along it were accessible in 1935–37. As shown in plate 26, it has been explored only between the May Day and Idaho faults. Other segments, if they exist, have not been identified; nevertheless, it seems possible that a vein exposed in an open-cut on the Dakota (?) sandstone ridge south of the May Day No. 2 portal is the southern extension of the Valley View. Most of the ore was taken from or near the Pony Express limestone. The vein has not been fully explored in the Entrada sandstone, possibly because of difficulties with water in the deeper workings. Parts of the vein are said to have contained good ore in the Junction Creek Sandstone, but the shape of the stope (pl. 26) indicates that the vein was not as productive there as it was lower down.

The Gertrude vein has been explored on the north side of the Idaho fault by a short drift and a 194-foot raise near the east end of the Idaho No. 2 tunnel. It strikes north and is nearly vertical. It is said to be marked by smooth walls bearing scattered crusts and slabs of dark-gray sulfides, which contain streaks of native gold and tellurides. Assay samples from high-grade streaks are reported to have yielded 2,600 to 3,000 ounces of silver and 4 to 7 ounces of gold to the ton, but very little ore has been produced. The first vein cut by the Derby tunnel is believed by some to be the northward extension of the Gertrude, but this relation has not been proved.

All the workings on the "810-foot" which is possibly the southward extension of the Gertrude, were inaccessible when the mines were examined, and little information about the ore deposits is available. Most of the work was done through the Miller incline shaft, which connects with a series of short sublevels several hundred feet below the May Day No. 2 level. A 545-foot shaft from near the breast of the May Day No. 4 tunnel was also connected with these workings by means of a long eastward-trending cross cut. Workable ore bodies have been found only in and near the Pony Express limestone. The ore shoots were spotty, but some of them were very high grade, and $68,000 worth of ore is reported to have been taken from one small stope. A series of small step faults, parallel to the May Day fault, was cut in the workings. So far as available maps and other records show, all the work was done on the south side of the May Day fault, but, according to Dan Cason, of Durango, the segment between the Idaho and May Day faults was also explored to some extent. It does not seem to have been adequately explored, however, in the thick sandstone horizons, particularly near the May Day fault, where, by analogy with nearby veins, workable ore bodies might be expected.

The May Day vein has produced more ore than any of the other veins in the Idaho and May Day mines. It varies in strike from due north to N. 25° W. and in dip from 55° to 85° E., and the displacement along it ranges from 20 to 30 feet. The vein has been explored for a distance of only 600 feet north of the May Day and Idaho faults. The drifts on the May Day No. 1 and *B* levels extend considerably farther north, but, as shown on the geologic maps (pls. 25 and 26), they followed westerly splits of the true vein. The same statement holds for a vein explored in the Derby Grizzly, and Lamb tunnels (pl. 25) that is supposed to be the May Day, although unfortunately there is as yet no proof that the real May Day vein extends this far north. This vein has been stoped continuously from the surface, where some of the ore is said to have been rich in free gold, to a depth of 455 feet. The wall rocks of its productive part thus range from the Entrada sandstone up into the lower part of the Morrison formation. The best ore is reported to have been taken from the vein between the two faulted segments of the Pony Express limestone member of the Wanakah and from replacement deposits in the limestone itself. The vein is known only on the north side of the May Day fault. Some ore was found in the crushed zone between the May Day and Idaho faults, but most of the ore lay north of the Idaho fault.

The Brooklyn vein is the easternmost of the veins developed by the Idaho and May Day mines. The discovery workings, which yielded an unknown but probably small amount of good ore, were south of the May Day fault, where the Dakota (?) sandstone forms the wall rock. Unless the weak veins exposed at the east end of the May Day No. 2 tunnel represent the downward extension of this same segment, all the underground development work has been done on the segment that lies between the Idaho and May Day faults. This segment has been opened on the No. 1 and *B* levels. It trends northwestward, dips northeast and is strong in most places. Several hundred tons of $12 ore are said to have been taken from the 7-foot wide stope above *B* level.

Limestone replacement ores.—All the known replacement deposits in limestone were either worked out or inaccessible when the mines were examined, and the following descriptions are based largely on data supplied by others. Near some of the veins the Pony Express limestone has been more or less completely replaced by ore minerals; elsewhere it is essentially unaltered. Workable ore rarely extends more than 50 feet from a fissure, and in general the tenor decreases uniformly with the distance from the fissure. Much of the best ore from the May Day and Valley View veins represented replaced limestone, and, as noted above, almost all the ore from the workings on the "810-foot" vein was from the limestone. Similar but smaller deposits have been exploited near the outcrop of the Idaho vein, in the Lamb tunnel, and in a winze at the east end of the May Day No. 2 tunnel, south of the May Day fault.

Porphyry ore.—The altered porphyry of the Idaho dike, at and near the intersection of the May Day vein with the two major faults, has received but little attention in the past, but it appears to deserve consideration as a possible ore reserve. As exposed at the surface and on the May Day No. 1 and *B* levels, the porphyry ranges in width from 8 to more than 25 feet. In the vicinity of the May Day fault it is strongly brecciated and kaolinized. According to R. D. McCausland, several hundred tons of this material that had caved into the open stope above the No. 1 level were milled in 1933 or 1934, and yielded $8 to the ton in gold and silver. Samples taken from the dike in places contained more than $10 to the ton.

Mineralogy.—Base metals are not abundant in the deposits, though small quantities of galena, sphalerite, pyrite, and arsenopyrite are widely distributed. The gold and silver occur largely as tellurides, but some free gold has been found in places, and free gold is said to have been abundant in the early near-surface workings. Locally, particularly in the replacement deposits, the ore contained solid masses of mixed tellurides, several feet in diameter.

Only one specimen of high-grade ore, from the Idaho mine, was obtained. It was probably taken from a limestone replacement body, but perhaps it is representative of the better grade ores from both veins and replacement bodies in this and the May Day mines. The gangue is quartz, which contains a mixture of hessite, coloradoite, galena, pyrite, chalcopyrite, petzite, krennerite (calaverite?), and gold, named in order of abundance. Pyrite and a little residual barite are earlier than the ore minerals and are replaced by them. They are contemporaneous with or slightly later than quartz. The various tellurides, which are believed to be essentially contemporaneous, filled open spaces and partly replaced all the older minerals.

The lower-grade vein ores are mostly in brecciated and somewhat silicified sandstone. Cracks and interstices between the breccia fragments are filled with gray to black films and veinlets of fine-grained metallic minerals. In at least one place this material consists of arsenopyrite associated with hessite, but in general pyrite is probably at least as abundant as arsenopyrite. Locally, interstices are filled with calcite or barite intergrown with the ore minerals.

In addition to the minerals noted above, engineers who have examined the deposits have recorded sylvanite, argentiferous gray copper, stephanite, and the chlorides and bromides of silver. They also report that ore with much galena and sphalerite contains a higher ratio of silver to gold than the telluride ores. White and pink mixed carbonates associated with barite are said to have characterized the limestone replacement type of ore, whereas quartz and opaline silica are the only abundant gangue minerals in the veins.

Tenor.—No detailed records are available regarding the tenor of the ore produced by these mines. Some of it was very rich, and some shipments contained several thousand dollars worth of gold and silver to the 100-pound sack. The production figures given above show that during the height of its activity, from 1907 to 1914, the Idaho mine produced ore averaging 2.88 ounces of gold and 22 ounces of silver to the ton. The ore shipped from the May Day during the years 1904–13 contained on the average 2.14 ounces of gold and 21 ounces of silver, but, as most of the shipments were of hand-sorted ore, these figures are doubtless higher than the average tenor of the ore mined. Most of the dumps containing the rejects from this sorting were reworked in later years. Incomplete records of present sampling in both mines seem to indicate that most of the ore that was left in them and was accessible for sampling ranged from 0.20 to 0.50 ounce of gold to the ton.

Structural control of ore deposits.—From the illustrations (pls. 25, 26) and the foregoing descriptions it should be evident that the main deposits that have been worked lie close to one or the other of the major east-west faults. The most reasonable explanation of this relation seems to be that the faults were in existence before the ores were deposited and that the gouge zones along them acted as diversion dams and guided the solutions. The fact that deposits have been found on both sides of each fault indicates clearly that the solutions rose vertically along the fissures and did not enter the host rocks along horizontal channels.

Character of wall rock was nearly as effective as the barren faults in controlling ore deposition. Nearly all the ore thus far produced has been taken from the easily replaced Pony Express limestone member of the Wanakah and from the competent Entrada and Junction Creek sandstones. The Dolores formation yielded a little ore in the Idaho mine, but in general the veins pinch to mere seams and are but weakly mineralized where they enter the redbeds. Some ore has also been taken from the shale beds above the Junction Creek sandstone, and rich float ore is said to have been found in rock that was definitely of Dakota (?) aspect. The brittleness of the thick sandstone units led to the formation of comparatively wide and open breccia zones along fractures in these rocks, whereas the factures were tight in the shaly beds. High-grade or wide shoots within the main shoots were doubtless localized in part by changes in strike or dip of the veins, which favored the formation and retention of strong breccia zones.

The vertical range of the ore deposits is not known, but so far as can be ascertained the ore in the lowest levels was similar in character and tenor to that just below the oxidized ore in the discovery workings. A vertical range of at least 1,250 feet is thus indicated. Although the lower workings are at the lowest altitude of any in the district, there is no indication that the ore deposits do not extend to even greater depths in places where the wall rocks and other structural conditions are favorable.

SUGGESTIONS FOR PROSPECTING

Whichever of the structural interpretations given above is accepted, there are several ways in which additional ore might be developed or utilized. Although most of the rich ore has undoubtedly been removed from the developed parts of the veins, large tonnages of ore that might be amenable to modern milling practice have probably been left on the vein walls and in the stopes. The larger dumps have indeed been washed and sorted several times, yet the recent success attained in milling the Idaho dumps indicates the other dumps might still be treated at a profit. The tenor of the Idaho dike has not been fully investigated, but data at hand indicate that thorough sampling might prove that the dike contains workable quantities of gold and silver.

It is of course possible that worthwhile ore bodies may yet be found in the Dolores formation or in the shale of the Morrison, but unless very extensive exploration is undertaken it would seem wise to confine further development to formations that are more favorable. Even though the main ore shoots on the May Day and Idaho veins are clearly controlled by the barren faults, further search for northward extensions of these shoots appears to be in order. The May Day vein has not been fully prospected between the *B* and No. 2 levels, and nothing is known of its northward extension above the No. 2 level beyond the point where that drift left the vein. If it can be shown that it continues farther north, its junctions with the two east-west faults exposed in the Lamb tunnel (pl. 26 *A*) might also prove of interest.

If the writer's interpretation of the structural relations is valid, there are several other possibilities for finding commercial ore bodies. If unrecognized segments of the chief veins exist, it would seem worthwhile to explore, in favorable beds, the ground opposite the extensions of the more productive veins. Search might be made for the extension of the May Day vein south of the May Day fault, and for the southward extension of the Idaho vein, which has never been found between the splits of the Idaho fault or south of them. The ore-bearing segment of the "810-foot" (Gertrude) vein, said to lie between the major faults, should be looked for, and the possibility of finding segments of the Valley View vein both north and south of the major faults seems to deserve consideration. Apart from the Brooklyn vein, the wedge of rock lying betwen the two faults and east of the May Day vein is virtually unknown.

It must be emphasized that, as the foregoing suggestions are based on inconclusive structural evidence, any prospecting should be carried out with caution. It is obviously possible that the northward-trending fractures failed to cross the barren faults or that certain segments were not mineralized. Nevertheless, these mines should not be considered as worked out until much further exploratory work has been done.

MAY ROSE GROUP (2b)

The May Rose group owned by the Curtet Bros., of Hesperus, consists of 16 unpatented claims on Bragdon Ridge. The claims extend from the mouth of Neptune Creek nearly to Burnt Timber Creek. Between 1887 and 1890 the Uncle Sam vein, then known as the Saxon, produced about $2,000 worth of gold ore. Much of the development on the Saxon was completed before Purington's visit in 1896. Most of the other claims have been worked intermittently since early in the present century. Some ore has been produced, largely from the May Rose and Uncle Sam claims, but no reliable production figures are available. An option to purchase was taken by the Amparo Mining Co. in 1936, and a large amount of exploratory work was done, but the option seems to have been dropped late in 1937. Development consists of numerous open cuts, a number of adits from 10 to 800 feet in length, and several shafts. The mine workings are indicated in figure 36.

As shown in plate 2, the country rocks on Bragdon Ridge comprise metamorphosed redbeds of the Cutler formation, diorite-monzonite porphyry, and syenite. All these rocks are slightly pyritized. The contacts between the syenite and older rocks are gradational in most places, and the areal mapping in plate 2 is highly generalized.

A large number of steeply dipping veins are exposed in the various mine workings. Most of them strike northwest, but a few strike northeast. They seem to be most numerous in the vicinity of the May Rose and Uncle Sam claims, but, as the sides of the valley of Neptune Creek are heavily timbered, the indicated distribution may be more apparent than real.

The veins consist of fracture zones from 6 inches to 5 feet wide in which the rocks are more or less thoroughly brecciated and silicified. Pyrite is abundant in most of the veins, where it partly or entirely fills interstices between the breccia fragments and also forms veinlets within the fracture zones. Presumably the gold contained in the ore is associated with the pyrite. Tellurides of gold and silver are reported, but they were not found in the specimens examined.

In the Amparo adit (fig. 37) all the wall rocks are more or less fractured and brecciated and contain irregular masses and veinlets of pyrite and quartz. The "cross veins" shown in figure 37 are merely zones where shearing and pyritization are especially marked. The vein followed by the adit is a strongly sheared pyritic zone from 6 inches to 3 feet wide.

Near the surface the vein matter is oxidized and consists in large part of a mixture of limonite and quartz. Some of this material yields gold on panning, and probably most of the ore produced from the property has been of this character.

The May Rose property undoubtedly contains a large tonnage of low-grade to medium-grade ore, and some small pockets of high-grade oxidized ore may yet be found. It should be fully realized, however, that most of the veins are relatively narrow and that the ore deposits in all of them are probably discontinuous. These facts, together with the relative inaccessibility of the deposits on the Burnt Timber side of Bragdon Ridge, would militate against large-scale, low-cost mining operations. It is possible, of course, that further exploration may uncover larger or richer deposits than those known at present. In that event, a crosscut adit from a point on the La Plata River between Neptune and Burnt Timber Creeks would render these ores, and also any that might be found on the Monarch property, accessible to transportation.

