Geology and Ore Deposits of the Chicago Creek Area Clear Creek County Colorado

GEOLOGICAL SURVEY PROFESSIONAL PAPER 319

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By J. E. HARRISON *and* J. D. WELLS

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GEOLOGY AND ORE DEPOSITS OF THE CHICAGO CREEK AREA, CLEAR CREEK COUNTY, COLORADO

By J. E. Harrison and J. D. Wells

ABSTRACT

The Chicago Creek area, Clear Creek County, Colo., forms part of the Front Range mineral belt, which is a northeast-trending belt of coextensive porphyry intrusive rocks and hydrothermal veins of Tertiary age. More than $4.5 million worth of gold, silver, copper, lead, zinc, and uranium was produced from the mines in the area between 1859 and 1954.

The bedrock in the area is Precambrian and consists of igneous rocks, some of which have been metamorphosed, and metasedimentary rocks. The metasedimentary rocks include biotite-quartz-plagioclase gneiss that is locally garnetiferous, sillimanitic biotite–quartz gneiss, amphibolite, and lime-silicate gneiss. Rocks that may be metasedimentary or metaigneous rocks are quartz monzonite gneiss and granite gneiss and pegmatite. The granite gneiss and pegmatite locally forms a migmatite with the biotitic metasedimentary rocks. These older rocks have been intruded by granodiorite, quartz diorite and associated hornblendite, biotite-muscovite granite, and granite pegmatite. During Tertiary time the Precambrian rocks were invaded by dikes and plugs of quartz monzonite porphyry, alaskite porphyry, granite porphyry, monzonite porphyry, bostonite and garnetiferous bostonite porphyry, quartz bostonite porphyry, trachytic granite porphyry, and biotite-quartz latite porphyry. Solifluction debris of Wisconsin age forms sheets filling some of the high basins, covering some of the steep slopes, and filling parts of some of the valleys; talus and talus slides of Wisconsin age rest on, or are mixed with, solifluction debris in some of the high basins. Recent and (or) Pleistocene alluvium is present along valley flats of the larger streams and gulches.

Two periods of Precambrian folding can be recognized in the area. The older folding crumpled the metasedimentary rocks into a series of upright and overturned north-northeast-plunging anticlines and synclines. Quartz monzonite gneiss, granite gneiss and pegmatite, granodiorite, and quartz diorite and associated hornblendite were metamorphosed during this period. The second period of folding appears to have been the reflection at depth of faulting nearer the surface; it resulted in crushing as well as some folding of the already folded rocks into terrace and monoclinal folds that plunge gently east-northeast. The biotite-muscovite granite, which is the youngest major Precambrian rock unit, is both concordant (phacolithic) and crosscutting along the older fold system and has been fractured by the younger fold system.

Arching of the Front Range highland during Laramide time is believed responsible for the development of a regional joint pattern consisting of a north-northwest-trending longitudinal joint, a related cross joint, and two related diagonal joints. Joints of this regional pattern can be distinguished from Precambrian and Tertiary joints. Northwest-trending faults known as the "breccia reef" system, formed possibly during or following the arching. During Tertiary time the bedrock was intruded by porphyritic dike rocks that probably were emplaced under tensional stresses. Later regional shear stresses caused east- to north-northeast-trending fractures in the bedrock and at places reopened the "breccia reef" faults. These openings were the loci of deposition of hydrothermal veins.

The fractures formed under the regional shear stress are as much as 2½ miles long and are relatively straight fault fissures that follow the "grain" of the bedrock. Many faults are subparallel to foliation, axial planes of folds, contacts between rock units, or preexisting joints.

The veins in the district are typical mesothermal fillings of fault fissures. Some of the veins are lodes that have smooth bounding walls and abundant slickensides; the faults containing these veins are fairly regular in strike and dip, and irregularities, where present, commonly provided favorable structures for the deposition of the ore minerals.

A series of 5 vein types and 1 subtype can be recognized in the area. Most of these veins contain quartz, carbonate minerals, pyrite, chalcopyrite, tetrahedrite-tennantite, galena, and sphalerite, and many contain minor amounts of gold, silver, or polybasite. The proportion of the metallic minerals in any vein is used as the basis for classifying the veins into types. The 5 vein types are (1) pyritic, (2) pyritic with copper sulfides, (3) pyritic galena-sphalerite with copper sulfides and copper and silver sulfosalts, (4) galena-sphalerite with pyrite and (or) marcasite and copper and silver sulfosalts, and (5) galena-sphalerite. The subtype is similar to the pyritic type but is telluride bearing. Many veins are composite and contain 2 or more types of ore. Wherever composite veins have been observed, the older type of ore is always more pyritic than a younger type. The writers believe that the veins resulted from repeated fracturing, each fracture being filled at the time of opening by solutions that changed with time from predominantly iron-depositing through copper-depositing, to lead-zinc depositing.

Some of the veins, pegmatites, and porphyries of Tertiary age are abnormally radioactive. All the known occurrences in the porphyries are of too low grade to be important commercially. Most of the abnormally radioactive material in veins and pegmatites is either too low grade or in too small quantities to be of commercial importance. Some of the occurrences in veins have been explored inadequately and could not be evaluated in 1955.

Structural control of some of the ore shoots in the area is well defined. Openings favorable for the deposition of ore were formed at vein intersections, along deflections in strike or dip of veins, and along deflections where veins enter rocks of different competency.

About 60 mines are scattered throughout the area; they range in size from those containing a few hundred feet of workings to those containing several miles of workings. Most of the mines

have not been worked for years; many have not been worked since before 1900. During 1953, 1954, and the first half of 1955, only 1 mine was in continual operation, and only 3 others had a small amount of exploration work done in them.

INTRODUCTION

The Chicago Creek area, in Clear Creek County, Colo., about 3 miles southwest of Idaho Springs (figs. 1 and 2) forms a part of the Front Range mineral belt, a northeast-trending belt of coextensive veins and porphyry intrusives of Tertiary age (Lovering and Goddard, 1950, p. 72–73, pl. 2, and fig. 21). The area occupies about 5½ square miles along the northwest side of Chicago Creek.

At least $4.5 million of gold, silver, copper, lead, zinc, and uranium ores has been produced in the area from mesothermal veins of Tertiary age. These veins occupy fractures that cut Precambrian metamorphic and igneous rocks and porphyry intrusive rocks of Tertiary age.

The first published study of the geology of the area is presented by Spurr, Garrey, and Ball (1908) as part of their investigation of the Georgetown quadrangle. Brief summaries abstracted from this report are given by Goddard (1947, p. 308–313) and by Lovering and Goddard (1950, p. 184–185). Lovering and Goddard (1950, p. 187 and fig. 65) also made a study of the "Jewelry Shop" (West Gold) mine. The Freeland-Lamartine district, adjacent to the Chicago Creek area on the northwest (fig. 2), was studied by Harrison and Wells (1956).

This report represents a part of the studies of the U. S. Geological Survey in the Idaho Springs-Central City area of the Front Range on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The Chicago Creek area was mapped during the field seasons of 1953 and 1954 on a topographic base map (scale of 1:6,000 and a contour interval of 20 feet)

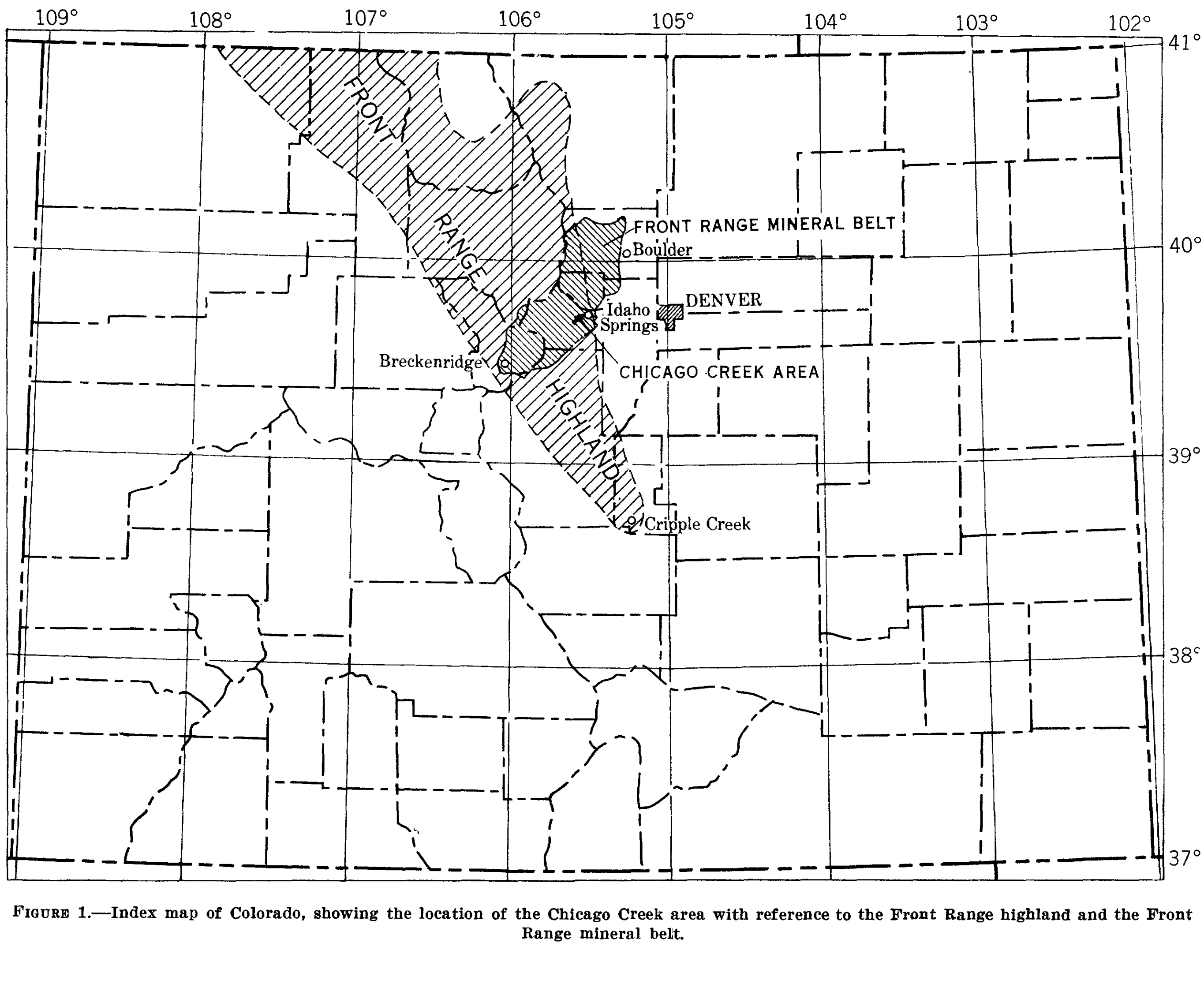

FIGURE 1.—Index map of Colorado, showing the location of the Chicago Creek area with reference to the Front Range highland and the Front Range mineral belt.