MINERAL WONDER (4)

The Mineral Wonder, Stamboul and Ruby Queen claims, near the headwaters of Junction Creek, between Fassbinder Gulch and Cumberland Mountain (pl. 14), were discovered about 1880. The Butterfly and September claims, which lie between the Mineral Wonder and Kennebec claims, were not located until much later. A good deal of rich ruby silver ore has been produced from various openings on the group, but no records of the early production are available. The table on page 150 shows the production since 1902:

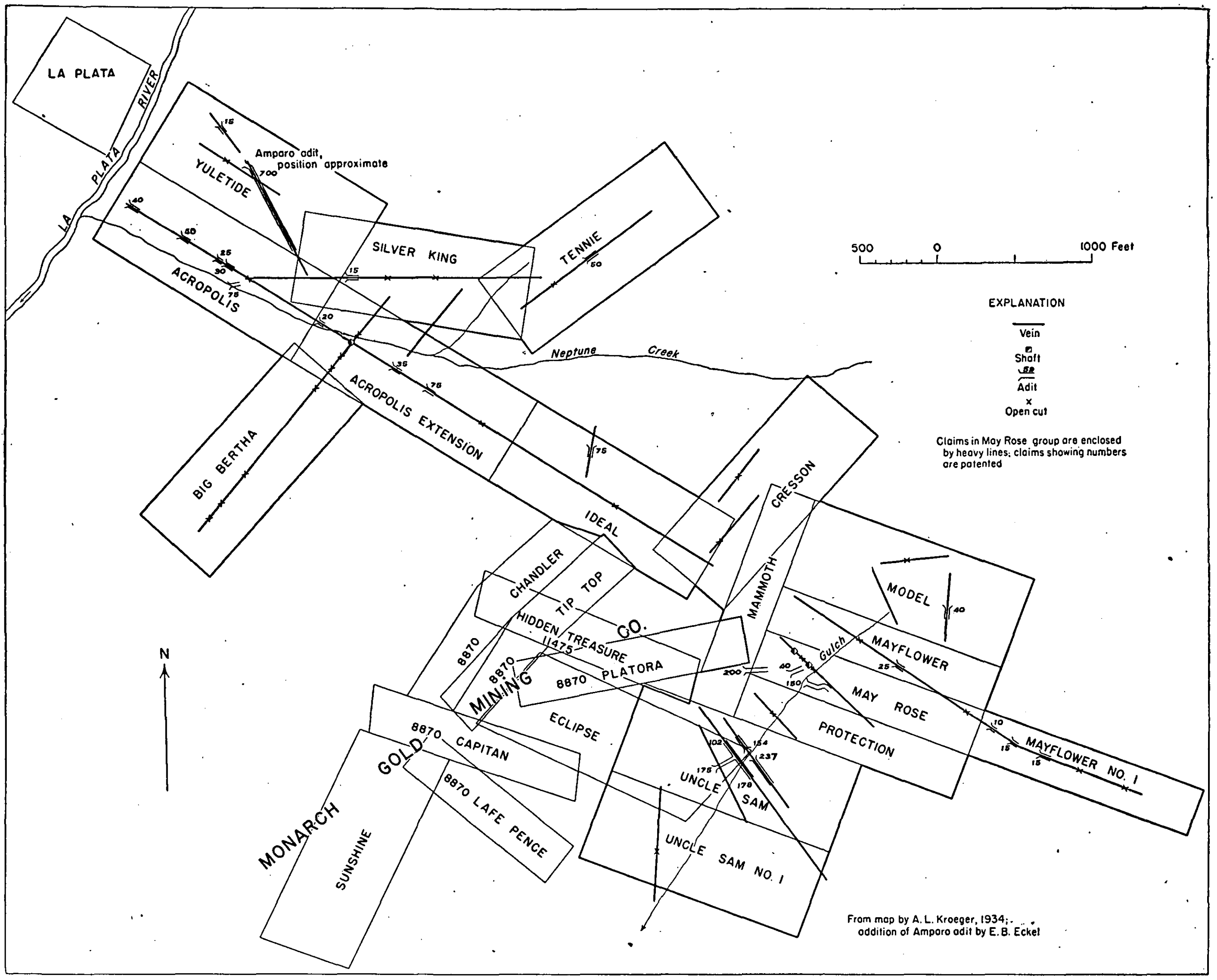

FIGURE 36.—Claim map of May Rose group, showing mine workings and relation to adjoining Monarch Mining Co. property.

Production of Butterfly and Stamboul mines, 1902–43 [1]

Year	Mine	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)
1912	Butterfly	13	2.58	834	83	1,933
1912	Stamboul	2	.53	283	--------	--------
1913	Butterfly	9	9.81	273	58	463
1913	Stamboul	.35	.10	44	3	4
1921	Butterfly	3	6.10	321	--------	113
1922	do	11	2.10	191	--------	--------

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

None of the mine workings were accessible in 1935–37, and nothing is known of their extent or character. As shown in plate 2, the vein system is believed to occupy a series of closely spaced, overlapping fractures, which strike a little north of east and represent the eastward continuation of the Cumberland-Muldoon and Tippecanoe-Kennebec vein systems. The topographic map is generalized, however, and the veins are not well exposed; hence the relations indicated are subject to correction. Judging from the material seen along the veins and from the production statistics presented above, the ore deposits on these claims are very similar to those of the Cumberland, Muldoon, Tippecanoe, and Kennebec mines.

MISSOURI GIRL (3)

by E. N. GODDARD

The Missouri Girl mine is on the north side of the Dolores River, half a mile northeast of Robinson's Ranch and 400 feet north of the road, at an altitude of about 8,200 feet. The workings, as shown in figure 38, consist of three parallel tunnels 40 to 80 feet long that follow the monzonite porphyry dike, and one crosscut tunnel that is caved but apparently did not reach the dike. The mine had been idle for some years prior to the writer's visit, but according to Jess Robinson two or three carloads of unsorted ore containing 4–5 percent copper were shipped in 1909–10, and the total production has been about six carloads.

The mine is near the base of the Dolores formation in a succession of gray and red sandstones and shaly

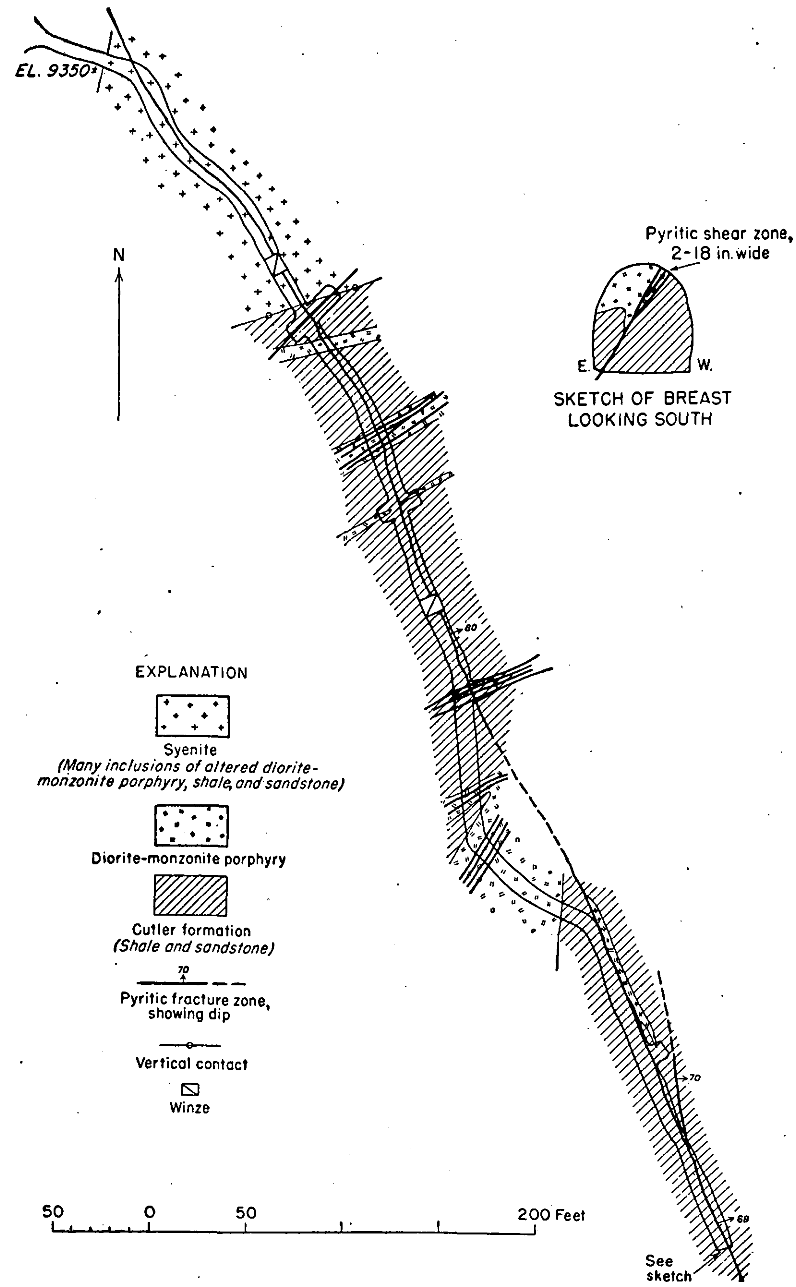

FIGURE 37.—Plan of Amparo exploration adit, on Yuletide claim of May Rose group.

sandstones containing considerable plant material and many small lenticular seams of coaly material. These sedimentary rocks are cut by a monzonite porphyry dike that strikes N. 35° W., dips 86° NE., and is 40 to 45 feet wide. The sandstone bordering the dike is very hard, having apparently been indurated by the intrusion. Red sandstone layers have turned gray for about 6 inches from the dike.

The workings explore three small steeply dipping faults along the borders of the dike, two on the east side and one on the west. The dike is bordered by a nearly vertical fracture zone, and 12 to 14 feet east of this zone is a parallel fault zone, 1 inch wide, that dips 78° E. and cuts into a bulge in the dike above the tunnel level (fig. 39). Between the fracture zone and the fault there are many small nearly horizontal slips and fractures that parallel the bedding planes and the coaly seams. They appear to branch from the fracture zone, but they are cut off by the fault, on which the northeast or hanging wall apparently moved up. The fault appears to be preore, for thin seams of chalcocite border it in places.

On the west side of the dike, a tunnel 40 feet long explores a fault zone 1 inch to 6 inches wide, which runs parallel to the dike at a distance of 4 to 6 feet. The fault strikes N. 34° W., dips 78° SW., and is bordered by from 1 to 3 feet of fractured rock. In this tunnel, which is about 25 feet higher than the tunnels

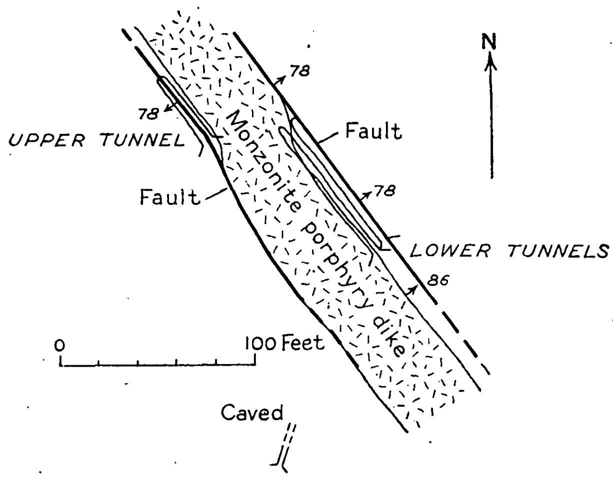

FIGURE 38.—Sketch showing the relations of the Missouri Girl mine workings to the monzonite porphyry dike.

on the east side of the dike, the seams of coaly material are less abundant; but shaly layers 1 inch to 1 foot thick are numerous.

Chalcocite occurs on both sides of the dike, though it is rather scarce on the west side. It is largely confined to the fractured coaly seams, where it occurs in irregular veinlets or lenticular masses or is finely disseminated in the adjacent sandstone. A little chalcocite is also found in the faults and fracture zones, and small rounded masses of chalcocite occur sparingly in the dike close to its border.

The chalcocite is so irregularly distributed in the rock that it is impossible to make any estimate of grade or tonnage. The ore shipped in the past appears to have been selectively mined, for the highest-grade rock observed by the writer appeared to contain only 1 or 2 percent copper, and only a small tonnage of such rock was in sight. Previous work was apparently not very profitable, for little stoping has been done and development work has not been carried far.

MONARCH (2b)

The Monarch mine is on the east side of Bragdon Ridge, at an altitude of 10,400 to 11,000 feet. It was originally known as the Tip Top, after one of the patented claims. It can be reached over a good pack trail from the mouth of Burnt Timber Creek. The Tip Top mine was active when visited by Purington in 1896, and a 300-foot adit had been opened, but there is no record of production until 1932, when the property was taken over by the Monarch Mining Co. and renamed. The claims held by this company are shown on the map of the May Rose group (fig. 37). The Monarch Company erected a small flotation mill and several other buildings, and did some underground development work. According to records of the Bureau of Mines, the mine produced bullion containing 4.66 ounces of gold and 1 ounce of silver in 1932 and 5.62 ounces of gold and 1 ounce of silver in 1933. Some further development work was done in 1934 and 1935, but the mine was virtually abandoned in 1936. The accessible workings are shown in figure 40. The old upper workings, which comprised several short adits and open-cuts, all in oxidized ore, were inaccessible in 1936.

With the exception of a small wedge of arkosic grit belonging to the Cutler formation and exposed in the lower crosscut, the country rock in the vicinity of the mine is diorite-monzonite porphyry. A little farther north this seems to grade imperceptibly into syenite (pl. 2), but exposures are so poor and the rock is so altered that the relations are not clear.

The deposit explored in the Monarch mine occupies a zone of crushed and altered porphyry at least 100 feet wide and several hundred feet long. Throughout this zone the rock is sheared along steeply dipping planes that strike N. 20° to 40° E. Pyrite is widely and rather abundantly disseminated throughout the zone, and the feldspars of the porphyry are almost completely sericitized. The "vein" exposed in the upper level shown in figure 40 is one of several silicified zones that parallel

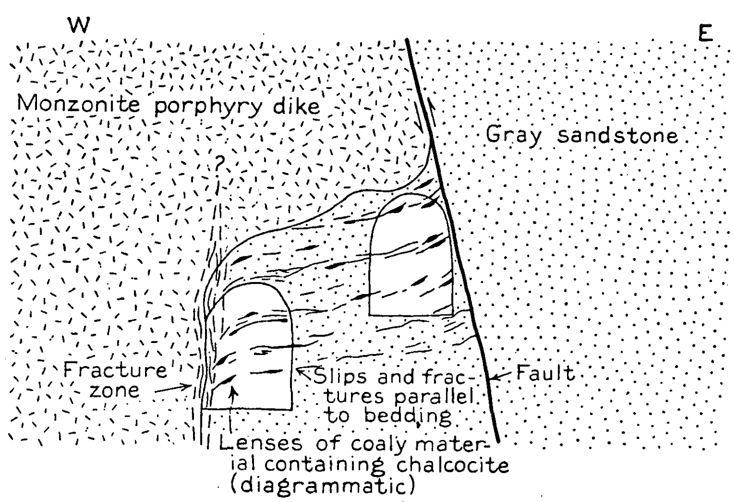

FIGURE 39.—Cross section of the lower Missouri Girl tunnels at the portals, showing the relation of chalcocite to the structure.

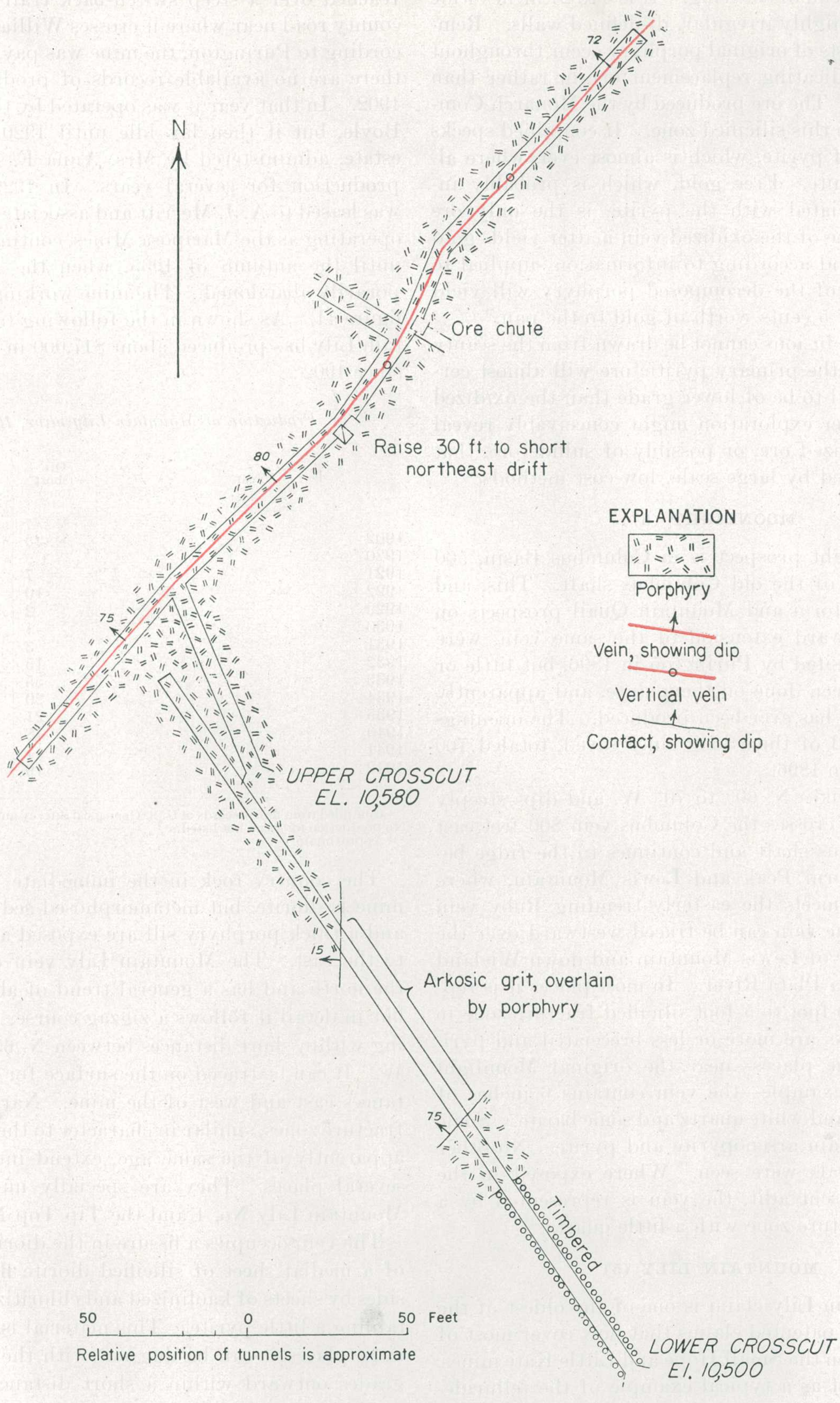

FIGURE 40.—Plan of lower workings, Monarch mine.

the regional trend of shearing. It is 3 to 24 inches wide and possesses highly irregular, ill-defined walls. Remnants and ghosts of original porphyry occur throughout the "vein," indicating replacement origin rather than fissure filling. The ore produced by the Monarch Company was from this silicified zone. It contained specks and veinlets of pyrite, which is almost everywhere altered to limonite. Free gold, which is probably intimately associated with the pyrite, is the only ore mineral. Some of the oxidized vein matter yields gold on panning, and according to information supplied to Purington all of the decomposed porphyry will yield "an average of 5 cents worth of gold to the pan."

Reliable conclusions cannot be drawn from the scanty data at hand; the primary pyritic ore will almost certainly be found to be of lower grade than the oxidized ore, and further exploration might conceivably reveal bodies of oxidized ore, or possibly of sulfide ore, that could be worked by large-scale, low-cost methods.

MOONLIGHT (57)

The Moonlight prospect is in Columbus Basin, 500 feet northeast of the old Columbus shaft. This, and also the Hailstorm and Mountain Quail prospects on the northwestward extension of the same vein, were active when visited by Purington in 1896, but little or no work has been done on them since, and apparently little or no ore has ever been produced. The openings on the vein, all of them long since caved, totaled 700 feet in length in 1896.

The vein strikes N. 60° to 70° W. and dips steeply southwest. It crosses the Columbus vein 800 feet east of the Columbus shaft and continues to the ridge between Snowstorm Peak and Lewis Mountain, where it apparently meets the easterly trending Ruby vein and stops. The vein can be traced westward over the northwest spur of Lewis Mountain and down Wieland Gulch to the La Plata River. In most places it is represented by a 2-foot to 5-foot silicified fracture zone in which the rocks are more or less brecciated and pyritized. In some places—near the original Moonlight workings for example—the vein contains 6 inches of mottled green and white quartz and some barite. Some specimens contain arsenopyrite and pyrite. No other metallic minerals were seen. Where exposed in the Columbus crosscut adit, the vein is represented by a very weak fracture zone with a little quartz.

MOUNTAIN LILY (5)

The Mountain Lily claim is one of the oldest of the large group of patented claims that now cover most of the area between the Small Hope and Little Kate mines. It is of interest as a typical example of the telluride-bearing veins that occur within the diorite stock of Diorite Peak. The workings on this and the adjoining Tip Top claim are on the southeast spur of Diorite Peak, at altitudes of 11,000 to 11,160 feet. They are reached over a steep switch-back trail that meets the county road near where it crosses Williams Gulch. According to Purington, the mine was paying in 1896, but there are no available records of production prior to 1902. In that year it was operated by the owner, O. F. Boyle, but it then lay idle until 1920, when Boyle's estate, administered by Mrs. Anna F. Boyle, renewed production for several years. In 1929 the property was leased to A. J. Merritt and associates. This group, operating as the Mariposa Mines, continued production until the autumn of 1935, when the lease was temporarily abandoned. The mine workings are shown in figure 41. As shown in the following table, the Mountain Lily has produced about $17,000 in gold and silver since 1902:

Production of Mountain Lily mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1902	25	[2] 150	
1920		5.70	8
1921	7	51.30	63
1922	10	96.00	154
1929	2	9.40	10
1930	1	7.00	11
1931	3	10.34	19
1932	15	19.25	19
1933	55	45.16	3
1934	20	31.37	24
1935	21	24.94	24
1940	48	62.58	77
1941	11	13.40	16
1942	19	140.57	141

[1] Compiled from mine records of U. S. Geological Survey and the Bureau of Mines. No production for years not listed.
[2] Approximate.

The country rock in the immediate vicinity of the mine is diorite, but metamorphosed sedimentary rocks and a thick porphyry sill are exposed a short distance to the east. The Mountain Lily vein dips steeply to the north and has a general trend of about N. 80° E., but in detail it follows a zigzag course, its strike varying within short distances between N. 65° E. to N. 80° W. It can be traced on the surface for only short distances east and west of the mine. Narrow subsidiary fracture zones, similar in character to the main vein and apparently of the same age, extend into the walls at several places. They are specially numerous on the Mountain Lily No. 1 and the Tip Top No. 1 levels.

The vein occupies a fissure in the diorite and consists of a medial sheet of silicified diorite flanked on both sides by sheets of kaolinized and chloritized diorite containing a little pyrite. This material is so soft that in most places it can be dug out with the fingers, but it grades outward within a short distance to unaltered diorite. The medial sheet ranges through all degrees of silicification from nearly fresh diorite to granular quartz. Most of the quartz is dark gray to dark green, and much of it contains residuals and ghosts of the

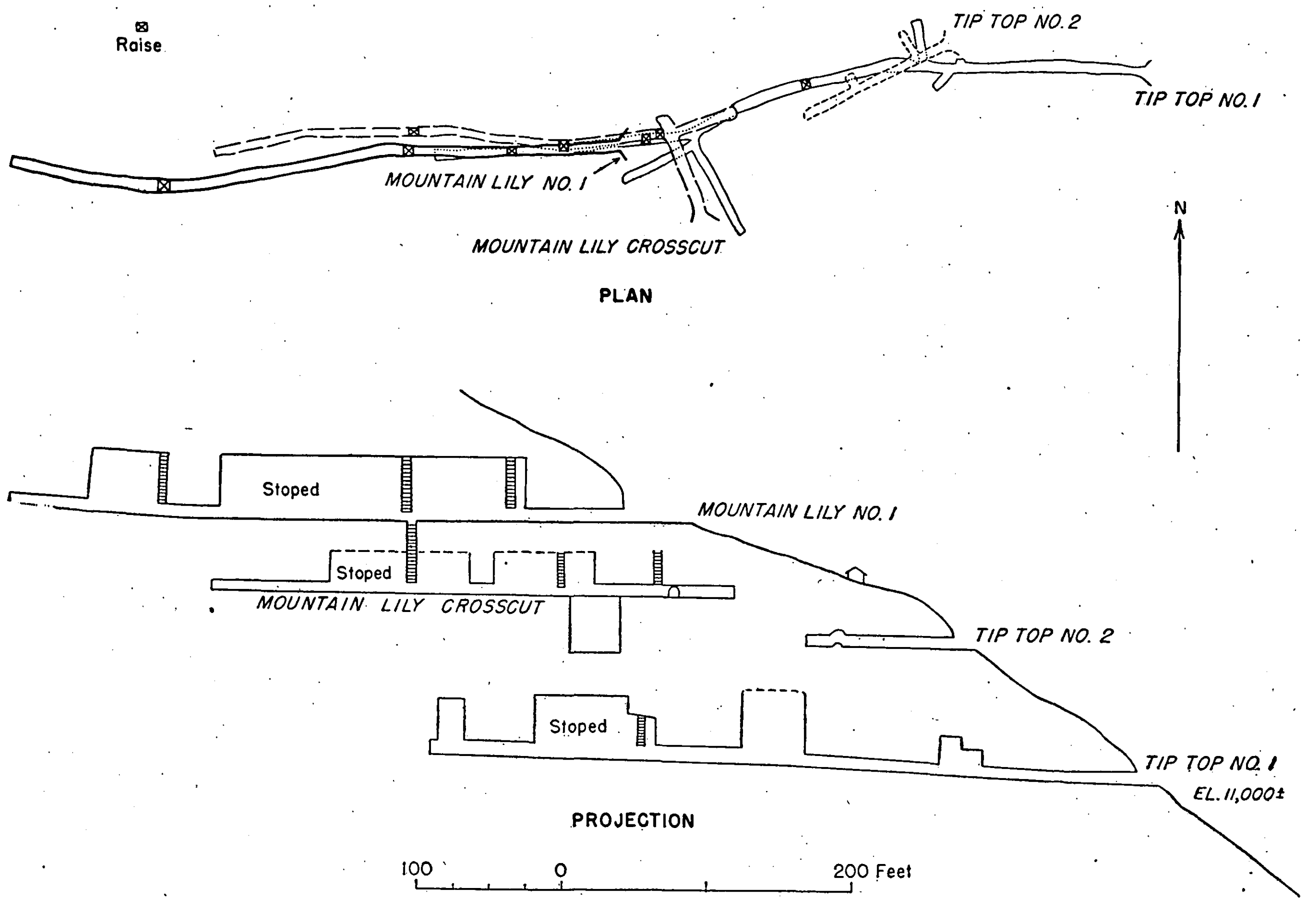

FIGURE 41.—Plan and projection of Mountain Lily mine.

original constitutents of the diorite. Varicolored chalcedony forms blebs and irregular lenses in the more coarsely crystallized quartz and lines a few small vugs. Arsenopyrite and a little pyrite are disseminated throughout the core and are locally abundant. Sylvanite is said to be the chief ore mineral, but no tellurides were found in the specimens examined. According to R. M. Wheeler, formerly of the Gold King mine, some of the ore contains native tellurium.

Wherever it is now exposed in the mine the entire vein zone, including the altered diorite, is 1 foot to 5 feet thick. The medial sheet, which is the only part that contains sufficient gold to be classed as ore, varies in thickness from less than 1 inch to 10 inches, pinching and swelling within short distances both vertically and horizontally. Since most of the productive parts of the vein have been removed or are concealed by lagging, no detailed study could be made of the relation of vein character to changes in strike and other structural features.

MULDOON (4)

The Muldoon mine, on the eastward extension of the Cumberland vein, is 1,000 feet east of Cumberland Mountain, at an altitude of 11,750 feet. It can be reached over a branch trail from Kennebec Pass. The Muldoon claim was patented in the early eighties, at the same time as the Cumberland, but there is no record of production prior to 1917. It was worked by P. W. Pittman from 1917 to 1919 and lay idle until 1935, when its owner, T. R. Marshall, leased it to Herman Dalla and Dave Bianchi. These two men worked it together in 1935, and Dalla continued alone in 1936. The mine was idle in 1937. The mine workings are shown in figure 42, A stope 10 to 20 feet high has been opened above

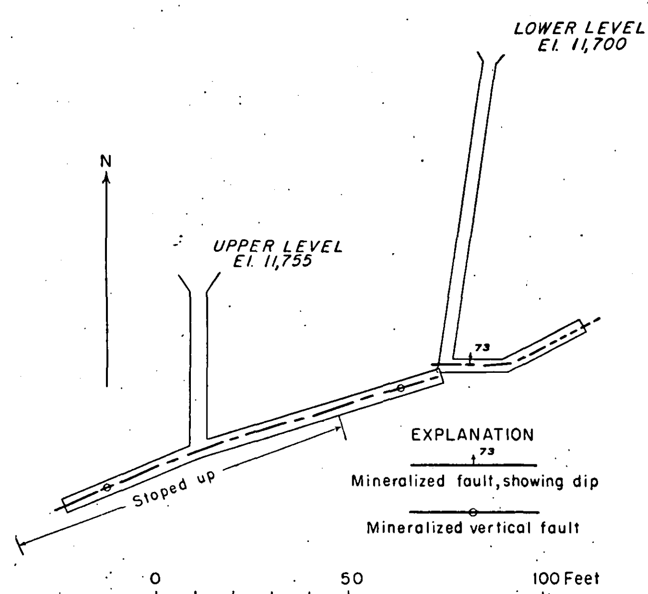

FIGURE 42.—Plan of Muldoon mine workings.

the upper level and extends 15 feet past the west end of the drift. The following table shows the production of the mine since 1902:

Production of Muldoon mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1917	2	0.07	158
1918	1	--------	75
1919	4	.10	271
1935	12	.71	1,881

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed. Production prior to 1902 unknown but probably small.

The country rock consists of soft red mudstone of the upper part of the Cutler formation, the base of the Dolores formation being not far west of the mine. The beds dip gently to the north. Porphyry is exposed in the west end of the stope, where its contact with the mudstone strikes N. 45° W. and dips steeply southwest.

The outcrop of the Muldoon vein trends N. 71° E. between the Cumberland and Muldoon mines, but just east of the latter it swings toward the north partly because of a northward dip. The Muldoon and Tippecanoe-Kennebec vein apparently intersect about 2,000 feet northeast of the Muldoon mine. In the upper level of the mine, the Muldoon vein is vertical and ranges from 4 to 29 inches in width; in the lower level it dips north and ranges from 4 to 14 inches in width. At the east breast of the lower level it is represented only by two or three small veinlets of quartz. Elsewhere the vein consists of white vuggy quartz with ruby silver and a little barite and is similar to the Cumberland vein.

NEGLECTED (5)

HISTORY AND PRODUCTION

The Neglected mine, the oldest of the district's large producers, is in Gaines Gulch, a tributary of Junction Creek, at an altitude of 10,300 feet. It has been owned for some years by a small group of Durango and Denver businessmen. The county-maintained Junction Creek road is usually open as far as the point where it leaves Flagler Fork, but the last mile between there and the mine is difficult to maintain and is often impassable.

The deposit was discovered about 1895, by Richard Gaines, and was worked in a small way by him and by several lessees until the spring of 1901. At that time James Dennison and W. J. Boyle took a lease, discovered rich ore, and soon began operations on a large scale. In October of the same year they sold a half interest in the lease to J. J. Gorman and F. H. Rivers. Some of the ore was concentrated in a small but reputedly inefficient Chile mill though much of it was shipped crude. The height of the mine's activity was reached in 1902, but production continued until 1905. The mine was then abandoned, owing, it is widely believed, to personal extravagance and discord among the new-rich operators resulting in their inability to meet payments on their lease. The subsequent histo-y of the mine, however, indicates that diminution of the visible ore reserves may have been the decisive factor. Some ore was produced by lessees in 1911–12 and a little development work was done in later years, but the mine was almost continuously idle until 1932, when it was leased to the Colorado Juneau Mining Co. This company did much surface development, and completed a 1,150-foot drainage and transportation adit in the spring of 1935. When the old workings had been unwatered the mine was sampled, but the results were so disappointing that the mine reverted to the owners.

No figures are available for production prior to 1902; but except for the latter part of 1901 the early production was probably small. The recorded production since 1902 is shown in the table below. The total of less than $300,000 is between one-third and one-half of that which is locally attributed to the property.

Production of Neglected mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1902	[2] 1,144	6,039.00	3,382
1903	853	5,502.40	3,343
1904	[3] 1,930	1,468.32	237
1905	34	164.01	101
1911	80	241.17	151
1912	31	66.01	60
Total recorded production		13,480.91	7,274

[1] Compiled from mine records of U. S. Geological Survey and the Bureau of Mines. No production for years not listed.
[2] Mined 11,344 tons.
[3] Shipped 130 tons of crude ore, 98 tons of concentrates derived from milling 1,800 tons of ore, and $9,429.58 worth of bullion.

The mine was originally worked through a vertical shaft, now caved, from which four levels were opened. Later a 65-foot adit and a long crosscut adit (pl. 27 *A*) were driven. Most of the 5,000 feet of workings are shown in plate 27. Part of the following description is based on Emmons' account,[23] but development work completed since his visit has thrown much additional light on the character of the ore deposit. The 85-foot level and the western part of the 125-foot level were inaccessible in 1935–37, and the geologic relations shown in plate 28 are in part projected from other levels and in part taken from an unpublished map made by G. H. Hand, mining engineer, in 1910.

GEOLOGIC RELATIONS

The main country rock of the mine consists of generally unaltered red shales and arkosic sandstones of the upper part of the Cutler formation, which dip 5° to 10° toward the east and southeast. These rocks are

[23] Emmons, W. H., The Neglected mine and nearby properties, Durango quadrangle, Colorado: U. S. Geol. Survey Bull. 260, pp. 121–127, 1904.

intruded by several bodies of diorite porphyry. On the upper levels the porphyry occurs as normal sills. The porphyry exposed on the lower levels has the form of a dike, 30 to 60 feet thick; which strikes nearly due east and dips south. The general shape of this body, however, as indicated by the cross sections in plate 28, is not altogether that of a dike; it has a sill-like top pitching gently eastward and steep, dikelike walls below. It is not exposed on the surface, and its horizontal and downward extent are not known. It may occupy the channel through which the porphyry magma rose and may connect with the overlying sills.