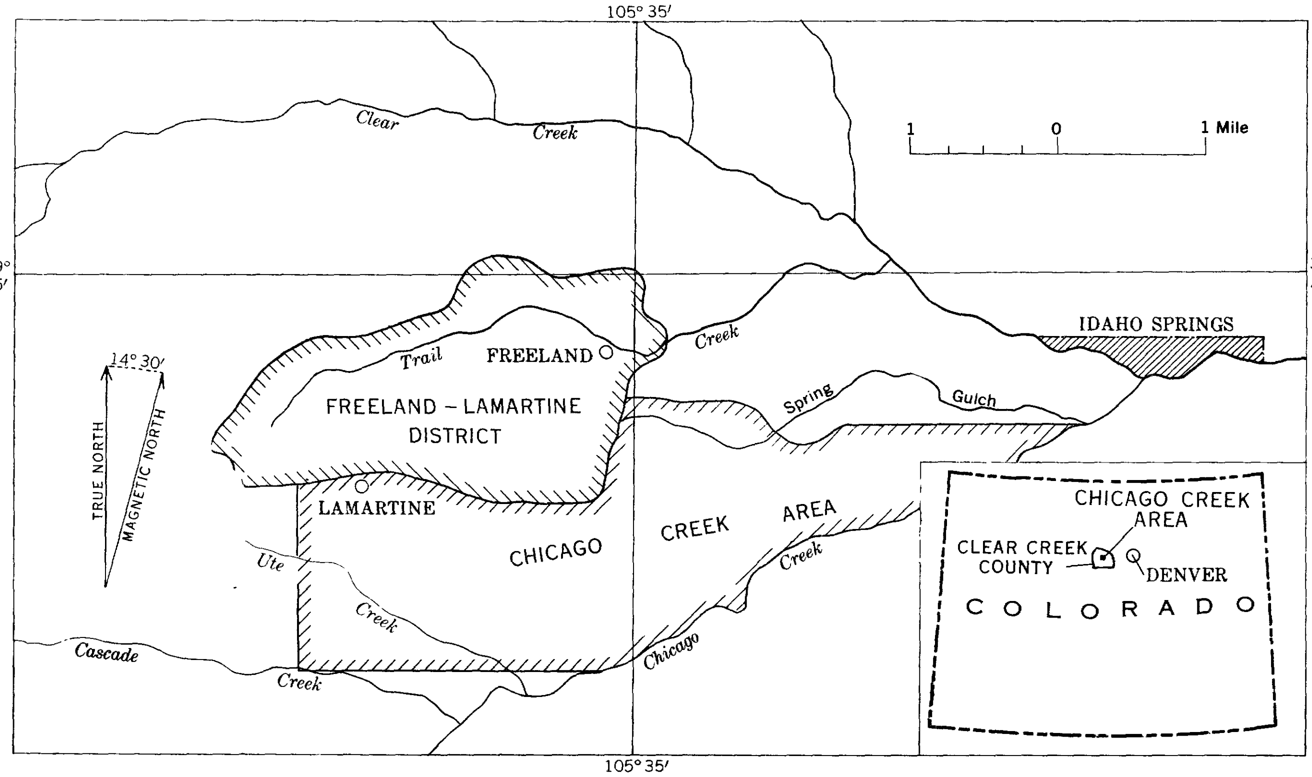

FIGURE 2.—Index map showing the location of the Chicago Creek area, Clear Creek County, Colo.

made by the Geological Survey. In addition to the 5½ square miles of surface mapped, about 30,000 feet of accessible mine workings was mapped on a scale of 1:1,200 or larger.

The writers thank the people who helped them in their study. Mr. C. L. Harrington, U. S. mineral surveyor, Idaho Springs, Colo., provided many maps of inaccessible mines. Much of the production data since 1902 was obtained from the files of the U. S. Bureau of Mines and is published with permission of that agency. Mr. A. J. Martin, of the Bureau of Mines, made the data available to the writers. Mr. Price Briscoe, Idaho Springs, Colo., allowed the writers to publish assay data taken from the records of the Idaho Springs Sampling Works, a now defunct company that Mr. Briscoe owned from 1919 to 1936. Local miners aided in the proper identification of abandoned mines and provided information on the workings and location of ore in inaccessible mines.

HISTORY OF THE DISTRICT

About April 1, 1859, pay gold ore was discovered in a placer near the mouth of Chicago Creek (Spurr, Garrey, and Ball, 1908, p. 311). Soon after this initial discovery a search for gold veins spread up Chicago Creek and into its tributary streams and gulches. Probably the first veins discovered were the Quito and the Little Mattie. Exploration was carried on in these and other mines. Only supergene-enriched ore was shipped at first, and extensive underground development of the veins did not begin until about 1880. By 1884 (Burchard, 1885) the Little Mattie, Silver Ring, Charter Oak, Muscovite, Kitty Clyde, Humboldt, Eclipse, and Silver Glance mines were all being worked. Vigorous development work in these and many other mines was carried on until the Silver Panic of 1894, when the silver mines shut down or drastically reduced operations. Mining picked up again after 1900, but it has been intermittent and generally on the decline since about 1910. Several base-metal mines were reopened during World War I and a few gold mines were reopened during the depression years. During the 20-year period between 1920 and 1940, only 2 new mines, the West Gold and the Dixie, were opened and developed to any great extent. Early in 1942 Government regulations and shortages of men and equipment forced the gold mines to shut down; some of the base-metal mines, however, were reopened during World War II. During 1953–54, the Humboldt and West Gold mines had a token amount of work done in them; the Dixie is the only mine that was operated throughout these years.

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GENERAL GEOLOGY

The bedrock in the Chicago Creek area consists of igneous rocks, some of which have been metamorphosed, and complexly folded metasedimentary rocks of the Precambrian. Dikes of quartz monzonite porphyry, alaskite porphyry, granite porphyry, monzonite porphyry, bostonite and garnetiferous bostonite porphyry, quartz bostonite porphyry, trachytic granite porphyry, and biotite-quartz latite porphyry have been intruded into the Precambrian complex during Tertiary time. Fissure veins bearing gold, silver, copper, lead, zinc, and uranium are, in part, in the same fracture systems as the dikes but are slightly younger. Quaternary solifluction debris, talus, and talus slides fill some of the high basins and valleys. Pleistocene and Recent alluvium covers the narrow valley flat of Chicago Creek and parts of the valley flat of Ute Creek, Maximillian Gulch, and Spring Gulch.

GEOLOGIC HISTORY

The geologic history recorded by the rocks in the Chicago Creek area includes Precambrian, Cretaceous, Tertiary, and Quaternary events. Every event cannot be dated precisely, and the following account of the geologic history is based, in part, on the writers' interpretation of the available data.

The first datable geologic event of the Chicago Creek area is a folding of the rocks into a series of north-northeast-trending folds. Whether the rocks were metamorphosed and foliated before they were deformed into these folds is a matter of conjecture. The writers believe that the oldest rocks were sediments that recrystallized mimetically before they were folded. During the first stages of folding these sedimentary rocks recrystallized with little appreciable change in chemical composition to mineral assemblages stable in the upper part of the amphibolite metamorphic facies. Migmatite and granite gneiss and pegmatite were formed during the early stages of this folding, either by metamorphic differentiation, transformation, or injection. As the folding continued, the now high-grade deformed rocks were intruded by granodiorite and then by quartz diorite and associated hornblendite. Preceding the time of intrusion of these units, some of the folds were overturned. Possibly pulsation of the stresses late in the period of folding deformed the granodiorite and quartz diorite and was accompanied by intrusion of biotite-muscovite granite phacoliths. This granite is sharply crosscutting at places, however, and is, in part, posttectonic. Following this sequence of events the area was uplifted, several thousand(?) feet of rock was removed, and then again the area was placed under stresses that deformed all the Precambrian rocks by fracturing and folding. Folds of this younger deformation trend east-northeast and are probably late Precambrian.

During late Cretaceous time the Front Range was uplifted, the Front Range highland was arched, and northwest regional faulting began (Lovering and Goddard, 1950, p. 58). This arching is believed to be represented in the Chicago Creek area by four joint directions that form a "regional" joint pattern, and the faulting is represented there by northwest-trending fissures.

Early Tertiary events in the Chicago Creek area were the intrusion of the porphyry dikes and plugs followed by formation of the east- to northeast-trending vein fissures under a regional shearing stress (Lovering and Goddard, 1950, p. 80). Some of the northwest-trending late Cretaceous faults were reopened, and ores bearing gold, silver, copper, lead, zinc, and uranium were deposited at places along faults of Tertiary age and in the reopened Cretaceous faults.

Quaternary time is represented in the Chicago Creek area by solifluction debris of early(?) Wisconsin age, talus, and talus slides, and by alluvium that is in part Pleistocene in age and in part Recent. The nearly constant daily freeze and thaw that affects rocks near glaciers aided the development of the debris and talus. The damming of streams tributary to Chicago Creek by a glacier moving down Chicago Creek valley resulted in Pleistocene alluvial deposits in the valleys of the tributary streams. Recent alluvium covers in part the valley flat of Chicago Creek.

PRECAMBRIAN ROCKS

The Precambrian rocks in the Chicago Creek area have been described and mapped by Ball (Spurr, Garrey, and Ball, 1908, pl. 2) and by Lovering and Goddard (1950, pl. 2), who compiled Ball's map onto the Front Range map. Both of the geologic maps are on a scale of 1:62,500 and are similar except for changes in rock names made by Lovering and Goddard. Because of differences in the map units used by Ball, Lovering and Goddard, and the writers, table 1 has been compiled to show the approximate equivalent units.

The biotite-quartz-plagioclase gneiss, sillimanitic biotite-quartz gneiss, lime-silicate gneiss, skarn, amphibolite, and quartz monzonite gneiss are the oldest rocks in the mapped area. During the Precambrian, these rocks were invaded by, and (or) transformed to, granite gneiss and pegmatite, and then intruded by granodiorite, quartz diorite and associated hornblendite, and finally by biotite-muscovite granite and pegmatite.