The Neglected vein occupies a strong fault zone, which strikes nearly due east but crosses the porphyry dike at an acute angle. It dips steeply south. The amount of displacement is unknown but probably small, as indicated on plate 28. Slickensided and grooved surfaces indicate that the south wall moved downward toward the west at a steep angle.

Near the porphyry on the two lower levels, the fault zone is split into two branches from 10 to 30 feet apart, and the intervening rock is somewhat broken and shattered throughout. The fault zones, which are from 1 foot to 16 feet wide in the porphyry, consist of sheared and brecciated country rock, more or less thoroughly silicified and transversed by numerous veinlets of white to gray fine-grained quartz. Both east and west of the limits of the dike the fault zone is weak, contains more gouge than quartz, and is in general from 6 to 18 inches wide. The wall rock is strongly altered close to the dike but is nearly fresh elsewhere. The shale and the groundmass of the porphyry have been bleached and silicified for distances of 2 to 10 feet away from the fracture zones. The feldspars of the porphyry and of the arkose are largely altered to sericite, which is accompanied by halloysite. Original hornblende phenocrysts have been changed in the partly altered porphyry to chlorite mixed with a little epidote and carbonate, but in the more thoroughly altered rock close to the vein they are represented by intergrowths of tourmaline, sericite, and chlorite, named in order of abundance. Pyrite is disseminated in considerable quantity throughout the altered wall rock.

It is evident that there were several periods of movements along the Neglected fault zone after the intrusion of the porphyry. During the first period fractures were opened in and near the dike. The wall rocks were altered by solutions, which probably rose along the same channel as that followed by the porphyry magma. They were thus rendered more competent, so that during a later period of movement they were sheared and brecciated. The breccia was later cemented and partly replaced by quartz and ore minerals.

ORE DEPOSITS

The principal ore minerals of the mine are the tellurides of gold and silver which are accompanied by various quantities of several sulfides. Free gold is said to have been abundant in the early near-surface workings but is rarely found in the deeper ores. Parts of the old tailings dump yield much free gold and amalgam on panning. Most of the mercury in the amalgam was introduced by milling operations, but Emmons[24] says that native amalgam occurred in some of the ore. The ore occurs in small veins and stringers, of quartz, which contain the telluride and other ore minerals. Some of the stringers occur in the fractured wall rock, particularly in the wedge between the two splits of the main vein.

Pyrite, intergrown with arsenopyrite in some places, is by far the most abundant metallic mineral in the specimens examined and forms scattered grains in the vein matter and in the wall rocks. It was the first of the ore minerals to be deposited. Intergrowths of bornite, chalcopyrite, tetrahedrite, and enargite, which are next to pyrite in abundance, have partly replaced the pyrite and gangue minerals and have also filled open spaces in the vein. Silver-bearing tetrahedrite and an unidentified mineral are associated with the copper minerals in a few places. In the single specimen of high-grade ore that was available, taken from a winze below the 175-foot level, tetrahedrite is extensively replaced by krennerite, with which a little coloradoite and a few tiny specks of petzite (?) and native gold are associated. The covellite and argentite found in a few specimens are supergene, and some of the bornite also is believed to be of supergene origin. Some of the free gold in the near-surface workings may have been derived from gold-bearing tellurides during weathering.

Quartz is the dominant gangue mineral, and the earliest. In massive crystalline aggregates of irregular grains it constitutes the greater part of the vein filling. Many specimens contain two generations of ankerite, one later and one earlier than the hypogene ore minerals. Barite is intergrown with the ankerite in places but is nowhere as abundant as it is in many of the district's telluride deposits. The last primary mineral to form was dickite, which is very abundant in the vein; some of it stained brown with iron oxide. Another clay mineral, halloysite, occurs in the veins but is relatively scarce.

As shown on the stope maps on plate 28, nearly all of the ore from the Neglected mine came from a single ore shoot, which is closely associated with the porphyry mass and likewise pitches 15° to 20° E. Little stoping has been done to the east of (or above) the porphyry, and stoping to the west of (or below) the porphyry has not extended as much as 200 feet horizontally from the porphyry on either the 125-foot or the 175-foot level. The most profitable ore zone lay between the 85-foot and 175-foot levels.

Although some of the altered rock in the wedge be-

[24] Emmons, W. H., op. cit. (Bull. 260), p. 125.

tween the splits of the fault was of milling grade, most of the best ore occurred in the silicified fault zones. The richest ores were found in places where the vein follows the contact between silicified shales and porphyry, but much shipping ore was obtained from the part of the vein that was within the dike. The arkosic sandstone appears to be a very unfavorable wall rock, doubtless because the feldspar grains became sericitized, so that the rock was made soft and crumbly, rather than hard and competent like the silicified interbedded shales.

FUTURE OF THE MINE

There are possibly several thousand tons of ore above the 175-foot level that could be recovered by careful mining and that might yield half an ounce or more of gold to the ton. Much broken ore remains in the stopes, but its tenor is not known. Most of it however, fell from the tops of the stopes, where the ore was presumably close to the lower limit of commercial grade. At best however, the Neglected deposit may be regarded as nearly worked out above the 175-foot level. Both the small tailings dump derived from the former milling operations and the larger waste dump near the old shaft probably deserve careful sampling.

As the close relations between the dike and the workable ore shoot seem well established, the dike should serve as the most important guide in any future search for ore. The localization of ore was controlled by mechanical conditions related to the shape of the dike and the silicification near it. That is, the tendency of the fault to follow the dike walls caused it to split and to assume a flatter dip where it crossed the dike. The porphyry itself and the silicified sedimentary rocks near it were brittle, and hence able to form open fractures, which allowed the passage of solutions and the deposition of the ore minerals.

There is no notable change in the character of the ore with depth. As the dike, which controls the ore shoot, extends downward below the lowest level, and as the vein must remain in or very near the dike for some distance the downward extension of the ore shoot along the pitch of the dike appears worthy of exploration.

OHIO-INDIANA (5?)

The Ohio-Indiana prospect is just below the road on the east side of Deep Creek, 3 miles southeast of Bald Knob. The chief development consists of a 200-foot crosscut adit trending N. 60° E. at an altitude of 8,625 feet; 100 feet higher, near the road, is a small open-cut.

The property is owned by the Bechtolt brothers, ranchers on lower Deep Creek, who first opened it in 1934. No ore has been produced.

The crosscut exposes southward-dipping beds of gray sandstone and green shale belonging to the lower part of the Morrison formation. Several strong fracture zones that strike N. 60° W. and dip from 55° to 80° NE. were cut in the last 50 feet of the adit. Each is a foot or more wide and marked by slickensided surfaces, and each contains considerable gouge and a little vein quartz. Small masses of good ore were found here and there along the fracture zones, and also on small bedding-plane slips between sandstone and thin beds of shale. Specimens of some of this ore are rich in gold. Finely divided free gold and pyrite are scattered through the sandstone within and near the fracture zones, and calcite locally fills interstices between the sand grains. Small specks of a telluride mineral can be seen in a few specimens. Free gold is smeared over the slickensided surfaces of some material, and the owners say that some of the limonitic gouge pans free gold. They believe that the adit should have to be driven about 25 feet farther to intersect the real vein, which is said to be parallel to the fractures described above and to be well-exposed in the sandstone cliffs below the prospect. This vein was not examined by the writer.

The existence of an ore deposit in the vicinity of Deep Creek is of interest because, like the Mason mine to the northeast, it offers some hope that exploration might reveal other ore bodies in a large and hitherto unproductive area. If the Ohio-Indiana deposit is like others in the district, the quantity and quality of the ore should be greater in the underlying Junction Creek sandstone than it is in the shale beds.

ORO FINO (5)

The Oro Fino mine is at the head of Leavenworth Gulch, half a mile north of the Neglected. It was worked for a short time about 1892, and some of the ore was run through a small stamp mill on Gaines Gulch, at the mouth of Leavenworth Gulch. There is no record of the production, but it was undoubtedly small.

The mine was first worked through a 158-foot vertical shaft, from which 15-foot to 25-foot drifts were opened to the west 35 and 90 feet below the surface. Later, a 450-foot crosscut adit was driven to connect with the bottom of the shaft, and a 50-foot westerly drift was turned from this adit. The shaft and upper workings were caved in 1936. The workings on the crosscut level are shown in figure 43.

The country rocks in the lower drift are soft red shale and sandstone beds of the Cutler formation dipping 25° E. Near the vein an irregular sill of diorite porphyry is exposed. It is faulted down to the north along the main Oro Fino vein, and probably also along a parallel fissure 15 feet farther south (fig. 43). The base of the sill is exposed on the south wall of the vein, and its top shows on the north wall. Without knowing the thickness of the sill it is impossible to determine the amount of displacement along the fault. In a short crosscut to the north, the sill becomes dikelike, being nearly vertical and striking due east. The areal map (pl. 2) indicates that one or more porphyry sills were probably cut by the shaft.

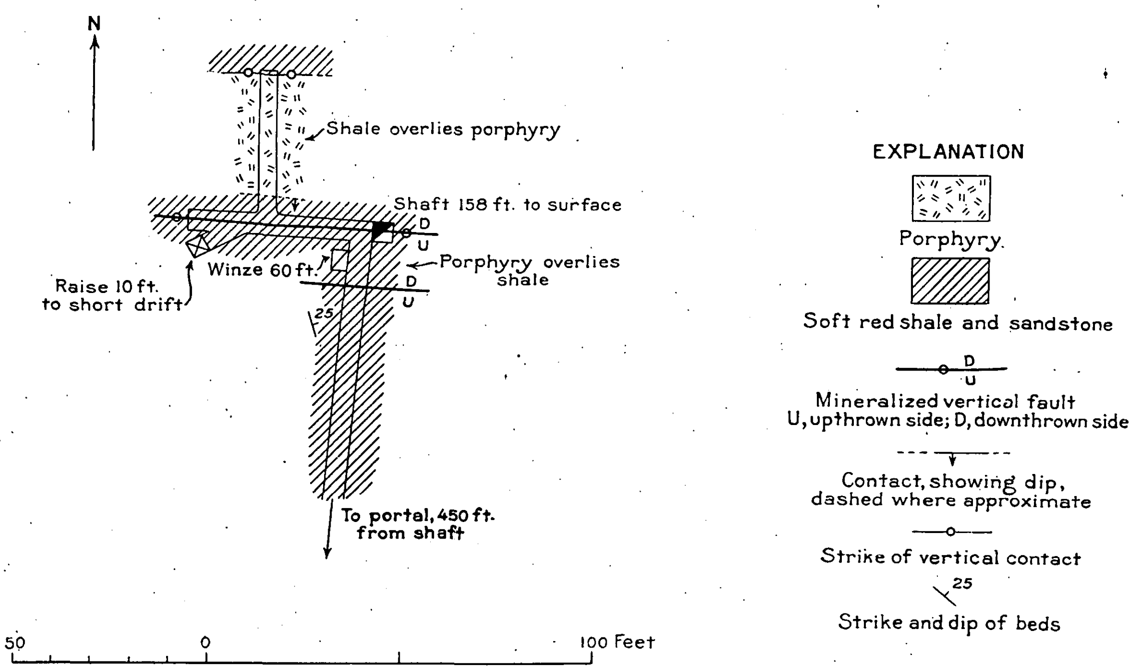

FIGURE 43.—Plan of lower level, Oro Fino mine.

The Oro Fino vein strikes due east and is vertical. It is on the eastward extension of the vein zone worked by the Gold King-Swamp Angel group. Where exposed in the lower drift, it consists of ⅛ inch to 1 inch of white calcite with a thin selvage of dark-green quartz along each wall. The microscope reveals minute grains of sphalerite scattered through the quartz, and also a few grains of tetrahedrite in the quartz and along the quartz-calcite boundaries. According to Mr. Dennison, the vein is 1 inch to 5 inches wide on the upper levels and there contains noteworthy amounts of gold in the form of tellurides. No tellurides were seen, however, in the specimens examined, and there is certainly no indication of rich ore on the lower level. The wall rocks are altered for distances of 6 to 24 inches from each side of the vein. The sedimentary rocks are bleached and slightly silicified and the porphyry is sericitized.

The Oro Fino vein is very narrow and shows little evidence of containing valuable minerals where it is now exposed. In some respects, however, it is similar to the Neglected vein, and it may conceivably contain workable ore shoots somewhere along its course.

ORO NEGRO

The Oro Negro group of unpatented claims is in a ravine locally known as Oro Negro Gulch, west of Deadwood Creek and about a mile east of the May Day mine. None of the numerous mine workings were accessible in 1936, and rock exposures in the vicinity are very poor. No ore has been produced.

The general geologic relations are indicated in plate 2. Little is known about the ore deposits. White calcite occurs abundantly in a strong eastward-trending fault zone, part of the May Day-Idaho fault system, and minute crystals of chalcopyrite and sphalerite are disseminated through the calcite, which in places is at least 30 feet thick. The Pony Express limestone member of the Wanakah formation is locally mineralized. Some evidence has been found of other veins, some trending northward and some eastward.

OUTWEST (2c)

The Outwest mine, operated by the Outwest Mining Co., is on the eastward extension of the Red Arrow vein and traverses the patented Gold Run placer claim. It was first opened shortly after the Red Arrow discovery in 1933. When the mine was examined in 1936 the only opening on the property was a 145-foot drift adit, 115 feet below the main Red Arrow adit. A 20-foot winze had been sunk 10 feet from the breast of the adit. Forty tons of ore recovered from development workings and from a small stope at the bottom of the winze yielded 387.02 ounces of gold, 189 ounces of silver, and 205 pounds of copper. The mine was idle in 1937 but was active in 1938–39. A lower adit was then driven on the vein, and stopes were opened both above and below the upper level (fig. 44). The vein is similar in all essential respects to that in the Red Arrow mine and is characterized by coarse free gold, chalcopyrite, tetrahedrite, and barite. The wall rocks belong to the Junction Creek sandstone.

PEERLESS (2b)

The Peerless mine is near the south bank of the West Mancos River, north of Jackson Ridge, at an altitude of 10,525 feet (pl. 19). Little is known of this or the nearby Gold Bed mine (pl. 14), but they are believed to have been part of the "Jackson contact" development, begun by George A. Jackson in 1890. There is no

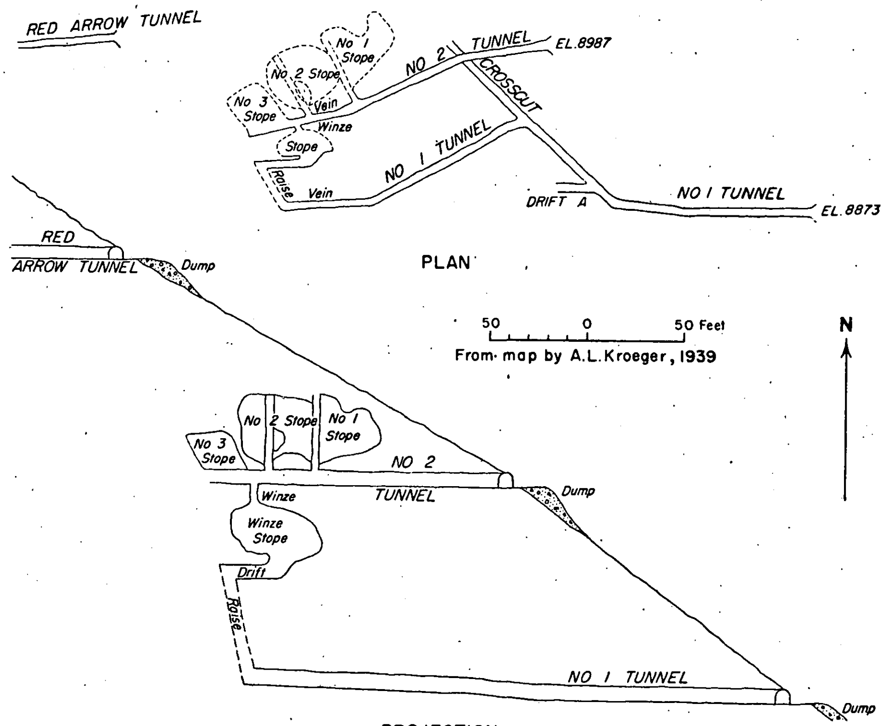

FIGURE 44.—Plan and projection of workings, Outwest mine.

record of production from any of the workings. The Peerless mine was worked through an adit trending S. 15° E., which was caved in 1935; the size of the dump indicates that there are several hundred feet of workings. The ruins of an old tram show that the mine was once connected with a small stamp mill, whose site is indicated in plate 19. Most of the ore put through this mill, however, is said to have come from the Doyle mine.