TABLE 1.—*Probable equivalent Precambrian rock units as mapped by Ball, by Lovering and Goddard, and by Harrison and Wells*

Ball (1908) [1]	Lovering and Goddard (1950)	This report
Idaho Springs formation Lime-silicate member	Idaho Springs formation	Biotite-quartz-plagioclase gneiss. Sillimanitic biotite-quartz gneiss. Lime-silicate gneiss. Skarn. Amphibolite.
Probably gneissoid granite	Probably granite gneiss and gneissic aplite, not shown in area Also quartz monzonite gneiss and gneissic pegmatite	Quartz monzonite gneiss.
Quartz monzonite	Boulder Creek granite and quartz monzonite	Granodiorite.
Quartz-bearing diorite and associated hornblendite	Quartz diorite and hornblendite	Quartz diorite and associated hornblendite.
Hornblende gneiss	Swandyke hornblende gneiss	Quartz diorite and associated hornblendite (metamorphosed). Amphibolite.
Silver Plume granite	Silver Plume granite	Biotite-muscovite granite.
Granite-pegmatite and associated granites and granite porphyry	Pegmatite; also probably some quartz monzonite gneiss and gneissic pegmatite and some granite gneiss and gneissic aplite	Pegmatite. Granite gneiss and pegmatite.

[1] *In* Spurr, Garrey, and Ball, 1908.

All these younger rocks but the granodiorite are found as sill-like or dikelike bodies in the older rocks, and perhaps only 50 percent of these bodies are large enough to be shown on the geologic map and sections (pl. 1).

METAMORPHOSED SEDIMENTARY AND VOLCANIC ROCKS

The Idaho Springs formation was named by Ball (1906), who considered it to be a series of metamorphosed sandstones, shales, and calcareous sandstones. He concluded that under regional metamorphism the sandstone yielded quartz gneiss, the shales yielded biotite schist and biotite-sillimanite schist, and the calcareous sandstones yielded the lime-silicate rocks.

On the geologic map of the Georgetown quadrangle (Spurr, Garrey, and Ball, 1908, pl. 2), all the metasedimentary rocks except the lime-silicate rocks are shown as one unit. In the present study detailed mapping allows separation of the rocks into lithologic map units, and these units will be referred to in this report by their lithologic names. The lithologic names have been chosen on the basis of quantitative mineral content, presence of diagnostic minerals easily recognized in the field, and structure of the rock. The characteristic mafic mineral is given first in the group of mineral modifiers, and this group of mineral modifiers is prefaced by a mineral ending in "-ic" or "-iferous" when a diagnostic mineral, generally in minor amounts, occurs in the rock. The igneous rock terms used in this report generally follow Johannsen's usage.

BIOTITE-QUARTZ-PLAGIOCLASE GNEISS

Biotite-quartz-plagioclase gneiss underlies about 20 percent of the map area (pl. 1). This rock is well exposed on the slopes of Chicago Creek, in the gulches tributary to Chicago Creek, and in the several crosscut tunnels that have portals near stream level along the creek. The gneiss also forms layers and lenses, too small to be mapped, in granite gneiss and pegmatite. Locally the biotite-quartz-plagioclase gneiss is migmatitic,[1] owing to scattered inch-wide, conformable layers of granitic material; at other places it contains garnet-bearing lenses too small to be mapped. Some of the gneiss contains sillimanite, and at a few places it contains garnet.

The biotite-quartz-plagioclase gneiss is interlayered with, and grades into, sillimanitic biotite-quartz gneiss in most of the mapped area; the interlayered units average about 4 feet in thickness. As these units grade into each other, an arbitrary distinction must be made to separate the units. For purposes of this report, those sillimanite-bearing gneisses containing less than 1 percent sillimanite are listed with the biotite-quartz-plagioclase gneiss.

The contacts between the biotite-quartz-plagioclase gneiss and the sillimanitic biotite-quartz gneiss, lime-silicate gneiss, amphibolite, and granite gneiss and pegmatite are gradational.

[1] Migmatitic and migmatite are used in this report as descriptive terms without genetic connotation. The terms are used to mean a rock consisting of two or more rock units that are mixed together in layers on the order of an inch wide.

Biotite-quartz-plagioclase gneiss has been described previously by the writers as biotite-quartz gneiss (Harrison and Wells, 1956). The reader is referred to this earlier report for petrographic details. In general, however, the gneiss is a fine- to medium-grained rock with a well-developed foliation shown by the segregation of the minerals into light and dark layers, and a well-developed lineation, shown by the alinement of groups of biotite crystals.

The composition of the gneiss differs from one outcrop to another as is shown by the modes (volume percent) given in table 2. About 90 percent of the volume of the typical rock consists of biotite, quartz, and oligoclase. Microcline is present only in a biotite-poor, light-colored variety or in migmatitic varieties of the gneiss. Not all the migmatitic varieties, however, contain microcline. The common accessory minerals in the gneiss include muscovite, magnetite, sphene, apatite, and zircon.

SILLIMANITIC BIOTITE-QUARTZ GNEISS

The only body of sillimanitic biotite-quartz gneiss sufficiently large to map crops out on the ridge crest in the northernmost part of the mapped area (pl. 1). Layers of sillimanitic biotite-quartz gneiss, however, are found at many places as alternating layers in biotite-quartz-plagioclase gneiss. Lenses and layers of sillimanitic biotite-quartz gneiss also occur in granite gneiss and pegmatite. At places the sillimanitic biotite-quartz gneiss is migmatitic. Contacts between this gneiss and the biotite-quartz-plagioclase gneiss and the granite gneiss and pegmatite are gradational.

The sillimanitic biotite-quartz gneiss is mottled black and gray, medium grained, and has a conspicuous gneissic structure. Lineation is pronounced and is given by biotite streaks, sillimanite alinement, and crinkling. The composition of the gneiss is shown by the modes (volume percent) given on table 3. Comparison of tables 2 and 3 shows that the sillimanitic biotite-quartz gneiss contains, in general, more sillimanite and muscovite and less plagioclase than the biotite-quartz-plagioclase gneiss. Microcline is present in the sillimanitic biotite-quartz gneiss only where it is migmatitic.

Details of the petrography of the sillimanitic biotite-quartz gneiss have been described by the writers in a previous report (Harrison and Wells, 1956). One variation of the gneiss not previously described is a rodded or podded variety that contains light-colored rods or pods as much as 2 feet long, which in cross section measure about ½ by 1 inch. These rods or pods consist of quartz intergrown with sillimanite and muscovite. They resemble what Ball (*in* Spurr, Garrey, and Ball, 1908) has described as "ellipsoidal masses" (p. 41) occurring in "pebble-bearing gneiss" (p. 177).

TABLE 2.—*Modes (volume percent)* [1] *of biotite-quartz-plagioclase gneiss from the Chicago Creek area*

Mineral	Mode (volume percent) of specimen—																
	1-4-34	2-2a-207	2-2b-40	2-3a-5a	2-3b-34	2-7a-61	2-7a-63	2-7b-41a	2-8-21b	2-8-69	2-8-85	2-11-101b	B-18	AI-9a	E-4a	X-2a	C-13
Microcline	1	1.3	0.5	Tr.	----	7	14	16	Tr.	0.6	----	----	12	37	----	27	----
Oligoclase	15	15	23	33	25	30	18	21	42	36	42	38	10	6	27	9	24
Quartz	75	52	61	44	56	50	56	51	51	33	30	52	70	50	58	51	68
Biotite	6	23	11	17	17	12	8	9	2	29	23	6	6	3	14	6	6
Muscovite	3	8	3	4	Tr.	.3	3	1.3	----	Tr.	Tr.	Tr.	2	3	.2	6	1.0
Sillimanite	----	.8	----	Tr.	----	----	----	----	----	----	----	----	----	.8	----	----	----
Magnetite	Tr.	.3	1.1	1.5	1.7	.5	1.0	1.6	2	1.6	4	3	.6	.4	.4	.6	1.0
Sphene	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	.3	Tr.
Apatite	----	Tr.	----	Tr.	Tr.	Tr.	----	Tr.	.5	Tr.	Tr.	Tr.	----	Tr.	Tr.	----	----
Zircon	----	Tr.	Tr.	Tr.	Tr.	----	----	Tr.	----	Tr.	----	Tr.	Tr.	Tr.	Tr.	.3	Tr.
Almandine	----	----	----	----	----	----	----	----	2	----	----	----	----	----	----	----	----
Epidote	----	----	----	----	----	----	----	----	----	----	.3	----	----	----	----	----	----
Hornblende	----	----	----	----	----	----	----	----	Tr.	----	----	1.4	----	----	----	----	----
Chlorite	----	----	----	----	----	----	----	----	----	----	Tr.	----	----	----	----	----	----

[1] Volume percent modes given in this report are determinations made on individual thin sections. All sections were cut at right angles to the gneissic structure of foliated rocks. Because most of the rocks are layered, many coarsely layered, a problem exists in obtaining a representative sample in a thin section. Recognition of this problem has led the writers to the following arbitrary system of presenting all modes in this report:

1. Principal mineral constituents (2 or more precent in the determination) are reported to the nearest percent.
2. Minor mineral constituents (0.3 to 1.9 percent) are reported to the nearest tenth of a percent.
3. Mineral constituents of less than 0.3 percent are reported as trace amounts (Tr.).

1-4-34. Quartz-rich gneiss from ridge in southwest corner of area.
2-2a-207. Sillimanitic gneiss from small layer in granite gneiss and pegmatite on the west end of the ridge north of Spring Gulch.
2-2b-40. Slightly migmatitic gneiss from layer in granite gneiss and pegmatite along Spring Gulch road.
2-3a-5a. Typical biotite-quartz-plagioclase gneiss from northeast shoulder of Alps Mountain.
2-3b-34. Typical biotite-quartz-plagioclase gneiss from southeast shoulder of Alps Mountain.
2-7a-61. Highly folded and slightly migmatitic gneiss from south flank of Alps Mountain.
2-7a-63. Migmatitic gneiss about 500 feet northwest of source of specimen 2-7a-61.
2-7b-41a. Slightly migmatitic light-colored gneiss from northeast slope of Eclipse Gulch.
2-8-21b. Garnetiferous and quartzitic gneiss pod in migmatitic gneiss outcrop along lower Ute Creek road.
2-8-69. Knotted gneiss, faintly migmatitic, from contorted rock on south-facing slope of lower Ute Creek.
2-8-85. Biotite-quartz-plagioclase gneiss from ridge between Ute Creek and Maximillian Gulch.
2-11-101b. Gneiss from 3- by 9-inch pod in migmatite near Ute Creek-Lamartine road on crest of ridge between Ute Creek and Maximillian Gulch.
B-18. Light-colored gneiss from slope south of Spring Gulch.
AI-9a. Very migmatitic gneiss from slope south of Spring Gulch.
E-4a. Typical biotite-quartz-plagioclase gneiss from slope south of Spring Gulch.
X-2a. Biotitic layer in migmatite from slope north of Martha E mine.
C-13. Light-colored gneiss from slope north of Martha E mine.

TABLE 3.—*Modes (volume percent) of sillimanitic biotite-quartz gneiss*

Mineral	Mode (volume percent) of specimen—										
	2-2b-36	2-3a-2b	2-3a-5b	2-3a-28	2-3b-20	2-3b-43a	2-3b-66	2-7x-31	2-8-15b	2-11-18	AW-4a
Microcline	10	6		5	0.5	1.0	Tr.	6	0.4	4	27
Oligoclase	16	11	5	16	6	5	1.5	10	11	14	8
Quartz	28	54	62	44	67	49	59	33	50	38	43
Biotite	27	19	28	20	16	34	28	27	32	32	7
Muscovite	12	6	1.4	7	3	2	1.8	5	1.8	1.8	6
Sillimanite	7	3	2	6	6	9	9	16	5	10	9
Magnetite	.3	.6	.8	1.5	.7	Tr.	.3	3	Tr.	.6	Tr.
Sphene	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	.3
Apatite				Tr.		Tr.		Tr.	Tr.		
Zircon	Tr.		Tr.		Tr.			Tr.	Tr.	Tr.	.3

2-2b-36. Gneiss from layer on ridge north of Spring Gulch.
2-3a-2b. Gneiss from area on east shoulder of Alps Mountain, containing interlayered sillimanitic biotite-quartz and biotite-quartz-plagioclase gneisses.
2-3a-5b. Gneiss from migmatitic outcrop 500 feet east of source of specimen 2-3a-2b.
2-3a-28. Gneiss from ridge crest east of head of King Solomon Gulch.
2-3b-20. Gneiss from south slope of Alps Mountain.
2-3b-43a. Gneiss from outcrop on southeast slope of Alps Mountain.
2-3b-66. Gneiss from outcrop on southeast slope of Alps Mountain.
2-7x-31. Migmatitic gneiss from slope east of upper Maximillian Gulch.
2-8-15b. Gneiss from outcrop exposing contact with granodiorite along lower Ute Creek road.
2-11-18. Migmatitic gneiss from ridge crest southeast of Lamartine.
AW-4a. Gneiss containing 1- by ½-inch pods of quartz, muscovite, and sillimanite in exposure on slope south of Spring Gulch.

AMPHIBOLITE

Only a few mappable layers of amphibolite are exposed in the area (pl. 1). The best surface exposure of amphibolite is on the crest of the ridge north of the Columbia shaft; a good underground exposure of amphibolite associated with lime-silicate gneiss is in the Wallace tunnel (fig. 28). Much of the amphibolite occurs as layers, too small to be mapped, in lime-silicate gneiss.

The amphibolite has 3 principal field occurrences: (1) as layers conformable with, and gradational into, biotite-quartz-plagioclase gneiss; (2) as layers alternating with pyroxene gneiss; and (3) as conformable layers and lenses in epidote-clinozoisite parts of the lime-silicate gneiss.

The amphibolite is a black to greenish-black or black and white, fine- to medium-grained gneiss consisting principally of hornblende, andesine-labradorite, and quartz. Modes (volume percent) of the amphibolite and related rocks are shown on table 4. In general, amphibolites associated with pyroxene gneisses or epidote-clinozoisite gneisses are lighter in color than those associated with biotite-quartz-plagioclase gneiss. The light-colored gneisses contain less hornblende and more quartz and feldspar than the dark-colored amphibolites. Microcline occurs only in the amphibolite associated with the lime-silicate gneiss. The amphibolite is conformable with, and gradational into, biotite-quartz-plagioclase gneiss, lime-silicate gneiss, and quartz monzonite gneiss. It is cut by stringers and vaguely defined patches of massive quartz-epidote rock. These crosscutting relations are particularly well exposed on the crest of the ridge north of Spring Gulch, where a former amphibolite layer is mostly massive quartz-epidote rock and has been mapped as the lime-silicate member of the Idaho Springs formation. In this same field area, amphibolite appears to grade into lime-silicate gneiss along the strike.

TABLE 4.—*Modes (volume percent) of amphibolite and related rocks*

Mineral	Mode (volume percent) of specimen—					
	2-2b-32a	3-1-8a	Wa-6a	2-7b-55a	AP-4b	AP-6
Hornblende	72	55	35	31	25	19
Andesine-labradorite	25	34	28	46	35	14
Quartz	1.0	1.0	5	.4	33	16
Biotite	.5	1.0	3	1.2	5	
Magnetite	1.0	1.0	Tr.	Tr.	.7	.8
Sphene		3	2	1.4	.8	.5
Epidote		2	4	5		1.3
Apatite	.4	3	.5	.4	Tr.	Tr.
Microcline			23	15		
Clinopyroxene						48

2-2b-32a. Typical amphibolite from outcrop along Trail Creek road.
3-1-8a. Amphibolite from outcrop near mouth of Trail Creek.
Wa-6a. Amphibolite layer in lime-silicate gneiss from the Wallace tunnel.
2-7b-55a. Amphibolite layer in lime-silicate gneiss from outcrop on south slope of Alps Mountain.
AP-4b. "Eyed" amphibolite from outcrop in gulch on east slope of Alps Mountain where cut by Spring Gulch.
AP-6. Pyroxene gneiss layer associated with amphibolite in outcrop near source of specimen AP-4b.

Foliation and lineation are conspicuous in most of the amphibolites. Foliation in the dark-colored varieties is marked by planar alinement of hornblende crystals and is less conspicuous than that of the lighter colored varieties where it is marked by the segregation of the minerals into light and dark layers. Lineation in all varieties is produced by the alinement of hornblende crystals.

Typical amphibolite in thin section has a fine- to medium-grained, hypidiomorphic granular texture. The hornblende crystals are commonly subhedral and are about 2 millimeters long. They are packed closely together in the dark-colored varieties and are in a matrix of fine-grained, equigranular, subhedral to anhedral quartz and feldspar grains in the light-colored varieties. Most of the plagioclase grains are twinned according to the albite or pericline laws; a few grains exhibit combinations of these two types of twinning.

One specimen of "eyed" amphibolite (AP-4b) has a texture similar to that of other light-colored amphibolites except in the areas of the "eyes." The "eyes" consist of millimeter-sized grains of magnetite surrounded by a thin rim of sphene that is surrounded in turn by a 0.5-millimeter rim of quartz and plagioclase. Perhaps a dozen of these light areas with dark centers occur in a square inch of the gneiss that is otherwise mineralogically and texturally similar to other light-colored amphibolites.

LIME-SILICATE GNEISS

Lime-silicate gneiss is poorly exposed in the Chicago Creek area, but scattered outcrops are present on the slopes north of Spring Gulch and on the crest of the ridge west of the head of Maximillian Gulch (pl. 1). A layer at least 160 feet wide was cut in the Wallace tunnel (fig. 28). The lime-silicate gneiss bodies exposed at the surface range in size from pods 3 inches wide and 12 inches long to layers 250 feet wide and half a mile long.

The lime-silicate rocks were considered by Ball (1906) to be a member of the Idaho Springs formation. This member was later divided by Ball (Spurr, Garrey, and Ball, 1908, p. 41–44) into 4 rock types: (1) quartz-magnetite gneiss, (2) hornblende-diopside gneiss, (3) quartz-epidote-garnet rock, and (4) calcite-lime-silicate rock.

The writers have found that, although Ball's 4 types of lime-silicate rocks exist, many variations of each type can be found. In general, the writers include varieties of Ball's quartz-epidote-garnet rock and calcite-lime-silicate rocks in the group mapped as lime-silicate gneiss. Skarns and skarn-type rocks that are not everywhere gneissic are also included in the lime-silicate gneiss. The hornblende-diopside gneiss in the Chicago Creek area is mostly amphibolite, or amphibolite interlayered with lesser amounts of pyroxene gneiss, and has been mapped as amphibolite where the unit is large enough to be shown. The quartz-magnetite gneiss forms 1- to 2-foot layers adjacent to, or within, the lime-silicate gneiss in the mapped area.

In the Chicago Creek area, the lime-silicate gneiss is a bright-green, greenish-black, or mottled white, brown, and green, fine- to medium-grained, massive to layered rock. Epidote or intergrowths of epidote and clinozoisite, quartz, and garnet are the principal constituents of the massive varieties; hornblende, feldspar, and clinopyroxene are more common in the layered varieties. The layers range in thickness from a fraction of an inch to 6 feet and are formed by segregation of the minerals into layers of different color. The gneissic varieties are concordant with, and gradational into, biotite-quartz-plagioclase gneiss and amphibolite. Many of the small pods of quartz-rich gneisses found in the biotite-quartz-plagioclase gneiss, such as specimens 2–8–21b and 2–11–101b listed on table 2, may be boudins of lime-silicate rocks. The massive varieties containing mostly epidote and clinozoisite commonly form irregular patches and pods as much as 2 feet in diameter that cut across amphibolites; the massive varieties containing abundant garnet form bodies as much as 50 feet wide and 250 feet long in the lime-silicate gneisses. At places these bodies appear to be podlike and concordant to foliation of adjacent rocks, and at other places they appear to be irregular patches and discordant.

The composition of the rocks mapped as lime-silicate gneiss varies from layer to layer within one outcrop, and the principal minerals may be combined in almost any proportions. (See table 5.) The only mineral found in all varieties is quartz; next most common is epidote and (or) clinozoisite; plagioclase, hornblende, clinopyroxene, or garnet are common in several varieties. Scapolite,[2] which fluoresces pale red, is a common mineral in some of the nongarnetiferous varieties; calcite in minor amounts occurs in a few of the varieties. Magnetite and sphene are the common accessory minerals, but magnetite is a principal mineral in the quartz-garnet-magnetite skarns.