The adit was driven at the contact between the Dolores formation and the Entrada sandstone, which here dip 20° to 30° W. A 20-foot dike of coarse-grained diorite-monzonite porphyry trending southeast is exposed near the portal. The dump contains much pyrite and relatively abundant masses of bladed arsenopyrite intergrown with a little dull-green chlorite. A few poor exposures, supplemented by hazy information from local sources, indicate that the sulfide ore occurred in a bed-replacement deposit about 5 feet thick. The ore is said to have contained about 0.25 ounce of gold to the ton.

This bed of ore is unique in the district, in that it lies at the Dolores-Entrada contact; the cause of its localization at that horizon is unknown. Burbank [25] has noted thin discontinuous lenses of limestone at and near this contact along the San Miguel River, and it seems possible that the Peerless deposit represents a similar lens.

PUZZLE (2c?)

The Puzzle mine is on and near the ridge between Lewis Creek and Lightner Creek. Two parallel veins that trend N. 60° to 75° E. follow the general course of the ridge; one of them passes under the cabin on Puzzle Pass and the other is somewhat less than 500 feet to the north. There are several openings on each vein between Puzzle Pass and Walls Gulch, but the only one accessible in 1937, aside from a few open-cuts, was a 300-foot adit whose portal is 2,500 feet east of Puzzle Pass, at an altitude of 11,350 feet. Despite the fact that the Puzzle mine has been worked in recent years, little information could be obtained as to the character of the deposits, or even as to what workings the ore was taken from. The mine has been known since about 1880 and may possibly have produced considerable ore before 1902. The following table shows the production since 1902:

Production of Puzzle mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)	Lead (pounds, wet assay)
1909	18	4.29	629	--------	2,959
1913	½	.07	13	2	20
1917	20	6.72	272	686	82
1919	--------	4.00	7	--------	--------
1921	6	3.70	161	--------	907
1923	--------	12.00	11	--------	--------
1925	10	2.00	68	--------	200
1930	1	1.30	4	31	--------

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The veins follow steeply dipping fracture zones that range from 1 foot to 8 feet in width. They consist of quartz, with galena, pyrite, a little tetrahedrite and barite, and possibly tellurides. The greatest thickness of vein matter in the exposures seen was about 10 inches.

[25] Burbank, W. S., personal communication.

On the northeast side of the ridge between Walls Gulch and Lightner Creek is a vein that must be the extension of the Puzzle system At 11,250 feet altitude, near a trail, there is either a caved open-cut or a stope that was opened to the surface. Here the vein strikes N. 75° E. and dips 70° NW., but because of the steep slope the course of the surface outcrop is N. 55° to 60° E. The wall rocks are fractured for 10 feet on each side of the vein. The open-cut or stope must have been 4 feet wide, but the largest piece of vein matter seen on the dump was 8 inches thick. The vein matter is predominantly dense, gray to brown quartz. Openings are coated with small crystals of quartz and minute tablets of barite. The most abundant ore minerals are pyrite and tetrahedrite, but small masses of galena, malachite, and azurite occur in places.

RED ARROW (2c)

HISTORY AND PRODUCTION

The Red Arrow mine, the most recent discovery of commercial importance in the La Plata district, is on the west side of Gold Run, 800 feet northwest of its junction with the East Mancos River and at an altitude of about 9,350 feet. It is about 8 miles from Mancos, with which it is connected by a good county road. The discovery was made by Raymond and Charles Starr on June 3, 1933, attracted wide attention in newspaper accounts, and led to a feverish but comparatively short-lived boom in the East Mancos sector. While panning small gravel bars along Gold Run the Starrs obtained spectacular showings of coarse gold in the creek, just below the crossing of a small fissure. Their effort to trace the gold to its source resulted in discovery of a comparatively small outcrop of oxidized vein material that contained coarse gold. This outcrop was explored by a small open-cut, and a drift adit was subsequently opened just below it.

Soon after the discovery the Red Arrow Gold Corp., composed largely of local owners, was formed. The company was almost immediately involved in a suit brought by the Starrs' former partner. This litigation, which was finally settled in 1936 in favor of the defendants, undoubtedly acted as a check on exploration and production for several years. As shown in the following table the mine produced nearly $150,000 in gold, silver, and copper in the years 1933–37, thus becoming, in a space of 5 years, the sixth largest producer in the district. According to local newspapers, the total expenses in 1937 amounted to about $42,000, against a production of about $70,000.

Production of Red Arrow mine, 1933–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)
1933	21	169.65	129	--------
1934	124	687.44	772	600
1935	81	270.00	562	438
1936	180	1,058.26	3,183	1,850
1937	215	1,929.15	2,382	1,945
Total	621	4,114.50	6,928	--------

[1] Compiled from mine records of the U. S. Bureau of Mines. No production for years not listed.

The vein is developed principally by means of two drifts and several raises and stopes. As the eastern part of the Red Arrow vein outcrop lies on the older Gold Run patented claim, where it is worked in the Outwest mine, the lower drift is reached by means of a crosscut on Red Arrow ground, instead of by the shorter course that could be taken from the Gold Run claim. By 1939 the Red Arrow and Outwest workings together had explored the vein for more than 1,000 feet along its strike and more than 300 feet vertically.

GEOLOGIC RELATIONS

The rocks in the vicinity of the Red Arrow include all the beds from Entrada sandstone to the top of the Morrison formation and are unmetamorphosed. The beds, which are very poorly exposed, dip 10° to 15° SW.

The Red Arrow vein occupies one of a series of discontinuous normal faults that strike nearly due east and dip south. They are believed to represent a westward extension of the Parrott fault system, and there are probably several more in addition to the three shown in plate 2. The displacement along the Red Arrow fault amounts to about 40 feet, and the other faults appear to have displacements of 5 to 30 feet. The vein has not been definitely identified east of Gold Run, nor could its extension west of the mine be traced with certainty by members of the writer's party for more than a few hundred feet; the mine management, however, feels confident that it extends several thousand feet in this direction.

At the mine the Red Arrow vein strikes N. 82° E. to N. 87° W. and dips 55° to 70° S. The base of the Morrison is about 10 feet below the main drift on the south wall of the vein, and 30 feet above the drift on the north wall. The beds consist in large part of greenish sandstone with many partings of soft green shale. The underlying Junction Creek sandstone is of normal aspect.

ORE DEPOSITS

On the main level, where the footwall is sandstone and the hanging wall is shaly sandstone of the Morrison, the vein occupies a 1-foot to 5-foot breccia zone that averages 3 feet in width. The footwall is well-defined and bears vertical slickensides in several places. The hanging wall is nearly as well defined, but locally the wall rock on that side is strongly seamed and fractured. Twenty-five to 30 feet above the floor of the drift, where the shaly beds form both walls, the vein pinches markedly. Its width and character on the lower crosscut level, where both walls are sandstone, have not been discolsed, but in the Outwest mine, at about the same altitude, it is about as wide as in the upper Red Arrow workings.

On and above the main level the greater part of the vein is characterized by brecciated and silicified sandstone. The breccia contains a little pyrite and appreciable quantities of finely divided free gold but is not known to have yielded any high-grade ore.

The rich ore for which the Red Arrow became noted lies almost exclusively on the footwall of the vein, though similar ore occurs in a few places along the hanging wall. The footwall streak ranges from less than an inch to 3 feet in thickness and probably averages 8 or 10 inches. Part of the typical ore is friable and oxidized and consists of interlocking fine to coarse crystals of barite, enclosing some fragments of country rock. The barite crystals are fractured and stained with limonite and with carbonates of copper. Vugs and interstices are filled with limonite and a little clay. Locally, small quantities of pyrite, chalcopyrite, tetrahedrite, and chalcocite are present.

Native gold is associated with the limonitic material. It occurs in platy or foliated forms that range in size from tiny flakes to large masses weighing several pounds. The largest "nugget" that has been reported weighed more than 5 pounds. Most of the masses are rough and irregular in shape. On a few of them wires and small octahedral crystals were seen. Tiny crystals of tetrahedrite are perched on some of the gold crystals. Some of the coarse gold is reported to be 880 fine, but some of it is said to be alloyed with copper and to be only about 500 fine. Some of the ore is very rich. One small sheet, where the vein was 8 inches wide, is said to have yielded 30 pounds of gold nuggets and thirty-six 100-pound sacks of 32-ounce ore from a stope 35 feet high and 10 feet long.

In several places a streak of sulfide ore from half an inch to 3 inches wide lies along the footwall side of the gold-bearing barite streak. This ore consists largely of pyrite in a gangue of barite, ankerite, and quartz. Small quantities of tetrahedrite, chalcopyrite, and barite, which appear to be nearly contemporaneous, are associated with the pyrite. Locally, sphalerite and galena are also present. This sulfide ore commonly contains one or more ounces of free gold to the ton. In several high-grade specimens that were examined the gold is intimately intergrown with tetrahedrite. A little hessite is associated with tetrahedrite in a single specimen, but tellurides are rare or absent throughout the deposit.

In mining, the low-grade silicified breccia is first removed, after which the high-grade streak and, if present, the sulfide streak are scaled off by hand. Careful hand-sorting is practiced. Much of the product has been shipped directly to the mint, but some has been amalgamated and retorted in a small mill at the mine. Some of the better-grade breccia and sulfide ore has been shipped crude to the smelter, but the greater part of the production shown in the foregoing table probably represents coarse free gold.

The scanty data that are available are not adequate to determine the origin of the coarse gold or to justify a confident statement as to the probable extent of the ore shoot. The close association of gold and tetrahedrite in many places, and the tetrahedrite crystals perched on crystals of gold, are clear evidence that some of the gold is primary. It seems probable, indeed, that all of it is primary, though some "nuggets" may have been slightly enlarged during oxidation of the deposit. Available data on this and other mines in the district seem to indicate that further exploration of the lower part of the Junction Creek sandstone, of the limestone member of the Wanakah, and of the Entrada sandstone would be fully justified. If any ore bodies exist in the marl member of the Wanakah they are likely to be small and erratic, but the base of this member may well have formed a structural trap for the ore-bearing solutions.

RED ARROW EXTENSION (3b)

The Red Arrow Extension prospect is on an unpatented claim on the East Mancos River, about 4,000 feet west of Twin Canyon Basin. This is not the patented Red Arrow Extension claim of the Red Arrow group (pl. 14). The workings are indicated near the west edge of plate 1. The prospect received some promotional development shortly after the discovery of the Red Arrow deposit, but no ore was produced. A vein that strikes N. 75° W. and dips 70° S. is exposed in two short adits and several open-cuts. The vein follows a normal fault with a displacement of 75 feet. The vein matter consists of small rounded masses of chalcocite, altered in part to copper carbonate and associated with calcite and a little quartz, in shattered sandstone and shale of the Junction Creek and Wanakah formations. The vein zone ranges from 3 to 18 inches in width. As shown in plate 2, it cannot be a geologic extension of the Red Arrow vein.

RUBY (5)

The Ruby mine is on one of the forks of Ruby Gulch, east of Lewis Mountain. The Ruby claim and the adjoining Major D. L. claim were among the first patented in the district. The mine was worked now and then from 1880 until 1898, when it is mentioned by Petre [26] as producing some of the richest sylvanite he had seen in the district. It apparently has not been worked since 1898, however, and there is no record of its production. The mine workings were not seen during the present survey. As shown in figure 45, they consisted of a shaft and two adits connected by an

[26] Petre, R. W., Mines of the La Plata Mountains, Colo.: Eng. and Min. Jour., vol. 66, pp. 667–668, 1898.

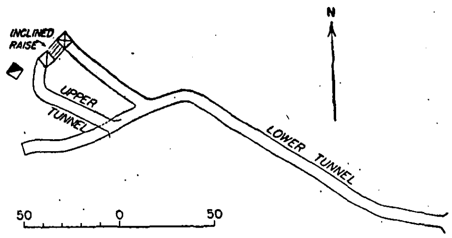

FIGURE 45.—Plan of Ruby mine.

inclined raise. The lower adit was more than 200 feet long.

The Ruby vein is exposed on the ridge north of Lewis Mountain at a point due east of the Columbus mine. There it strikes due east and consists of a weak pyritized fracture zone containing a little vein quartz. It can be traced only a short distance to the west, where it meets the Moonlight vein. East of the ridge it was not found, but the claim map (pl. 14) and the mine map (fig. 45) indicate that it trends east for several hundred feet and then swings abruptly southeastward. At an altitude of 11,600 feet in Ruby Gulch it is crossed by a strong northeasterly vein that can be traced northeastward for several thousand feet and is possibly the one on which the Wilhelmina claim was located (pl. 14).

Emmons [27] barely mentions the Ruby mine in his paper on the Neglected mine, but in his field notes he states that the ore contained gold, silver, amalgam, and a considerable quantity of native mercury. The shipping ore is said by him to have contained as much as 34 ounces of gold and 20 ounces of silver to the ton.

RUBY KING (4)

The Ruby King mine is on Fassbinder Gulch, 800 feet north of the Wheel of Fortune property and about 4,200 feet north of the junction of Fassbinder Gulch with Flagler Fork. The deposits in this mine and the adjoining Luella mine were discovered about 1880. According to Mr. Fassbinder, owner of the Wheel of Fortune group, 8 or 10 tons of high-grade ruby silver "float" ore was recovered and shipped from the gulch before any of the veins were discovered. The mines are reported to have produced considerable quantities of ore during the next decade. Activity was revived in 1902, owing to the discovery of rich ore in the Neglected mine, but no ore was produced then, and there is no record of activity or production since that year.

The Ruby King and Luella veins are shown in their approximate relation to other nearby veins in figure 49. This figure also shows the chief mine workings on the Ruby King and Luella claims, none of which were accessible in 1936.

The country rocks are unmetamorphosed redbeds of the Cutler formation. The Ruby King vein trends about N. 75° E. across the Ruby King claim. At the east shaft on this claim its course swings to N. 55° E., and it probably connects with the N. 62° E. vein that was explored on the Luella claim. A shaft on the Silver Dollar claim exposes a vein that is on the direct continuation of the N. 75° E. segment of the Ruby King vein. According to Burchard,[28] the Ruby King vein was 4½ feet wide from wall to wall. He says that a 105-foot shaft exposed good ore for its entire depth. The vein contained two pay streaks, of which one was 8 to 12 inches thick and the other 12 to 16 inches thick.

Material on the dumps indicates that the vein was a foot or more in width and consisted of fractured redbeds and several irregular veinlets of quartz, some of it in well-formed crystals. Late barite crystals are abundant. The ore contains spots and streaks of ruby silver and is stained with copper carbonates. A few streaks of green quartz, up to 1 inch in width, occur in places and possibly contain tellurides.

SADIE (5)

The Sadie mine, on an unpatented claim, is on the steep west-facing slope 1,200 feet southwest of Eagle Pass. It explores an eastward-trending vein that is almost certainly the extension of the Gold King vein. It is owned by William Krell and Joanna Todd, and in 1937 it was under lease to Jack Marvin of Durango. The following table shows the production since 1928. There is no record of earlier production.

Production of Sadie mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1928	2	1.90	257
1930	4	2.40	371

[1] Compiled from mine records of the Bureau of Mines. No production for years not listed.

The vein was explored from 2 adits, approximately 100 feet apart. The upper adit, which is short, was caved in 1937. The other trends S. 70° E. and is 95 feet long. About 30 feet from the portal there is a small overhand stope 12 feet long. A third adit, still lower on the hill, is said by Mr. Marvin to have been driven parallel to the vein for a distance of 25 feet and then to have turned south and continued 205 feet, parallel to the hillside, but no vein was cut. Apparently no account had been taken of the northward dip of the Sadie vein, and all the work was south of the vein.

The country rocks are bleached and partly silicified shale and sandstone of the Cutler formation. The vein is not exposed below the mine workings, but there is little doubt that it is either the extension of the Gold King-Eureka vein or a parallel vein close to it. Near the portal of the lower drift adit it dips 60° to 70° N., but near the breast the dip is only 55°. The course of

[27] Emmons, W. H., The Neglected mine and nearby properties, Durango quadrangle, Colorado: U. S. Geol. Survey Bull. 260, p. 127, 1905.

[28] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1883, p. 371, 1884.

the outcrop near the workings is N. 55° W., but above the upper adit it swings to N. 70° W., indicating that the vein is there nearly vertical. The vein can be traced to the top of the ridge between Lewis and Lightner Creeks, where it meets an eastward-trending vein, which in turn can be traced through several open cuts for several thousand feet farther east.

The vein follows a 1-foot to 4-foot fracture zone. Near the portal the vein matter is 8 to 14 inches wide and consists of veinlets and small lenses of intimately intergrown pyrite and tetrahedrite and a little galena, arsenopyrite, and dark-brown sphalerite, in silicified shale and sandstone. Vein quartz and barite are generally subordinate to the metallic minerals. According to Mr. Marvin, hand-sorted ore contains from 100 to 350 ounces of silver to the ton, and some pieces of pyrite and arsenopyrite in which no other minerals can be distinguished have yielded assays as high as 170 ounces of silver to the ton. Near the breast the vein widens to 20 inches, apparently because of a series of weak northward-trending cross fractures. Like the better-grade Gold King ore, it contains much green quartz, and representative samples across the whole width of the vein are said to contain 4½ ounces of gold to the ton. When the mine was examined late in 1937, not enough work had been done to determine the extent of this shoot of gold ore.

The developments on the Sadie claim are of particular interest in that they prove the existence of workable ore bodies far to the east of any ore hitherto known in the Gold King vein zone. The part of the vein that lies between the Sadie and Eureka-Bulldozer workings therefore seems to be worthy of exploration; and, for that matter the eastward extension of the Sadie has never been adequately prospected.

SARAH S. (5)

The Sarah S. mine is in a small gulch 300 feet north of the Mountain Lily mine, at an altitude of 11,100 feet. It is on the patented Sarah S. claim, which parallels the Mountain Lily. Except for 1932, when 1 ton of ore containing 10 ounces of gold and 5 ounces of silver, and for 1939, when 1 ton of ore containing 2.90 ounces of gold and 2 ounces of silver was shipped, there is no record of production since 1902. Several hundred pounds of sacked ore were on the dump in 1935. The vein is developed by two adits, less than 100 feet apart. The lower adit, above which a small stope has been opened, is 180 feet long and follows the vein for most of its course. Here the vein strikes N. 87° E. and dips 80° to 85° N. The upper adit is 100 feet long and follows a vein that strikes N. 77° E. and dips 55° N. There are no connections to show whether or not the veins exposed in the two adits are identical. The vein matter is similar to that of the Mountain Lily mine, but the 1932 shipment indicates a considerably higher gold content in the Sarah S. ore.

SHOO FLY

The Shoo Fly prospect is on one of the tributaries to Tirbircio Creek, opposite the Bonnie Girl mine. It was discovered in 1882, and exploratory work was done on it from time to time until 1895, but there are no records to show that it ever produced ore. Development consists of a shallow shaft and two drift adits, one on each side of the creek and each about 100 feet long.

The adits follow a northeastward-trend silicified breccia zone, 10 to 40 feet wide. At the mine the zone strikes N. 65° E., but farther east, where it crosses Tirbircio Creek and the ridge between Silver Mountain and Baker Peak, its course is N. 75° to 80° E. The geologic map (pl. 2) shows that the country rocks consist of metamorphosed Cutler beds and diorite-monzonite porphyry sills. The relations shown in Tirbircio Creek indicate that the breccia zone follows a fault of considerable magnitude. At most places within the breccia zone the rocks are thoroughly silicified, but in one part of the eastern Shoo Fly adit the porphyry is sericitized. Pyrite is widely disseminated in the rocks, and much of the quartz is dark gray to black owing to finely divided pyrite. Here and there a little barite and white quartz fill interstices in the breccia. According to V. H. Steele, the breccia zone as a whole contains from 0.08 to 0.12 ounce of gold to the ton. No vein was seen within this silicified zone in the adit workings, but Burchard [29] noted a 23-inch vein, rich in silver sulfantimonides, and a 4-foot ore-bearing streak, on the south wall of the zone. According to Purington some of the ore was rich in gold. The history of the mine indicates clearly that the ore minerals are very spottily distributed.

SILVER FALLS (2a)

The Silver Falls mine, on the Sunflower group of unpatented claims, is on the east bank of the East Mancos River, S. 70° E. of Helmet Peak. The ore deposit is similar in many respects to that of the Bay City mine, on the La Plata River. The mine is owned by Paul Klavon, of Mancos, and is locally reported to have produced about $1,000 worth of gold some years ago. In 1936 and 1937 it was worked in a small way, but no ore was sold.

The mine workings, which consist of several short, irregular adits, are just above the top of the porphyry sill that separates the Cutler and Dolores formations. The beds strike N. 40° E. and dip 20° NW. The ore deposit partly replaces a bed of limestone conglomerate resting directly on the porphyry. All these rocks are cut by a weak fracture zone, which strikes due east and is vertical. The ore appears to extend only 10 or 15 feet along the vein and to pinch out in both directions, but the workings are not sufficiently extensive to prove it. The ore bed is 6 inches to 2 feet in thickness and

[29] Burchard, H. C., op. cit. (for 1883), p. 374, 1884.

contains unusually large pebbles of limestone. Several beds and lenses of limestone conglomerate overlie the ore bed, but none of them has been replaced by ore minerals in the exposures seen.

The primary ore is an intergrowth of pyrite, chalcopyrite, and calcite, with a little hematite, in a gangue of quartz, garnet, chlorite, and unreplaced limestone. The pyrite forms brilliant octahedra up to half an inch in diameter; the chalcopyrite occurs in irregular masses. Both minerals appear to have replaced calcite. Some of the sulfide ore pans considerable free gold, but some of it is barren. Near the surface the ore is rather thoroughly oxidized, and nearly all of it contains free gold.

SMALL HOPE (5)

The Small Hope mine is on the ridge between Williams and Shoebeck Gulches, on the southeast slope of Diorite Peak. Data for the following description have been assembled from C. W. Purington's field notes of 1896, from Petre's description,[30] from a private report prepared in 1937 by John L. Craig, who sampled the Grassy Hill tunnel in 1932, and from observations made during the present survey.

The vein was discovered in the late eighties or early nineties and was a more or less regular producer at least until 1898. The ore was taken from a 275-foot shaft and a short adit, both at an altitude of 11,600 feet. Some of it was treated in a small bromination plant, which is reported to have made a 95-percent recovery.

The Grassy Hill crosscut tunnel, at an altitude of 10,600 feet, was driven between 1898 and 1900. At 1,800 feet it cut a vein that was believed by the operators to be the Small Hope, and considerable drifting was done. This tunnel is said by Craig to have caved 2 years after completion and to have remained closed until 1932, when it was reopened and examined by him. It was open in 1935 but was too gassy to permit thorough examination, and it caved near the portal in 1936. There are three other crosscut adits on the hill at altitudes of 10,800, 10,850, and 11,200 feet. Their histories are not known. The upper two were caved at the portal in 1935, and the lower one was caved 180 feet from the portal.

Craig says in his report that "the books of the American Smelting and Refining Co., at Durango, show that 1,000 tons of ore were shipped from the Small Hope having a total value of $115,000. One 20-ton carload of this ore brought a little over $20,000. This ore was all mined by hand and hauled down by ox teams to Hesperus, the nearest shipping point." The production figures quoted seem high, but the records referred to by Craig no longer exist. The following table shows that since 1902 the mine has produced nearly $7,000, but from what workings the ore was taken is not known:

Production of Small Hope mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1903	24	63.60	48
1904	2	9.00	----------
1907	8	16.98	41
1908	6	12.54	21
1917	3	13.29	4
1918	13	186.41	26
1919	12	22.80	17

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

With the exception of a small wedge of sedimentary rock in the Grassy Hill tunnel (fig. 46) all the rock in the vicinity of the mine is diorite. The Small Hope vein trends northeast and can be traced almost without interruption as far as Fall Gulch. In places it is vertical; elsewhere it dips steeply to the northwest. At the shaft Purington noted that the vein dipped 55° NW. at the surface but had steepened to 65° at a depth of 30 feet. He thought the flatter dip was due to slight movement of the near-surface rocks. The fracture zone was 3 feet wide in the old workings, with a 1-foot pay streak on the footwall or southeast side. Purington says that the whole fracture zone contained some gold and that the unsorted ore yielded 1 ounce of gold to the ton. It consisted of gold telluride, with less pyrite and chalcopyrite, in a quartz gangue. Petre says that the ore shoot was only 30 feet long but extended continuously to the bottom of the 275-foot shaft.

The Grassy Hill crosscut tunnel is shown in figure 46. At the drifts 1,800 feet from the portal the bad air extinguished carbide lamps and prevented completion of the survey or examination of the vein. Within 300 feet of the portal two broad breccia zones are exposed. Gouge makes up fully 50 percent of the larger of the two. Ten or more northeastward-trending fracture zones were also cut by the tunnel. They range from 1 foot to 6 feet wide, and most of them are similar to the Mountain Lily and other veins that occur in diorite; they are characterized by a hard silicified medial sheet containing pyrite and possibly other metallic minerals, flanked by soft altered diorite which grades into the fresh wall rock. Several of the veins contain calcite and a little specular hematite. None of these fracture zones has been thoroughly sampled, but some are known to contain a little gold.

The vein that was cut at 1,800 feet from the portal strikes N. 60° E. and dips steeply northwest. Craig states in his report that the southwesterly drift is about 400 feet long and the northeasterly drift about 500 feet. He says: "In the south drift there is a streak from 4 inches to 1 foot of ore that assays from 1.5 to 2 ounces

[30] Petre, R. W., Mines of the La Plata Mountains, Colo.: Eng. and Min. Jour., vol. 66, pp. 667–668, 1898.

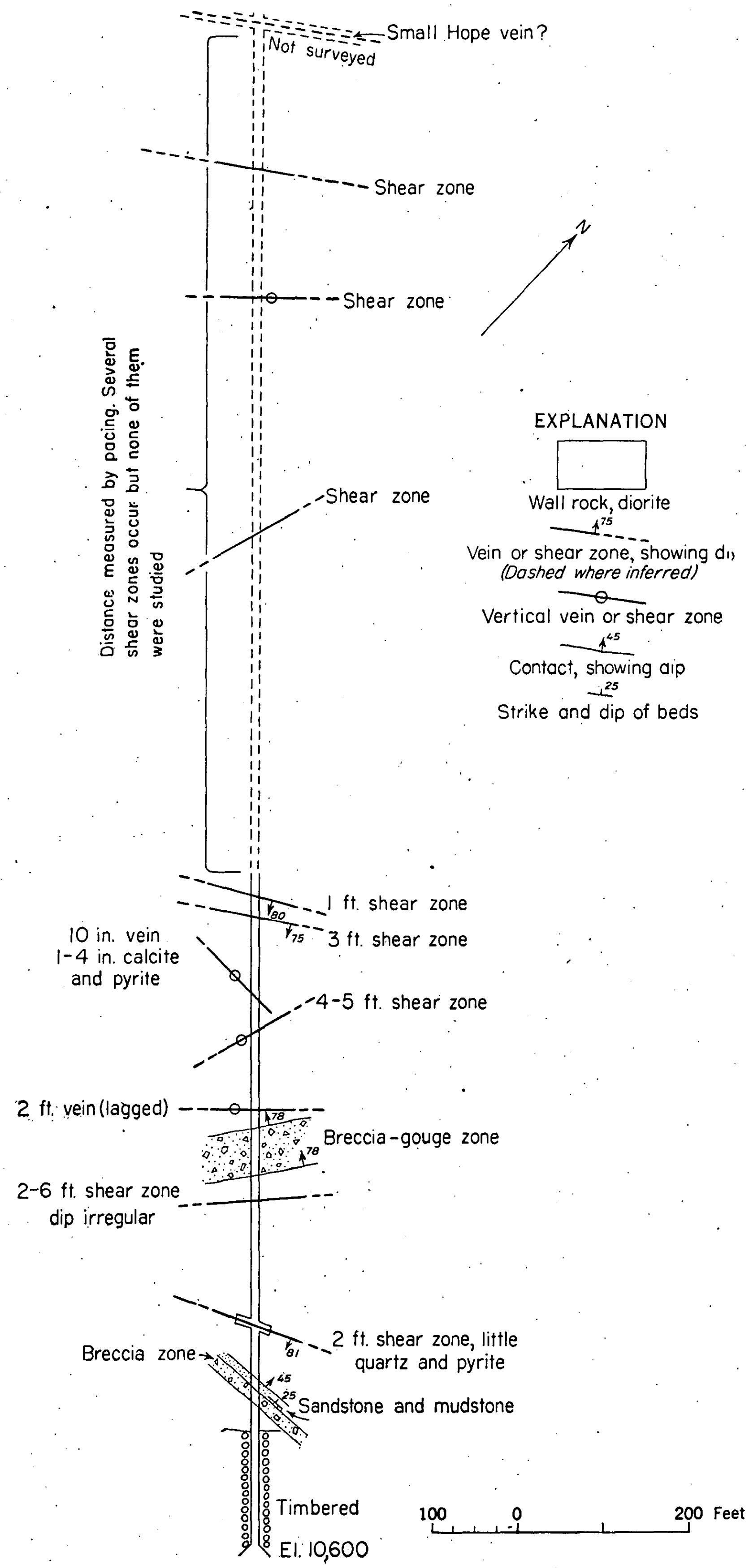

FIGURE 46.—Plan of Grassy Hill adit, Small Hope mine.

of gold per ton and a trifle more in silver. The ore in the north drift is a little wider and softer but only runs from 0.5 to 1 ounce gold per ton. There is some ore on each side of this streak that will make mill ore but the writer has not sampled enough to know how much." He further says that the mine was abandoned because the ore would not pay the high costs of mining and transporting it by the methods employed at that time, but various other reasons are given by local residents.

The vein described above has always been considered to be the Small Hope vein, but the relations shown in plate 2 indicate that even if the dip is vertical the Small Hope vein is at least 450 feet northwest of the end of the Grassy Hill tunnel. If that is true, the vein developed by the crosscut is a parallel vein of similar character, which apparently does not extend to the surface. An accurate survey of the workings and of the surface features is necessary to check this conclusion. If it is found to be correct, extension of the crosscut to its original objective might well seem worth while. All the veins exposed in the Grassy Hill tunnel seem to deserve careful sampling and possibly further development.

SNOWSTORM (4)

The Snowstorm vein, which is supposed to be the southwestward extension of the Cumberland (pp. 410–417), is on the southeastern side of Cumberland Basin, 700 feet northwest of Snowstorm Peak. As was noted in the description of the Cumberland mine, the vein differs in trend from the Cumberland and is characterized by a somewhat different type of ore. Either the Cumberland vein turns sharply to the south on the Snowstorm ground or the Snowstorm vein is a different vein, at least in part. Both mines were worked under the same management and the early history of the Snowstorm closely parallels that of the Cumberland. Both deposits were discovered in 1878, produced little ore until 1884, and were active from then until about 1890. There is no record of production from the Snowstorm since 1888. According to information given to Purington in 1896 by local residents, the total production of the Snowstorm was $25,000. The recorded production, shown in the following table, amounts to less than $10,000. Except for 1888, the figures are taken from an engineer's private report. They contain all the data available to him but are said to be incomplete.

Recorded production, Snowstorm mine, 1884–1943 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1884	33	143. 62	732
1885	27	138. 56	210
1886	1	5. 50	----------
1888 [1]	----------	4. 40	2, 492

[1] Kimball, J. P., Report of the Director of the Mint upon the production of the precious metals in the United States for 1888, p. 112. No production recorded 1878–83, 1887, and 1889–1943.

Development on the Snowstorm vein consists of four adits and several open-cuts. The two upper adits, which follow the vein, are at altitudes of about 11,500 and 11,400 feet, respectively. They were probably less than 100 feet long. The third level, which also follows the vein, is 200 feet below the second level and is 225 feet long. The lowest or fourth level, whose portal is near that of the Cumberland fourth level, is said to be 600 feet long. It starts as a crosscut, and the extent of drifting on the vein is not known. Only the third level was accessible when the mine was visited in 1935.

The country rocks are unmetamorphosed Cutler and Dolores redbeds, which are cut by one large dike and several thin sills of porphyry. The two lower levels are in the Cutler formation, whose contact with the overlying Dolores is only a few feet above the third level. In the vicinity of Snowstorm Peak the beds are warped into a series of irregular folds. Near the mine they dip 12° to 22° north and northwest. The irregular structure was probably caused by the intrusion of the large porphyry mass shown in plate 2. This is a crosscutting dike near the mine but is sill-like farther west and south.