Examination of the lime-silicate rocks in thin section indicates that the foliation of the gneisses is due to segregation of some of the quartz or some of the quartz and feldspar into discontinuous layers. Within these layers, the quartz is commonly in a mosaic arrangement and has sutured boundaries; feldspar is less sutured but is in the same mosaic pattern. Within the dark-colored layers, the same mosaic texture is common and includes all the minerals in the rock, although quartz and feldspar are less abundant than in the light-colored layers.

Epidote, in irregular patches, commonly replaces clinopyroxene or hornblende and is intergrown, at places myrmekitically, with clinozoisite. Garnet is in crystals 0.2 millimeter to 0.5 millimeter in diameter and forms crystal aggregates intergrown with quartz or quartz and clinopyroxene. Garnet in the quartz-epidote-pyroxene type of lime-silicate assemblage has a refractive index of 1.805±0.002 and a length of cubic axes of 11.967±0.005 angstroms[3] and, according to the data given by Levin (1950, p. 529), is about half grossularite and half andradite. Garnet in the quartz-garnet-magnetite skarn (specimen 2–2b–59) has a refractive index of 1.805±0.002, an axial length of 11.676±0.001 angstroms, contains 7.8 percent man-

[2] N_o is about 1.58 which, according to Winchell (1948, p. 294), corresponds to the variety mizzonite.

[3] X-ray determination using Bradley-Jay method by A. J. Gude 3d, U. S. Geological Survey.

TABLE 5.—*Mineral assemblages typical of different varieties of lime-silicate gneiss and related rocks*

[X, principal mineral; (X), minor amount of mineral present; Tr., trace. Specimen 2-2a-206a: G, garnetiferous layer; NG, nongarnetiferous layer]

Mineral	Mineral assemblage of specimen—															
	1-3-67	2-2a-206a		2-2a-206b	2-2a-206c	2-2b-45	2-2b-50	2-2b-59	2-7b-55b	2-11-20a	2-11-20b	2-11-20d	2-11-20g	Wa-6b	Wa-6c	Wa-7
		G	NG													
Quartz	X	X	(X)	X	X	X	X	X	X	X	X	X	X	X	X	X
Epidote	X			X	X	X	X			X	X	(X)	X	X	X	X
Clinozoisite		(X)				X	X						X		X	(X)
Plagioclase	X								X	X	X	(X)	X	(X)		X
Percent An content	32-36								44-56	27-30				31-36		31-37
Hornblende	(X)			X			X		X	(X)	(X)		X	(X)		
Clinopyroxene		X	X	X	X	X		X	X		(X)	(X)	(X)		(X)	
Garnet	X	X			X	X		X			X	(X)	(X)		X	(X)
Scapolite			X						X			(X)		X		
Calcite				(X)	(X)				(X)					Tr.	(X)	
Sphene	(X)	(X)	(X)	(X)	(X)		Tr.		(X)	(X)	(X)		(X)	(X)	(X)	(X)
Apatite	Tr.													Tr.		(X)
Magnetite	(X)							X		(X)	(X)		(X)			Tr.
Microcline							X						X			
Biotite							(X)									

1-3-67. Lime-silicate gneiss from knob on ridge about 500 feet south of Lamartine.
2-2a-206a, b, and c. Suite of lime-silicate rocks from knob on ridge north of Spring Gulch:
a. Layered lime-silicate gneiss.
b. Massive lime-silicate rock crosscutting a.
c. Massive pyroxene-garnet skarn crosscutting a.
2-2b-45. Lime-silicate gneiss from outcrop 700 feet east-southeast of source of specimen 2-2a-206.
2-2b-50. Lime-silicate gneiss from pit on slope north of Spring Gulch.
2-2b-59. Garnet-magnetite skarn from 50- by 250-foot pod in lime-silicate gneiss layer 300 feet up slope from point where gneiss layer crosses mine access road on east slope of Alps Mountain.
2-7b-55b. Lime-silicate gneiss containing layers of amphibolite, from outcrop on south slope of Alps Mountain.
2-11-20a, b, d, and g. Suite of lime-silicate gneisses of different types, from outcrop on crest of ridge southeast of Lamartine.
Wa-6b, 6c, and 7. Suite of lime-silicate rocks from the Wallace tunnel:
6b. Lime-silicate gneiss at contact with amphibolite layer.
6c. Possibly discordant pod of quartz-epidote-garnet rock.
7. Light-colored lime-silicate gneiss.

ganese,[4] and is about 25 percent spessartite; most of the remaining 75 percent is almandite, although some calcium must also be present. Scapolite, unaltered hornblende, and clinopyroxene occur in subhedral to anhedral crystals that have smooth, relatively straight boundaries. Calcite and some quartz fill interstices between other grains or form irregular veinlets and patches in hornblende, clinopyroxene, epidote, clinozoisite, and garnet. Sphene, in crystals as much as 1 millimeter long and 0.3 millimeter across, is scattered through the rock and at places forms several percent of the rock. Magnetite is commonly associated with garnet and is most abundant in the garnet-rich varieties.

ORIGIN

The gradation between biotite-quartz-plagioclase gneiss, sillimanitic biotite-quartz gneiss, lime-silicate gneiss, and amphibolite and the interlayering and interlensing of the units suggest to the writers that these rocks are metamorphosed sedimentary rocks. The broad regional distribution of rocks of similar character has been pointed out by Ball (Spurr, Garrey, and Ball, 1908), Bastin (Bastin and Hill, 1917), Lovering and Goddard (1950), and Lovering and Tweto (1954). These rocks now contain mineral assemblages characteristic of the upper part of the amphibolite facies as defined by Turner (1948, p. 76–88). In a broad sense, the mineralogic variations in the rocks are principally the result of differences in original mineral composition of the sediments; but certain local variations in the rock units suggest to the writers that the metamorphic rocks derived from regional metamorphism have been modified, at least in part, by metasomatism. These metasomatic variations, however, form only a small part of the total volume of metasedimentary rocks exposed in the mapped area.

The biotite-quartz-plagioclase gneiss contains a mineral assemblage that could be derived from original sandy beds. A slight increase in the amount of iron and magnesium in the original sediment would favor the formation of almandine (Turner, 1948, p. 85), and the garnetiferous biotite-quartz-plagioclase gneiss may, therefore, represent a facies of the biotite-quartz-plagioclase gneiss. A relative deficiency of iron and magnesium in the original sediments would favor the formation of potash feldspar, and the biotite-poor, light-colored variety of biotite-quartz-plagioclase gneiss is also probably a facies of the more common variety of this rock. The close field association of the garnet-bearing gneiss and the biotite-poor, light-colored gneiss to the biotite-quartz-plagioclase gneiss supports the belief that these three varieties of rocks are genetically related. A metasomatic modification of parts of these rocks is suggested by field observations in the Freeland-Lamartine district (Harrison and Wells, 1956), where a ½- to 1-inch-thick garnet "envelope" followed along a 1-inch-thick granitic stringer that cut across nongarnetiferous biotite-quartz-plagio-

[4] Quantitative spectrographic determination by A. T. Myers, U. S. Geological Survey.

clase gneiss at about 45° to the foliation. As granitic stringers in the gneiss are commonly concordant, and as garnet commonly is more abundant near the granitic stringers, the writers infer that some of the garnet in migmatitic biotite-quartz-plagioclase gneiss also formed by metasomatic processes.

The sillimanitic biotite-quartz gneiss contains a mineral assemblage that could have been derived from alumina-rich sediments. The 4-foot-wide alternating layers of this rock and biotite-quartz-plagioclase gneiss suggests that much of this gneiss was derived from sediments that originally contained alternating sandy and shaly beds.

The rodded or podded variety of the sillimanitic biotite-quartz gneiss was believed by Ball (Spurr, Garrey, and Ball, 1908, p. 177) to represent metamorphosed conglomeratic shales. The few exposures of this rock type in the Chicago Creek area occur near or on crests of folds. The rodded rock seen is always migmatitic and contains several times as much microcline as the nonmigmatitic gneiss. The rods are intergrowths of quartz, sillimanite, and muscovite, which in the presence of potash feldspar represents a state of disequilibrium (Turner, 1948, p. 85). The writers suggest, therefore, that the rods and pods may not be metamorphosed pebbles but rather may be metamorphic differentiates formed along crinkles or warps in sillimanitic biotite-quartz gneiss where this gneiss recrystallized under stresses associated with folding.

A metasomatic modification of some of the usual variety of sillimanitic biotite-quartz gneiss is also plausible. In the migmatitic parts of this gneiss the amount of sillimanite present seems to be proportional to the amount of granite in the rock. Even if the more sillimanitic gneiss was more subject to migmatization, the proportionality of thickness of sillimanite layers to thickness of granite stringers is suggestive of local change in the original bulk chemical composition of the gneiss.

The amphibolite and lime-silicate gneiss are calcium-rich layers intercalated with biotite-quartz-plagioclase gneiss and sillimanitic biotite-quartz gneiss. These calcium-rich rocks may represent limy sandstones, impure limestones, or sediments rich in mafic volcanic detritus; some of the amphibolite may represent metamorphosed basic volcanic rocks.

Some local metasomatic modifications of these gneisses are indicated in many outcrops by "eyed" amphibolites or by crosscutting stringers, pods, and patches of massive quartz-epidote rock. The magnetite "eyes" probably formed by extraction of iron from the area immediately surrounding the "eye" and thus represent a local recrystallization. The stringers, patches, and pods of quartz-epidote rock represent a considerable loss of iron where they cross amphibolite. Metasomatism of calcareous rocks by granitic solutions to produce skarns and skarn-type assemblages of minerals is too common to be overlooked as a possible origin for some of the lime-silicate gneiss.

QUARTZ MONZONITE GNEISS

A few small layers of quartz monzonite gneiss are exposed in the Chicago Creek area (pl. 1). The best exposure of this gneiss is on the ridges and steep slopes in the northeast part of the area.

The quartz monzonite gneiss is a black and pink, fine- to medium-grained rock that is finely layered and has a well-developed foliation. It forms discontinuous layers and lenses concordant with, and gradational into, biotite-quartz-plagioclase gneiss and amphibolite.

The quartz monzonite gneiss can be distinguished from the light-colored biotite-quartz-plagioclase gneiss on the basis of mineralogy and texture. In general, the quartz monzonite gneiss contains more microcline and plagioclase, less quartz, and is more evenly and thinly laminated than the light-colored biotite-quartz-plagioclase gneiss.