Near the portal of the third level the vein strikes N. 77° E., but it gradually swings toward the south, and where it crosses the ridge west of Snowstorm Peak it strikes N. 35° E. and dips 75° NW. It can be traced only a few hundred feet on the south side of the ridge. At the crest it consists of a 3-foot to 5-foot shear zone in partly bleached and silicified redbeds. Within the shear zone the rocks are largely replaced by fine-grained quartz but large irregular bladed masses of white barite are the most conspicuous feature of the vein filling. No metalliferous minerals were seen. On the third level the vein traverses the porphyry dike between points 50 and 180 feet from the portal. On each side of the dike the wall rocks consist of soft red shale and sandstone, in which the vein zone is weak and poorly defined. Where it passes through the porphyry it is somewhat wider but is weak as compared to the vein in the Cumberland workings and contains little vein matter. A little stoping was done 50 to 100 feet from the portal. Burchard [31] states that in two short adits that were open in 1882 the vein had an average width of 9 feet and consisted of white quartz rich in free gold and ruby silver. In the ore mined the ratio of gold to silver is notably high in strong contrast to that in the ore from the Cumberland mine.

Little can be said of the future of the mine, and few suggestions can be made as to prospecting. As reports on the early operations indicate that in places the vein contained rich ore, further well-considered examination and development would seem to be justified. As in the Cumberland, the best ore is likely to be found where the

[31] Burchard, H. C., Report of the Director of the Mint upon the production of the precious metals in the United States, 1882, p. 508, 1883.

vein lies between walls of porphyry. The extension of the vein southwestward in Columbus Basin, if any exists, might prove to be of interest, particularly in the thick porphyry sill there. The sharp change in direction of the vein indicates that the extension of the Cumberland vein, west of the Snowstorm, may be represented by one or more eastward-trending fractures. Even though no such fractures were seen at the surface, it is reasonable to suppose that they exist. If they do, they may contain ore, at least near their intersection with the main Snowstorm vein.

SOUTHERN BOY (2c)

The Southern Boy and Southern Girl claims, on the east side of the La Plata River, south of Burnt Timber Creek, were located in the late eighties and early nineties. There is no record of the early production, but Petre[32] mentions the mine as being noteworthy because some very rich "sylvanite" ore was found there near the surface.

The known production is shown in the following table. In addition, an unpublished report in the files of the State planning commission, Mineral Resources Project, states that in 1901 the Southern Boy produced 19 tons of ore, which yielded in all 116.73 ounces of gold and 142 ounces of silver.

Production of Southern Boy mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1913	5	0.73	62	25	312
1920	1	15.40	30	--------	--------
1921	1	8.00	112	--------	95
1923	1	15.50	31	--------	--------
1924	1	13.20	3	--------	--------

[1] Compiled from mine records of U. S. Bureau of Mines. No production for years not listed.

Most of the development on the vein consists of opencuts, none of which was more than 20 feet deep. One or more shallow shafts also were sunk. A 640-foot crosscut that trends N. 79° E. is situated near the bank of the La Plata River, 1,500 feet south of Burnt Timber Creek. At the end of the crosscut a 40-foot drift was turned N. 10° E. on an inconspicuous seam of quartz. It is evident either that the crosscut stopped short of its objective or that the vein is very weak at the crosscut level.

The vein is nowhere well-exposed. It strikes due north to N. 11° W. and dips steeply east. Where seen in the open cuts it consists of a 1-foot to 3-foot silicified fracture zone in porphyry and contains quartz, brown ankerite, barite, pyrite, galena, and chalcopyrite. The weathered material near the surface is said to have yielded considerable free gold.

[32] Petre, R. W., Mines of the La Plata Mountains, Colo.: Eng. and Min. Jour., vol. 66, pp. 667–668, 1898.

TEXAS CHIEF (2c)

The Texas Chief mine, formerly known as the Mountain Meadow, is on one of the spurs between Paine Ridge and South Fork Lightner Creek, a little less than 1½ miles northeast of Baldy Peak. The various mine workings range in altitude from 9,400 to 10,200 feet. The property, which consists of seven or more unpatented claims, can be reached over the Lightner Creek road, which was in fair condition during the summers of 1936 and 1937. The mine was worked during the First World War and occasionally thereafter until 1928. More recently a small mill of somewhat novel design was built, and a little development work was done by a stock company. The mine was inactive when examined in 1936, and the mill was destroyed by a snowslide during the following winter. All the recorded production is shown in the following table:

Production of Texas Chief (Mountain Meadow) mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)
1917	66	1.55	1,154	1,019
1918	3	--------	42	--------
1922	2	.10	64	--------
1925	3	.10	210	--------
1926	6	8.60	931	--------
1928	1	--------	15	--------

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The underground development comprises seven short drift adits with an aggregate length of 360 feet, three shafts, each less than 100 feet deep, and numerous prospect pits. The new crosscut adit was less than 200 feet long in 1936. Large parts of the workings were inaccessible at that time.

The country rocks consist of slightly bleached Dolores redbeds, which dip southeastward. These rocks have been intruded by several irregular sills and dikes of diorite-monzonite porphyry. Ten or more veins are known. Most of them fall into two sets, which strike N. 60° to 70° W. and N. 5° to 15° E., respectively. Surface and underground exposures are inadequate, but all the veins appear to be discontinuous, both laterally and horizontally. No evidence of faulting has been recognized. Near the veins the wall rocks are moderately silicified.

The principal gangue minerals are quartz, siderite, and manganocalcite. Metallic minerals noted include pyrite, which is the most abundant, sphalerite, galena, chalcopyrite, pyrargyrite, and an unidentified mineral associated with the galena. Nearly all of the ore seen was partly oxidized.

THUNDER (2c)

The Thunder prospect is west of the East Mancos River, 4,000 feet south of Helmet Peak. It is on the Thunder group of unpatented claims, held by Charles

Starr, of Mancos. Two tons of ore, which yielded 0.69 ounce of gold and 6 ounces of silver were shipped in 1937.

The lower adit, at an altitude of 10,500 feet, extends N. 40° W. for 55 feet, then turns to follow a vein striking S. 65° W., which occupies a strong fracture zone in the Entrada sandstone, 2 to 5 feet in width and having in most places 2 to 12 inches of limonite gouge along each wall. The middle part of the zone consists of pyritized breccia and resembles in some respects the May Day and other veins in sandstone.

The vein has been traced uphill to a point about 1,000 feet to the southwest of the lower adit and at 10,625 feet altitude. There it is explored by an 80-foot adit in which the vein contains more pyrite than in the lower adit but is otherwise similar. The wall rocks are Junction Creek sandstone. In this adit a vein parallel to the main vein and 30 feet northwest of it is exposed. This lesser vein, which is 12 to 18 inches wide, is composed of brecciated sandstone, much gouge, and considerable quantities of quartz and coarsely crystallized galena. A strong fracture zone that strikes due east crosses the two veins at this place, but it apparently has no influence on the localization of ore.

TIPPECANOE (4)

The Tippecanoe, Monitor, Cora G., and Laura A. claims are all on the same vein, which lies north of the Cumberland vein and is nearly parallel to it. The vein has been opened in many places by means of open cuts, pits and short adits. The aggregate length of the workings may be as much as 1,000 feet. Some ore has been produced from each of the four claims, but the mine has been idle since 1918, and none of the workings were accessible in 1935. The following table summarizes the available information on the mine's production:

Incomplete production from Tippecanoe mine, 1882–1943 [1]

Year	Claim	Ore (short tons)	Gold (value)	Silver (value)	Average price of silver per ounce
1882	Tippecanoe	9		[2] $1,260.00	$1.14
1887	Cora G			165.00	.98
1887	Monitor		$20.00	[3] 620.00	.98
1887	Laura A		24.00	112.00	.98
1888	Cora G		579.60	95.67	.94
1889	do			402.09	.84
1891	Tippecanoe			1,939.00	.99
1917	do	1		66.75	.824
1918	do	19	14.47	1,161.00	1.00

[1] Figures for 1882–91 from annual reports of the Director of the Mint; for 1917–18, compiled from mine records of the Bureau of Mines. Production for other years prior to 1902 unknown; no production in 1902–16 or 1919–43.
[2] Includes an unknown sum received for gold.
[3] Also produced 143 pounds of lead.

The country rocks are unmetamorphosed Cutler and Dolores redbeds, cut by several thin dikes and sills of porphyry. The vein strikes a few degrees north of east and dips steeply to the north. It has not been traced west of the Laura A. claim, but the Kennebec vein is believed to be its eastward extension. The vein matter, which is 2 to 5 feet wide in most places, is vuggy white quartz with barite and is similar in all respects to that of the Cumberland vein. No ore minerals were found on the dumps, but those most abundant in the ore mined are said to have been the ruby silver minerals.

TOMAHAWK (5)

HISTORY AND PRODUCTION

The Tomahawk mine, from which Tomahawk Basin takes its name, is on the southwest slope of Diorite Peak, three-quarters of a mile northwest of the mouth of Basin Creek. It is connected with the county road by an abandoned wagon road and by several steep but good trails. The group of 32 patented claims covers a series of veins that are related to the Black Diamond and Little Kate deposits. Part of the following description is based on a private report on the Tomahawk-Black Diamond properties by R. D. McCausland.

Several of the veins were discovered and partly explored shortly after the Little Kate was opened in the early nineties, but there are few records of the early activities. In 1904 the Tomahawk Mining Co. was organized and combined the claims that now make up the Tomahawk group. This company built a 20-stamp mill, with tables and vanners, the ruins of which are still standing. About 7,500 feet of exploratory work was done on the more promising veins. Most of the ore developed was of too low grade to be shipped crude, and efforts to mill it were unsuccessful. The best saving made by the mill is said to have been 40 percent. The company continued to work the property until 1911, but since that time it has been idle except for a few brief periods of operation by lessees.

The early production is not accurately known but was probably between $40,000 and $75,000. According to Mr. August Ekburg, of La Plata, who has been acquainted with the Tomahawk since its discovery, about $30,000 worth of ore that contained $300 in gold to the ton was taken from a rich shoot on the Little Jane vein in 1897. As shown in the following table, somewhat less than $10,000 worth of ore has been produced since 1902:

Production of Tomahawk mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)
1907	2	3.29	68
1908	60	120.02	900
1909		130.80	112
1911	7	10.66	43
1917	3	5.40	20
1919	20	26.20	142
1922	1	1.70	18
1924	17	28.80	[2] 201
1925	18	30.80	[3] 133
1926	355	8.00	60

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.
[2] Also 488 pounds of copper.
[3] Also 100 pounds of lead.

As shown in figure 47, the principal workings are the 1,100-foot Tomahawk crosscut adit, from which two drifts, 800 and 1,250 feet long, have been turned, and the Ground Hog tunnel, which is about 800 feet long. In addition to these openings, there are shorter drift adits and shafts on several of the veins, and numerous open-cuts and prospect pits. Except for the Ground Hog, shown in detail in plate 29, and the outer cross-cutting part of the Tomahawk adit, nearly all of the workings were inaccessible in 1935–37.

GEOLOGIC RELATIONS

The more important deposits lie within the diorite stock for which Diorite Peak is named. Many veins, most of them relatively unimportant, occur in the breccia, described above in connection with the Little Kate mine, on the southwest border of the stock. The rocks are cut by a network of nearly vertical mineralized fissures, but the most prominent fall into two sets that strike northeast and nearly due east, respectively. These sets of fissures represent the extensions of the Mountain Lily and Small Hope fracture systems, but it is doubtful whether any single fissure in them extends more than 2,000 or 3,000 feet. None of the fissures in the Tomahawk group have been traced very far to the west or southwest. As is clearly shown in figure 47, several of the veins that cut the breccia body follow faults with considerable displacement, but the amount or direction of displacement along the veins in diorite is not known.

The fissures range from 3 inches to 10 feet in width and average about 3 or 4 feet. As indicated in figure 47, most of them show a tendency to pinch and swell within short distances and to split off into the walls in many places. Those in diorite are similar to the Mountain Lily, Sarah S., and Small Hope veins in that they are characterized by hard central parts of silicified diorite or of quartz and ore minerals, flanked by walls of soft, altered wall rock.

No gold-bearing or silver-bearing minerals were noted in any of the specimens examined from this group, but from the similarity of the Tomahawk ore to that from nearby mines, and from the fact that the Tomahawk stamp mill made such poor recovery of the precious metals, it is inferred that most of the gold and silver occurs in tellurides. Pyrite, chalcopyrite, sphalerite, tetrahedrite, and enargite, together with a little galena and covellite, were all found in the specimens examined.

The Clydesdale and Tomahawk veins are the most prominent and best developed of the eastward-trending fissures. Where they are cut by the Tomahawk adit they are nearly parallel and about 100 feet apart, but they converge slightly toward the east and probably join about 1,800 feet east of the Tomahawk adit. The actual intersection has not been uncovered, but several nearby open cuts indicate that near it both veins widen and are fairly rich in gold. The two veins extend at least as far west as the main workings of the Little Kate. The Tomahawk vein is followed by the 800-foot east drift from the Tomahawk level, and this drift is said to expose a good ore shoot 150 feet long. The vein is also cut by the Ground Hog adit, but it has not been explored there.

The Clydesdale vein is explored by the 1,200-foot west drift of the Tomahawk workings and by the main drift on the Ground Hog level. Most of the ore produced by the old Tomahawk Co. came from the lower level, and nearly all that produced by lessees in recent years was taken from stopes above the Ground Hog. The existence of an ore shoot at least 600 feet long that extends at least 300 feet vertically is indicated, but it has not been completely blocked out.

The Ground Hog vein, which appears to be the southwestward extension of the Surprise vein (fig. 47) is a weakly mineralized shear zone several feet wide. It does not now contain workable ore in the exposures made so far, but its intersection with the Little Jane vein contained the most productive ore shoot that has been found in the group. The Little Jane, which strikes about N. 70° E., was worked through three short adits, connected by stopes that worked out a small but high-grade ore chimney. This chimney was stoped to a point 75 feet below the lowest adit. A raise was opened from the Ground Hog level, but it missed the ore shoot, reportedly because the shoot pitches to the southwest. The K. P. shaft, which is shown in figure 47, is near the Little Kate workings, was opened on a second high-grade shoot on the westward extension of the Little Jane vein.

The sorted ore shipped by Mr. Ekburg in 1923 and 1925 contained from 0.92 to 2.35 ounces of gold and 5.6 to 8.9 ounces of silver to the ton. Much of the ore exposed in the Clydesdale, Tomahawk, and Little Jane veins may contain somewhere between 0.10 and 0.60 ounce of gold to the ton. The other veins in the group are less well known, but they are possibly comparable in tenor to those named.

The future of the mine cannot safely be predicted from the information available. Total production has been comparatively small in proportion to extent of development work, but several rather large bodies of low-grade to medium-grade ore have been partly exposed, and two small high-grade ore shoots have been exploited. There is reason to hope that other ore shoots may be discovered by further exploration. Some of them, particularly those at intersections of two or more veins, may conceivably contain high-grade ore. Much of the ore in the mine should prove amenable to concentration by modern ore-dressing methods.