The principal minerals in the gneiss are quartz, plagioclase, microcline, and biotite. According to R. H. Moench (oral communication, 1955), the gneiss in the Idaho Springs-Central City area commonly is composed of about 30 percent quartz, 30–60 percent oligoclase, 5–30 percent microcline, from a trace to 10 percent biotite, and minor amounts of magnetite, zircon, apatite, allanite, and sphene. Foliation in the gneiss is formed by segregation of the minerals into biotite-rich and quartz-feldspar-rich laminae. Alinement of the biotite flakes in the biotite-rich layers forms lineation in the rock.

ORIGIN

So little of the quartz monzonite gneiss is exposed in the Chicago Creek area that little data could be gathered to show the origin of the unit. As it occurs in discontinuous layers and lenses concordant with, and gradational into, biotite-quartz-plagioclase gneiss and amphibolite, it may be a metasedimentary rock.

GRANITE GNEISS AND PEGMATITE

Granite gneiss and pegmatite underlies about 20 percent of the mapped area (pl. 1). The rock is relatively resistant to weathering and forms prominent outcrops on many ridges. A layer of this rock about 800 feet thick is exposed in the Perkins tunnel (pl. 11), showing its contact with the metasedimentary rocks.

The granite gneiss and pegmatite at most places is conformable with metasedimentary rocks, but at a few places the pegmatite appears to cut across other Precambrian rocks older than the biotite-muscovite granite. Contacts between the conformable parts of the granite gneiss and pegmatite and metasedimentary rocks are gradational, commonly over several tens of feet. The gradational area between this gneiss and metasedimentary rocks is occupied by a migmatite that contains more and wider layers of granite gneiss and pegmatite as it approaches the granite gneiss. The contacts between granite gneiss and metasedimentary rocks shown on maps in this report have been drawn through the areas of migmatite where the composition is about 50 percent granite and 50 percent metasedimentary rock.

The granite gneiss and pegmatite unit varies more in composition than any other Precambrian rock in the mapped area. It contains rocks which could be classified as silexite, alaskite, granite, and quartz monzonite. Most of the rock is granitic or alaskitic, and the typical rock in the Freeland-Lamartine district is composed of about 30–50 percent quartz, 10–30 percent oligoclase-andesine, 20–40 percent microcline, and 1–10 percent biotite and muscovite (Harrison and Wells, 1956); modes of certain other facies are given in this report on table 6.

The granite gneiss and pegmatite is either pink and white, or mottled black, pink and white, and is a medium- to coarse-grained and pegmatitic rock. At least four varieties of this rock can be recognized. The most common variety consists of a medium-grained biotite-bearing gneiss containing irregular massive patches and concordant lenses and pods of pegmatite. This variety in some places grades into the second variety, a massive, alaskitic coarse-grained and pegmatitic rock; and in other places it grades into a third variety, a migmatite. The fourth variety is a quartz-rich facies that forms discontinuous layers as much as 3 feet wide in the granite gneiss and pegmatite or alaskitic varieties.

TABLE 6.—*Modes (volume percent) of granite gneiss and pegmatite*

Mineral	Mode (volume percent) of specimen—					
	2-2b-52	2-3a-55	2-3b-33	2-3b-43b	2-7b-82	X-2a
Microcline	45	Tr.	-------	8	5	19
Oligoclase-andesine	44	36	Tr.	6	48	33
Quartz	9	57	89	83	45	45
Biotite	-------	5	2	2	-------	-------
Muscovite	2	2	2	1.0	1.4	0.8
Magnetite	-------	Tr.	7	Tr.	-------	2
Sphene	-------	Tr.	0.4	-------	Tr.	Tr.
Zircon	-------	-------	Tr.	-------	-------	Tr.
Sillimanite	-------	-------	-------	Tr.	-------	-------

2-2b-52. Typical cataclastically deformed granite gneiss and pegmatite from slope north of Spring Gulch.
2-3a-55. Migmatitic granite gneiss from outcrop along road in King Solomon Gulch.
2-3b-33. Sheared quartz-magnetite gneiss from 3-foot-wide layer within 15-foot-wide layer of granite gneiss and pegmatite near crest of prominent knob about 1,000 feet east of eastern peak of Alps Mountain.
2-3b-43b. Granitic layer 1 inch wide in migmatite on crest of small ridge on south-east slope of Alps Mountain.
2-7b-82. Cataclastically deformed white facies of granite gneiss from crest of ridge between Eclipse and Maximillian Gulches.
X-2a. Granitic layer in migmatite from slope south of Spring Gulch.

The pegmatites occurring with the biotite-bearing gneiss differ from the gneiss in their field relations and distribution. In areas of tight folding, such as that exposed on the slopes northwest of Chicago Creek, massive pegmatite bodies occur in the axial regions of overturned folds and terrace-type folds. These massive pegmatite bodies grade into granite gneiss or mixtures of granite gneiss and pegmatite along the strike of the layers from the axial regions into the flanks of the folds. Some discordant dikelike bodies of pegmatite that appear related to granite gneiss and pegmatite have been seen at a few places cutting the metasedimentary rocks, quartz monzonite gneiss, and quartz diorite. Pegmatites traceable from concordant vaguely defined patches in granite gneiss and pegmatite into dikes in metamorphosed quartz diorite can be found in the same areas where inclusions of granite gneiss and pegmatite exist.

Inclusions of metasedimentary rocks in the granite gneiss and pegmatite range in width from thin wisps to mappable layers 50 feet or more wide. An area of granite gneiss and pegmatite containing abundant inclusions is moderately well exposed on the slopes north of Spring Gulch (pl. 1).

Much of the granite gneiss and pegmatite has a fractured appearance. Large crystals have been broken and thin streaks of granulated rock give a foliation to the gneiss that at places transects the layering. Magnetite in the quartz-rich variety of the rock is commonly smeared or lined out in the plane of the cataclastic foliation. For details of the petrography of this rock, the reader is referred to the report on the Freeland-Lamartine district (Harrison and Wells, 1956).

ORIGIN

The geologic history of this rock unit is very complex, and conclusive statements of its origin cannot be made from the meager data available. A few tentative conclusions about the rock, however, should be mentioned: (1) The bulk of the migmatite seems genetically related to the granite gneiss and pegmatite; (2) except for the pegmatitic facies, the unit is conformable, occurring in a number of mappable layers intercalated with the metasedimentary rocks; and (3) parts of the unit (now pegmatite) appear to have been redistributed during at least two widely separated periods of deformation, and in the field these parts appear to be younger than the bulk of the unit.

GRANODIORITE

The granodiorite is exposed (1) in an area of about one square mile along Ute Creek, (2) as a small hook-shaped body on the ridge between the Eclipse and upper Golden Glen Gulches, and (3) as a small elongate body in the extreme northeast corner of the area (pl. 1).

The granodiorite along Ute Creek constitutes the north margin of a large body described by Ball (Spurr, Garrey, and Ball, 1908, p. 51–54) as quartz monzonite. After Boos and Boos (1934, p. 305–306) applied the name Boulder Creek granite gneiss to a similar body of rock west of Boulder, Colo., the name Boulder Creek granite was applied by Lovering and Goddard (1950, p. 27) to all rocks of this type in the Front Range.

Composition of the rock ranges from quartz monzonite to quartz diorite and has an average composition of granodiorite. This rock unit may be a phase of the main mass described by Ball and is similar to the granodiorite phase of the Boulder Creek granite described in the Boulder County tungsten district by Lovering and Tweto (1954, p. 8–9).

FOLIATION AND LINEATION

The granodiorite is a massive to weakly foliated and lineated rock that is cut by numerous pegmatitic dikes and contains local xenolith and wall rock inclusions. The foliation, imparted by the planar alinement of biotite flakes and alternating biotite-rich and biotite-poor layers, strikes northeast and generally dips steeply to the northwest (pl. 1). The contacts are sharp, straight, and steep, showing no contact metamorphic effects. The trend of the contact is across the lithologic layering and regional foliation in some places and parallel to it in others.

From a study of the internal structures in the granodiorite and in the country rock, several relationships between the foliations, lineations, inclusions, and the contact have been noted. The foliation and lineation is the same in the granodiorite and in the wall rocks; the foliation trends across the contact; and the small tabular inclusions are oriented parallel to the contact.

Linear elements in the granodiorite are represented by mineral alinement and streaking, the same type of structures found in the metasedimentary wall rock. The most prominent lineation in the granodiorite has an average plunge of 64° N. 29° E., and a poorly defined lineation plunges moderately steep N. 45° W. or S. 45° E. (fig. 3). The prominent linear direction, b_1, in the granodiorite is virtually identical to the lineation maximum in the country rocks (fig. 9). The poorly defined linear directions in the granodiorite

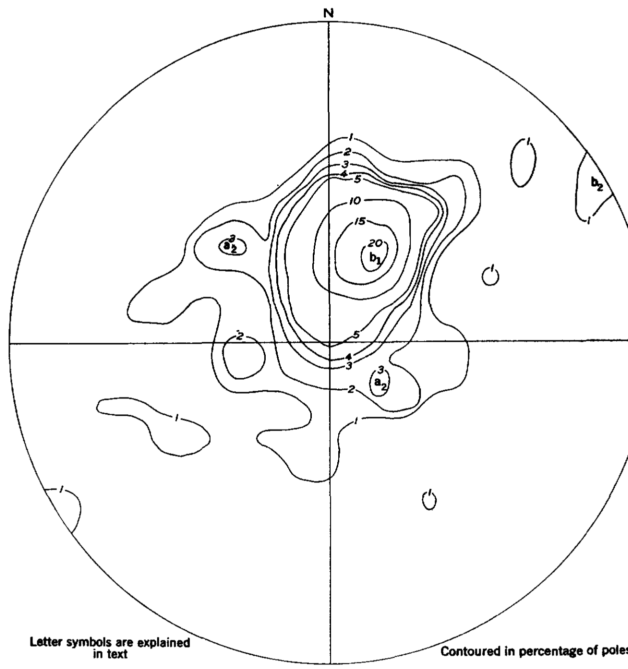

FIGURE 3.—Contour diagram of lineations in the granodiorite, lower hemisphere plot of 176 poles.

correspond approximately to the lineation nearly at right angles to the axes of the major folds (a_2) shown on figure 9.