TULA MAY

The Tula May prospect, on the Tula May patented claim, is on the southwest side of Helmet Peak, a few

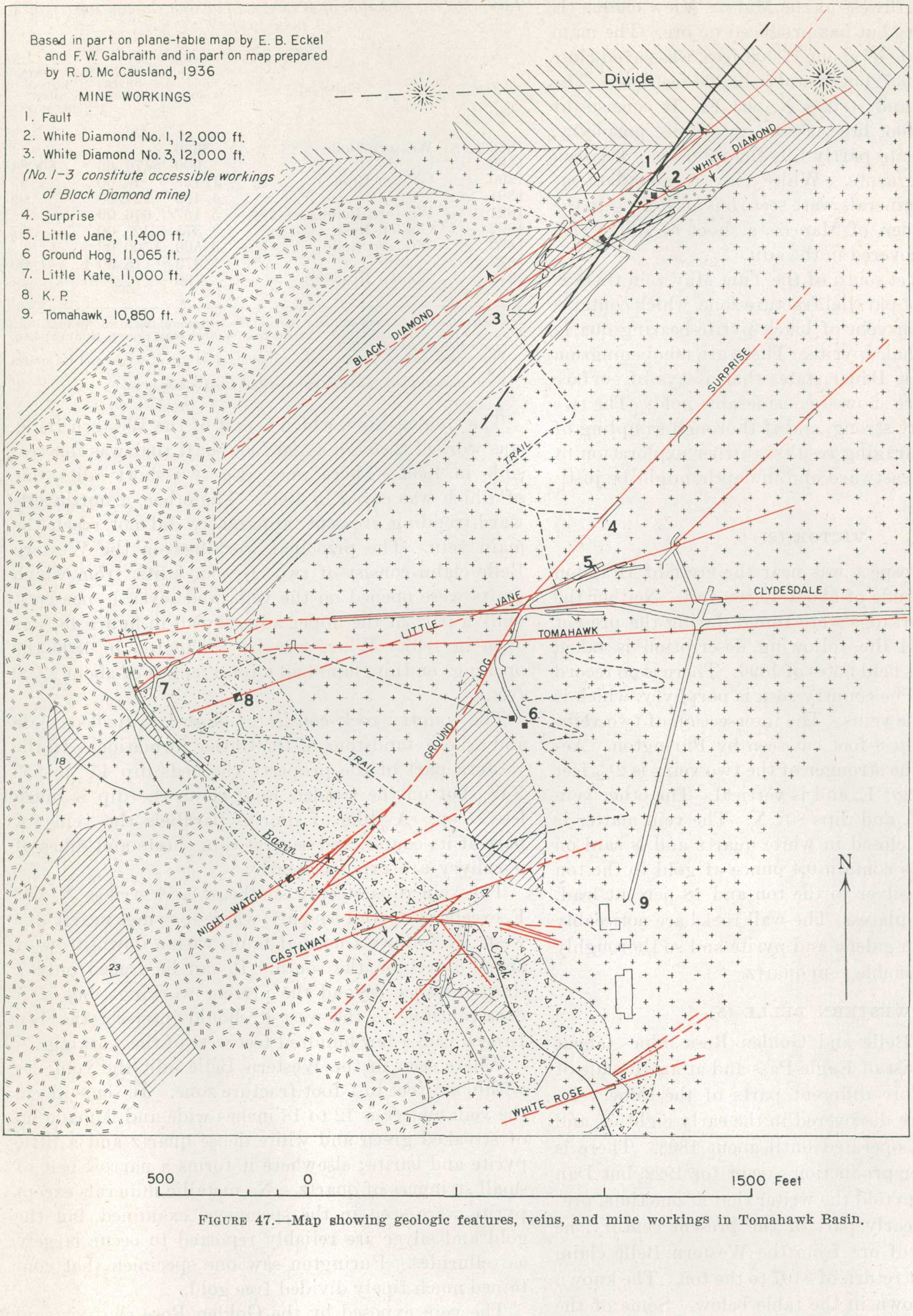

FIGURE 47.—Map showing geologic features, veins, and mine workings in Tomahawk Basin.

hundred feet northwest of the Mancos View claim. It is an old property but has produced no ore. The main adit, at an altitude of about 11,400 feet, was caved close to the portal in 1937, but is said to be 300 feet long. The vein is vertical and strikes N. 80° E. It consists of a 10-foot to 15-foot breccia zone in syenite porphyry. Light-brown calcite partly fills the interstices between the breccia fragments. White clay is abundant in places. No ore minerals were seen, but according to the owner, John Bauer, of Mancos, a shoot of fairly rich gold ore was uncovered in the adit.

Seventy-five feet south of the Tula May vein there is a 4-foot to 12-foot parallel fracture zone, which contains a 3-inch to 4-inch vein of black pyrite-bearing quartz enclosing some chalcopyrite. There are no openings on this vein, but Mr. Bauer states that assays of surface samples of the ore showed considerable gold. The two fracture zones are strong, and if thorough sampling of them gives encouraging results, further exploration of both zones, both eastward and in depth, might be justified.

VICTOR (2c)

The Victor prospect was near the crest of Bragdon Ridge, at an altitude of about 10,800 feet. Neither the veins nor the workings were found during the present examination, and the following description is taken from Purington's field notes of 1896. There is no record of production. The country rock is porphyry, which is silicified along the veins. The intersection of two veins was exposed in an 8-foot cut seen by Purington. According to him, the stronger of the two veins is 2½ feet wide, strikes N. 28° E. and is vertical. The other vein strikes N. 22° W. and dips 80° N. The vein matter is mostly galena enclosed in white quartz and is said on good authority to contain 0.4 ounce of gold to the ton and 3 ounces of silver to the ton and 18 percent lead. Calcite occurs in places. The wall rocks are noticeably impregnated with galena and pyrite and so thoroughly silicified as to resemble vein quartz.

WESTERN BELLE (5)

The Western Belle and Golden Rose mines, about 3,000 feet northeast of Eagle Pass and at an altitude of 11,000 feet, explore different parts of the same vein. The deposits were discovered in the early eighties, and both mines were operated until about 1895. There is no record of later production except for 1922, but Dan Cason of Durango told the writer that at one time, presumably in the early part of the present century, he shipped 30 tons of ore from the Western Belle claim that yielded a net return of $107 to the ton. The known production is shown in the table below. Some of the ore was concentrated in a small cyanide mill at the mouth of Walls Gulch, but most of it was shipped direct to the smelter.

Incomplete production of Western Belle and Golden Rose mines, 1888–1943 [1]

Year	Claim	Gold (value)	Silver (value)	Average price of silver per ounce
1888	Western Belle	$360		
1889	do	1, 900	$170. 66	$0. 84
1890	Golden Rose	1, 153	26. 00	1. 05
1891	do	4, 465	124. 00	. 99
1891	Western Belle	5, 167	646. 00	
1892	Golden Rose	3, 375	1,125. 00	. 87
1892	Western Belle	3, 500	1,500. 00	
1922	do	[2] 1, 373	115. 00	1. 00
1942	Golden Rose	[3] 80		

[1] Figures for 1888–92 from annual reports of the Director of the Mint; for 1922, from mine records of Bureau of Mines. Production for other years prior to 1902 unknown; no production 1902–1921, 1923–1941, or 1943.
[2] Production includes 14 tons of ore containing 66.42 ounces of gold and 115 ounces of silver.
[3] Production includes 10 tons of ore containing 2.28 ounces of gold.

The Golden Rose, which is east of the Western Belle, was worked through a 100-foot shaft that was inaccessible in 1936. There were also two short adits, one of which was caved in 1937. The other, a northwestward-trending crosscut, apparently did not reach the main vein. The principal workings on the Western Belle claim consist of two crosscut adits, from which drifts were opened on the vein, and several open-cuts. Only a part of the upper adit, shown in figure 48, was open in 1937. When seen by Purington in 1896 the openings on this claim had a total length of about 2,000 feet.

The country rock consist of slightly silicified shale and arkosic sandstone of the Cutler formation. In the western part of the property the beds dip 45° to 55° NW., but on the Golden Rose claim the dip is much less steep. A dike of diorite parallels the vein for part of its course, and several thin sheets and dikes of porphyry are exposed nearby.

The vein dips steeply southeast and strikes N. 65° E. except in its western part, where it swings nearly due west. It follows a normal fault, with a downthrow of about 8 feet on the south. It can be traced only a short distance beyond the present workings, but if it does continue to the west it should intersect the Ten Broeck vein a few hundred feet west of the workings.

Where seen in the Western Belle adit the vein lies within a 3-foot to 7-foot fracture zone. In some places the vein matter is 12 to 18 inches wide and is made up of streaked green and white dense quartz and a little pyrite and barite; elsewhere it forms a narrow belt of small stringers of quartz. No metallic minerals except pyrite were seen in the specimens examined, but the gold and silver are reliably reported to occur largely as tellurides. Purington saw one specimen that contained much finely divided free gold.

The vein exposed by the Golden Rose shaft is said to have been similar to that farther west but to have contained more free gold, especially near the surface. According to Dan Cason, the vein was weak or pinched

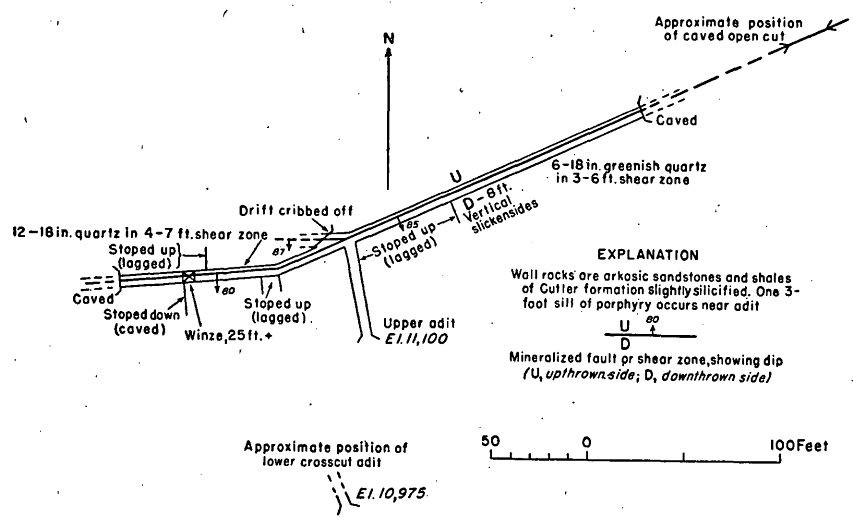

FIGURE 48.—Plan of upper adit, Western Belle mine.

out althogether in places where the walls were of shale, but it was as much as 8 to 10 feet wide where sandstone or porphyry formed the wall rock. He says also that in places the ore extended along bedding planes for several feet away from the vein.

WHEEL OF FORTUNE (5)

The Wheel of Fortune group of unpatented claims is on Fassbinder Gulch, between the Ruby King and Gold King-Swamp Angel mine and 1 mile above the mouth of Gaines Gulch. The claims are shown in figure 49. They have been held by the two Fassbinder brothers of Durango for many years, but so far as known to the writer no ore has been produced. Development work has been done on all the claims, but the most extensive workings are adits on the Wheel of Fortune and Bonaparte claims. Only the upper adit on the Bonaparte claim (fig. 50) was open when the property was visited in 1936.

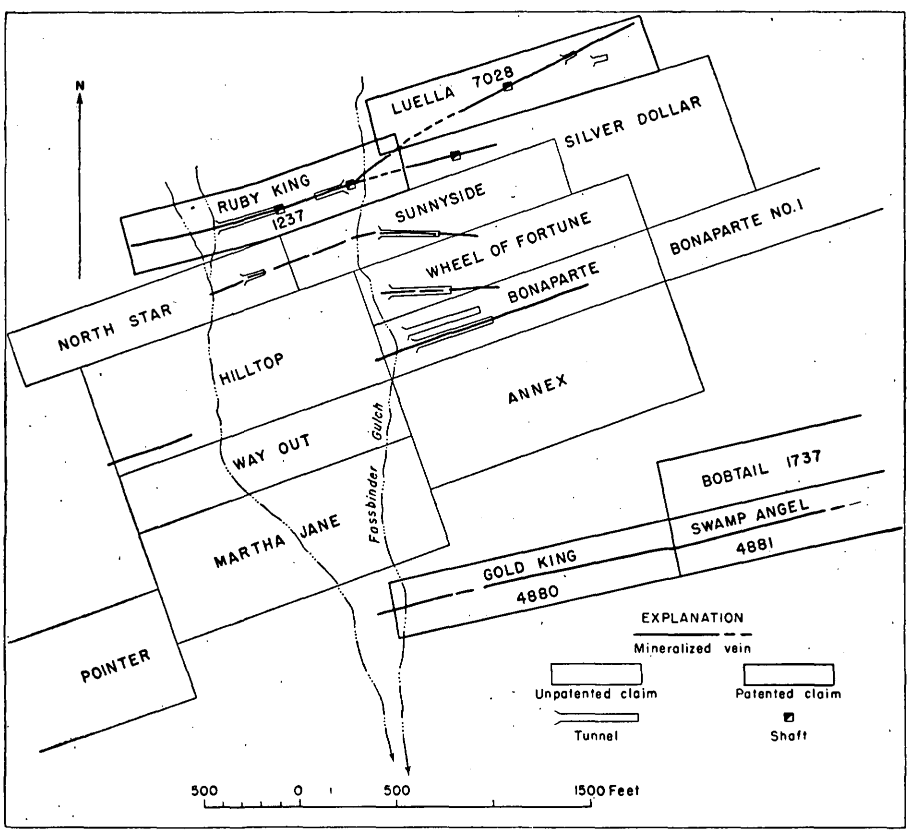

FIGURE 49.—Sketch map showing Wheel of Fortune group and adjacent properties. From map in files of State Planning Commission, Mineral Resources Project.

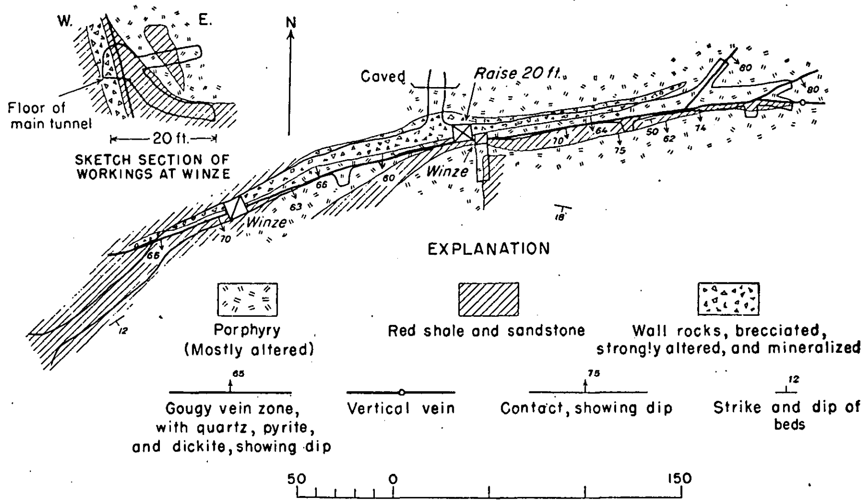

FIGURE 50.—Plan of upper adit on Bonaparte claim, Wheel of Fortune group.

The country rocks are generally unaltered redbeds of the Cutler formation, which dip up to the south and east and are cut by a few sills and dikes of porphyry. A series of eastward-trending veins traverses the property. They are all apparently of the same general character as the one on the Bonaparte claim, the description of which follows:

The upper adit on the Bonaparte claim is about 400 feet long and follows a vein zone that strikes a few degrees north of east. As indicated in figure 50, a series of redbeds is exposed near the portal. These beds are overlain by an irregular porphyry sill, which forms the wall rock along most of the adit's length. Several large wedgelike inclusions of shale are exposed along the south wall.

The vein zone, which dips 60° to 70° S., is 3 to 18 feet wide. Within it the rocks have been strongly crushed and kaolinized. Pyrite is widely disseminated. The crushed zone is traversed by innumerable discontinuous veinlets, which consist largely of white clay (dickite) and gouge but also contain light-brown carbonate, quartz, and pyrite. Copper stains indicate the presence of chalcopyrite. In most places, as shown in figure 50, the strongest vein of this character lies south of the crushed zone.

According to Mr. Fassbinder, the crushed and altered rock and vein matter contain from 0.06 to 1.0 ounce of gold to the ton, the gold being partly free and partly in tellurides. This informant says that the tenor commonly varies directly with the amount of pyrite in the ore but that some small pockets of high-grade ore have been found.

Further development and sampling are necessary to delimit the ore deposit and to determine its average tenor. Present indications encourage the belief that the Wheel of Fortune contains comparatively large deposits of medium-grade gold ore and that further exploration is justified.

YELLOW EYE (2c, 5)

The Yellow Eye mine is on Bragdon Ridge, several hundred feet east of the point where the 10,400-foot contour crosses the nose of the ridge. It was being worked in 1896, when it was visited by Purington, but its early production, if it made any, is unknown. The following table shows the production since 1902:

Production of Yellow Eye mine, 1902–43 [1]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds, wet assay)
1909	2	5.27	12	20
1910	14	67.30	26	--------
1911	7	9.63	2	--------

[1] Compiled from mine records of the U. S. Geological Survey and the Bureau of Mines. No production for years not listed.

The mine was not found during the present examination, and the following brief description is taken from Purington's field notes of 1896. The ore body is entirely in porphyry. The vein strikes N. 35° W. and dips 70° NE. It consists of several stringers of quartz, which make up a nearly solid vein of quartz and sulfides 12 inches wide. The ore contains galena, gold telluride, pyrite, and chalcopyrite. The principal value is in gold.

A caved adit was found in 1936 about 200 feet west of the supposed location of the Yellow Eye. It follows a vertical vein striking N. 15° W., in silicified redbeds of the Cutler formation. This vein, which is probably a split from the Yellow Eye vein, consists of 1 foot to 2 feet of brecciated quartz containing blebs of galena up to half an inch in diameter. Comb quartz is present in places, and rosettes of white barite are fairly abundant.

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