The foliation of the granodiorite and the foliation in the gneissic wall rocks strike northeast. The contacts of the granodiorite bodies have a general north or east trend (pl. 1). The contact of the granodiorite is discordant to the structure of the biotite-quartz-plagioclase gneiss, as shown in a large-scale plan of a part of the contact exposed on the slope north of lower Ute Creek (fig. 4). Also shown is a small, thin, tabular inclusion near the contact that is nearly parallel to the contact but oriented at a large angle to the foliation. Similar angular relations between inclusions and the foliation in the granodiorite have been observed elsewhere. Other inclusions several thousand feet away from the contact are nearly parallel to the foliation in the granodiorite. In those places where the foliation is nearly parallel to the inclusions, the foliation contains lineations that reflect the regional structure.

ASSOCIATED GRANITIC DIKES

Three types of granitic dikes occur in joints in the granodiorite. They are (1) leucocratic granodiorite dikes, ½ to 12 inches wide, medium to coarse grained, and in places pegmatitic; (2) dikes and irregular bodies of biotite-muscovite granite; and (3) granite pegmatite dikes. Because of their small size, the leucocratic granodiorite dikes were not mapped. The biotite-muscovite granite and the granite pegmatite

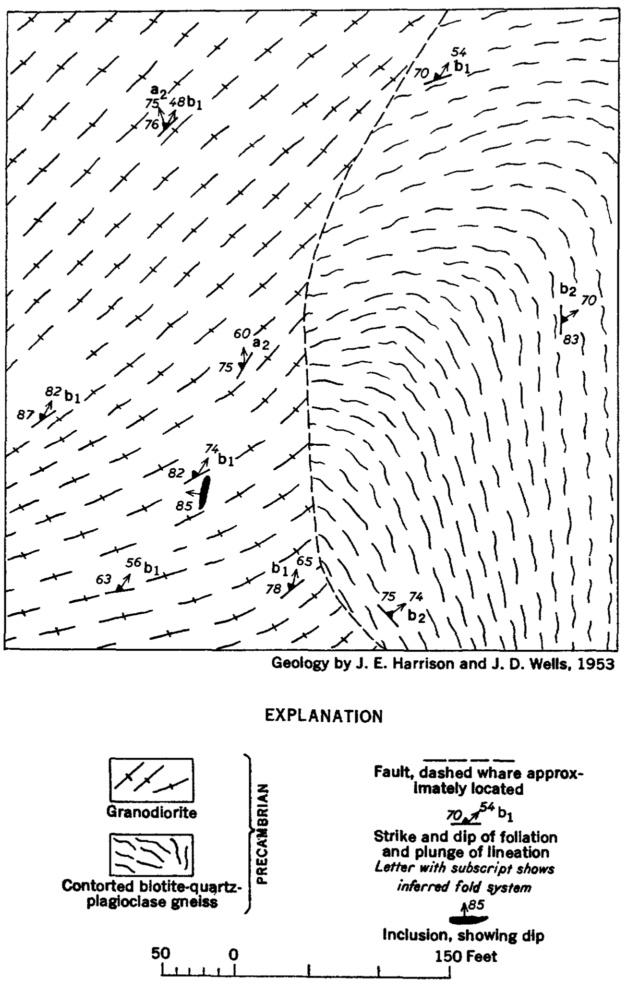

FIGURE 4.—Sketch of part of the contact area between grandiorite and biotite-quartz-plagioclase gneiss.

were both mapped as biotite-muscovite granite because of the intimate association and gradation of one into the other.

The leucocratic granodiorite dikes are believed to be genetically related to the granodiorite because of composition, age, and occurrence. The leucocratic granodiorite dikes have the composition of a granodiorite (table 7) instead of a granite, as the other granitic dikes in the area. The leucocratic granodiorite dikes are cut by biotite-muscovite granite dikes. In outcrop the thin leucocratic dikes occur as a series of intersecting dikes; this dike pattern and dike type have been recognized only in the granodiorite. These dikes, which have little or no internal structure, commonly have contacts that are jagged and offset in the plane of the foliation of the granodiorite where the dikes strike across the foliation. The dikes, therefore, are prefoliation in age. The ages of the leucocratic granodiorite dikes and the granodiorite are probably nearly the same.

PETROGRAPHY

The granodiorite is a gray, mottled black and white, medium- to coarse-grained, seriate porphyritic rock consisting essentially of quartz, oligoclase to calcic andesine, biotite, and microcline; hornblende occurs in some specimens. Accessory minerals are sphene, magnetite, apatite, epidote, zircon, and allanite; less commonly, muscovite, pyrite, hematite, and calcite are present.

The granodiorite has a hypidiomorphic granular texture; in sections that show breaking and recementing (mortar textures), the texture along the broken zones is allotriomorphic. Myrmekitic texture is common. Plagioclase is more or less altered and forms euhedral to subhedral crystals and crystal aggregates from 1 to 3 millimeters long. Some grains have well-developed pericline and albite twinning; the pericline and albite twins may occur separately or in combination. The plagioclase crystals contain grains of biotite, quartz, and microcline. Where abundant, microcline is generally in euhedral to subhedral crystals as much as 10 millimeters long; where sparse, it occurs as small, 1- to 2-millimeter, anhedral grains scattered through the rock. Some grains do not show twinning and may be orthoclase. The microcline has varying amounts of vein and patch perthite. Biotite occurs as well-alined to poorly alined subhedral laths from 1 to 2 millimeters long that are grouped together to form aggregates or discontinuous layers. Sparse hornblende occurs in nonfoliated parts of the rock as subhedral to anhedral grains from 0.5 to 1 millimeter long. The hornblende contains small rounded quartz grains and commonly is cut by biotite laths. Sphene, magnetite, apatite, epidote, and allanite generally occur as small euhedral to anhedral grains associated with the mafic silicate minerals.

The rock ranges in composition from quartz diorite to quartz monzonite; most of the rock in the mapped area is granodiorite. The mineralogic variations of this unit are shown by modes (volume percent) on table 7 and by the triangular diagram (fig. 5).

Samples represented by the group of points near the center of the triangular diagram have mineralogic, structural, time, and geographic similarities to each other and to samples from the quartz diorite. Two of the samples, 2–7b–34 and 2–7b–41b, are from the small hook-shaped body; 3 samples, 2–7x–17, 2–7x–20, and 2–11–91b, are from the northeast part of the large body (pl. 1). Between the main body and the hook-shaped body is a quartz diorite body that was intruded after the granodiorite. These bodies are nearly on, or on line with, a major (b_1) synclinal axis. As discussed in the section on quartz diorite, parts of the

TABLE 7.—*Modes (volume percent) of granodiorite and associated leucocratic granodiorite*

Mineral	Mode (volume percent) of specimen—																							
	1-3-82a	1-4-80	1-4-103	1-7b-8c	1-7b-11c	2-7b-34	2-7b-41b	2-7x-11a	2-7x-17	2-7x-20	2-8-9	2-8-14a	2-8-15a	2-8-84	2-11-43	2-11-65	2-11-91a	2-12-1a	2-12-21	DX-3	D-WCC	1-3-82b	2-8-58a	2-8-58c
Microcline	3	4	2	1.2	0.4	18	12	4	18	15	7	4	0.3	19	1.0	1.7	24	0.3	3	1.6	5	9	16	24
Plagioclase	45	37	30	53	44	23	31	41	36	36	42	36	38	30	40	36	25	37	40	41	41	42	59	45
Quartz	28	37	39	28	30	37	31	31	33	33	30	26	38	40	35	35	34	40	35	31	28	47	24	28
Biotite	20	18	22	15	22	17	19	20	11	13	14	27	20	11	20	25	15	14	18	20	17	2	.8	3
Muscovite	--	--	--	--	--	--	--	--	--	--	--	--	1.0	--	--	--	--	--	--	--	--	--	--	--
Hornblende	--	--	Tr.	--	--	--	--	--	--	--	.7	--	--	--	--	--	--	Tr.	--	.5	3	--	--	--
Magnetite	1	2	2	2	3	1.5	2	1.3	1.0	1.3	1.5	3	1.3	.5	1.6	.6	.9	3	1.4	3	3	Tr.	Tr.	Tr.
Sphene	2	1.6	2	Tr.	Tr.	2	4	1.4	Tr.	1.5	3	3	--	--	2	1.4	Tr.	3	1.4	1.6	1.7	--	Tr.	Tr.
Apatite	1	.6	.8	.6	.6	1.0	.9	.3	.3	.5	.8	.6	1.2	Tr.	Tr.	.4	.4	1.3	.6	.5	.9	Tr.	.6	--
Epidote	Tr.	.4	1.0	Tr.	--	--	Tr.	.6	.3	Tr.	1.5	Tr.	--	Tr.	.7	Tr.	Tr.	.7	.8	--	Tr.	--	--	Tr.
Zircon	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	--	--
Allanite	Tr.	--	--	Tr.	--	--	--	--	Tr.	--	--	--	--	--	--	--	--	1.0	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Tr.

1-3-82a. Weakly foliated granodiorite from near Ute Creek on slope south of Lamartine.
1 4-80. Weakly foliated granodiorite from southwest corner of mapped area.
1-4-103. Weakly foliated granodiorite from Maximillian Gulch.
1-7b-8c. Well-foliated granodiorite from northwest corner of mapped area.
1-7b-11c. Weakly foliated granodiorite from along Ute Creek at the west edge of the area.
2-7b-34. Well-foliated and granulated granodiorite from south edge of small hook-shaped body on south slope of Alps Mountain.
2-7b-41b. Well-foliated and granulated granodiorite from western part of small hook-shaped body on south slope of Alps Mountain.
2-7x-11a. Well-foliated granodiorite from near biotite-muscovite granite contact on west slope of Maximillian Gulch.
2-7x-17. Weakly foliated granodiorite from a knob at an altitude of 10,100 feet on the ridge separating Ute Creek and Maximillian Gulch.
2-7x-20. Weakly foliated granodiorite from prominent knob near stream level in Maximillian Gulch.
2-8-9. Weakly foliated granodiorite from road level along lower Ute Creek.
2-8-14a. Weakly foliated granodiorite from road level 100 feet west of contact on lower Ute Creek.
2-8-15a. Nearly massive granodiorite from contact at road level on lower Ute Creek.
2-8-84. Massive, granulated, bleached granodiorite from dike on slope east of lower Ute Creek.
2-11-43. Nearly massive granodiorite from southwest-trending ridge south-southeast of Lamartine.
2-11-65. Weakly foliated granodiorite near contact with biotite-quartz-plagioclase gneiss on crest of south-trending ridge southeast of Lamartine.
2-11-91a. Well-foliated, coarsely porphyritic granodiorite from slope northeast of Ute Creek.
2-12-1a. Massive dark granodiorite from road level along Ute Creek.
2-12-21. Weakly foliated granodiorite from road level along lower Ute Creek.
DX-3. Nearly massive granodiorite from the M and M crosscut tunnel.
D-WCC. Massive granite with dark pods from a mine dump outside the mapped area at the mouth of West Chicago Creek.
1-3-82b. Leucocratic granodiorite from 8-inch dike in granodiorite 100 feet east of the Argosy shaft.
2-8-58a. Leucocratic granodiorite from 2-inch dike with jagged contact in granodiorite in gulch northeast of the Silver Link shaft.
2-8-58c. Leucocratic granodiorite from ½-inch dike with smooth contact in granodiorite in gulch northeast of the Silver Link shaft.

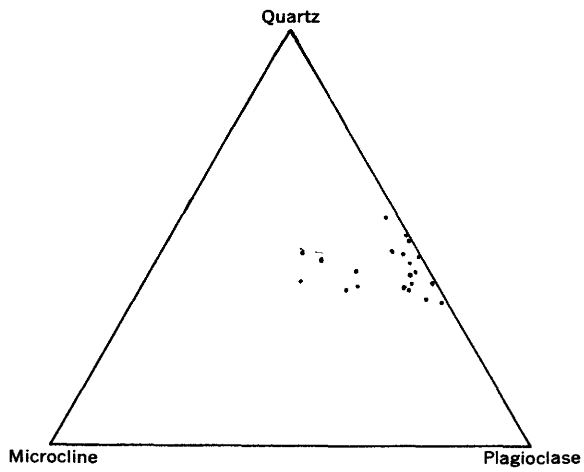

FIGURE 5.—Triangular diagram showing variations in composition (volume percent) of the granodiorite.

quartz diorite have been retrograde metamorphosed to a more alkalic rock by recrystallization and metasomatism. The samples near the center of the triangular diagram represent more alkalic parts of the granodiorite, similar to the quartz diorite. Sample 2–8–84 is from an area where the wall rocks are strongly deformed, possibly on a minor fold axis.

ORIGIN

The writers believe that the granodiorite represents a magma intruded during the first period of Precambrian deformation and that the leucocratic granodiorite dikes represent a late magmatic phase that was intruded into joints. The small lenticular inclusions oriented parallel to the contact probably represent primary flow structure formed during the intrusion. Identifiable wall rock inclusions are contorted about as much as the wall rock, indicating that some regional deformation occurred before implacement of the magma. The foliation and lineation in the granodiorite appears to have been formed by the regional stresses of the first Precambrian deformation that deformed the country rock, because the structures are essentially the same in the granodiorite as in the country rock. Partial recrystallization and alkali metasomatism may have occurred in the axial areas of folds in the granodiorite in a manner similar to the retrograde metamorphism of the quartz diorite. Cataclastic textures and lineations probably were formed during the second period of Precambrian deformation.

QUARTZ DIORITE AND ASSOCIATED HORNBLENDITE

Quartz diorite and associated hornblendite form plugs(?) as much as 800 feet in diameter and short, conformable and disconformable dikes that range in width from 6 inches to 50 feet. The rock is well exposed on the northwest side of Chicago Creek, near the eastern edge of the mapped area, and on the ridge between Maximillian Gulch and Eclipse Gulch (pl. 1).

Although some of the quartz diorite and associated hornblendite rock unit is massive, most of it has a foliation developed by a faint to prominent mineral layering and a lineation shown by alinement of hornblende and biotite crystals. The layering is conformable with the foliation in the adjacent Precambrian rocks both where the gross outline of the body is concordant and where it is discordant. Lineations in the plane of the layering in the quartz diorite are parallel to lineations in the foliation planes of adjacent Precambrian gneisses.

Certain foliated varieties of the quartz diorite and associated hornblendite resemble the amphibolite and others resemble the granodiorite. Parts of the varieties that resemble amphibolite cannot be distinguished megascopically from true amphibolite but can be distinguished in thin section primarily on the basis of the type and amount of twinning in the plagioclase feldspar (Harrison and Wells, 1956); facies resembling the granodiorite can be recognized by an abundance of hornblende, which is sparse in the granodiorite.

Age relations indicate that quartz diorite and associated hornblendite are younger than the metasedimentary rocks, granodiorite, and some of the granite gneiss and pegmatite and are older than some of the granite gneiss and pegmatite, and biotite-muscovite granite. Both quartz diorite and hornblendite occur separately as dikes that at places cut across metasedimentary rocks, granite gneiss and pegmatite, and granodiorite. Large pluglike bodies of quartz diorite commonly contain patches of hornblendite as minor parts of the plugs; no large pluglike bodies of hornblendite have been observed. The metamorphosed quartz diorite and hornblendite are cut by dikes of pegmatite related to granite gneiss and pegmatite and by dikes of biotite-muscovite granite and its related pegmatite.

The massive quartz diorite is a black to mottled black and white, fine- to coarse-grained, hypidiomorphic granular rock consisting principally of hornblende, complexly twinned andesine-labradorite, and quartz. Some of the rock contains enough biotite to be called a tonalite; and some contains so little quartz that it is a diorite. The common accessory minerals are apatite, magnetite, and sphene. The massive variety contains only traces or no microcline (table 8).

The foliated quartz diorite is gneissic, owing to segregation of the minerals into mafic-rich and quartz-feldspar-rich layers. This variety contains microcline

TABLE 8.—*Modes (volume percent) of quartz diorite and associated hornblendite*

Mineral	Mode (volume percent) of specimen—										
	1-3-24	2-3a-10	2-3a-38a	2-3a-43	2-7b-26a	2-7b-26b	2-7b-50	2-7b-66	2-7b-67	2-7x-22	2-8-70
Hornblende	47	85	89	50	43	73	31	31	26	33	51
Biotite	6			43	8	4	13	10	9	7	2
Plagioclase	41		6		24	9	32	33	38	34	37
Quartz	4				9	12	10	9	6	4	6
Epidote		12					Tr.	Tr.	Tr.	Tr.	Tr.
Apatite	.4	1.0	4	4	.9	1.3	.7	1.1	1.0	1.1	.7
Sphene	Tr.	2	1	3	.5	.6	.7	2	1.3	.5	Tr.
Magnetite	1.0	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	3
Microcline	.3				15		12	14	18	20	Tr.
Allanite									.5	Tr.	
Actinolite	.4										
Chlorite											Tr.
Zircon	Tr.										

1-3-24. Poorly layered quartz diorite from 20-foot dike about 200 feet south of Lamartine.
2-3a-10. Hornblendite from 10-foot dike crosscutting granite gneiss and pegmatite on knob about 1,000 feet east of the eastern peak of Alps Mountain.
2-3a-38a. Hornblendite from 5-foot dike crossing road about 750 feet east of the eastern peak of Alps Mountain.
2-3a-43. Well-foliated hornblendite from dragged layer along road on crest of ridge east of King Solomon Gulch.
2-7b-26a and 26b. Well-foliated quartz diorite (26a) and hornblendite (26b) from outcrop near prominent fork in Eclipse Gulch.
2-7b-50. Well-foliated quartz diorite from outcrop on west slope of Eclipse Gulch.
2-7b-66 and 67. Well-foliated quartz diorite from outcrops in Eclipse Gulch.
2-7x-22. Well-foliated quartz diorite from body on ridge between Maximillian Gulch and Eclipse Gulch.
2-8-70. Fine-grained and massive quartz diorite from small body on slope north of road along lower Ute Creek.

as a principal mineral constituent, as well as hornblende, plagioclase, quartz, and biotite. The plagioclase is oligoclase-andesine and is, on the whole, less complexly twinned than that in the massive facies. Epidote is an accessory mineral common in the foliated facies but not in the massive facies.

The massive hornblendite is a black to greenish-black, fine- to medium-grained, hypidiomorphic granular rock composed predominantly of hornblende, with minor amounts of quartz, plagioclase, and biotite. The common accessory minerals are apatite, sphene, and magnetite.

The foliated hornblendite is gneissic, owing to discontinuous layers of light-colored minerals or biotite-rich layers. The rock is composed essentially of hornblende and biotite and minor amounts of quartz and simply twinned plagioclase. Accessory minerals are those of the massive facies plus epidote. Microcline was not seen in the thin sections of this rock.

Textures of the massive quartz diorite and hornblende and of the dark layers of the foliated varieties of each are hypidiomorphic granular. Textures of the light layers in the foliated varieties are allotriomorphic granular, irregular, and poikilitic.

ORIGIN

The writers have concluded that the foliated varieties of quartz diorite and associated hornblendite have been metamorphosed. The parallelism between foliation and lineation within these rocks and within enclosing rocks, even where the contacts are discordant, and the textural change between massive and foliated varieties of these rocks support this conclusion.

Certain mineralogic changes accompanied metamorphism of the quartz diorite, and other mineralogic changes accompanied metamorphism of the hornblendite. These changes are indicated on figure 6, where samples from the Chicago Creek area and the adjacent Freeland-Lamartine district (Harrison and Wells, 1956) have been plotted from left to right in the order of increasing hornblende content. This diagram shows samples of the massive and foliated varieties of quartz diorite and associated hornblendite, and samples are included from concordant and discordant dikelike masses as well as from pluglike bodies. This diagram, when considered in conjunction with the perfectness of foliation, is believed to illustrate the following points concerning the nature of the original intrusives and the mineralogic changes accompanying metamorphism of those rocks.

1. The original quartz diorite is defined by massive texture, essentially no microcline, plagioclase in amounts of 25–50 percent, plagioclase of composition ranging from An_{38} to An_{54}, and complex twinning of the plagioclase. It is represented by specimens I–16b, 1–3–24, 2–8–70, 2–6b–52, 2–5–49b, and 2–5–41a. These specimens suggest that the intrusive quartz diorite had a broad range in composition.

2. The metamorphosed quartz diorite is foliated and contains from 10 to 20 percent microcline, plagioclase ranging in composition from An_{23} to An_{32}, and complexly twinned plagioclase. This rock is represented by specimens 2–7b–67, 2–7b–50, 2–7b–66, 2–7x–22, and 2–7b–26a. In general, this rock contains less hornblende and about the same quantity of quartz, biotite, and plagioclase as the intrusive quartz diorite from the same geographic area. These mineralogic changes suggest that some metasomatism accompanied a retrograde metamorphism of the igneous rock. The plagioclase has been reduced in calcium content and now is oligoclase-andesine, the same as the plagioclase of the metasedimentary rocks. The potash content of the

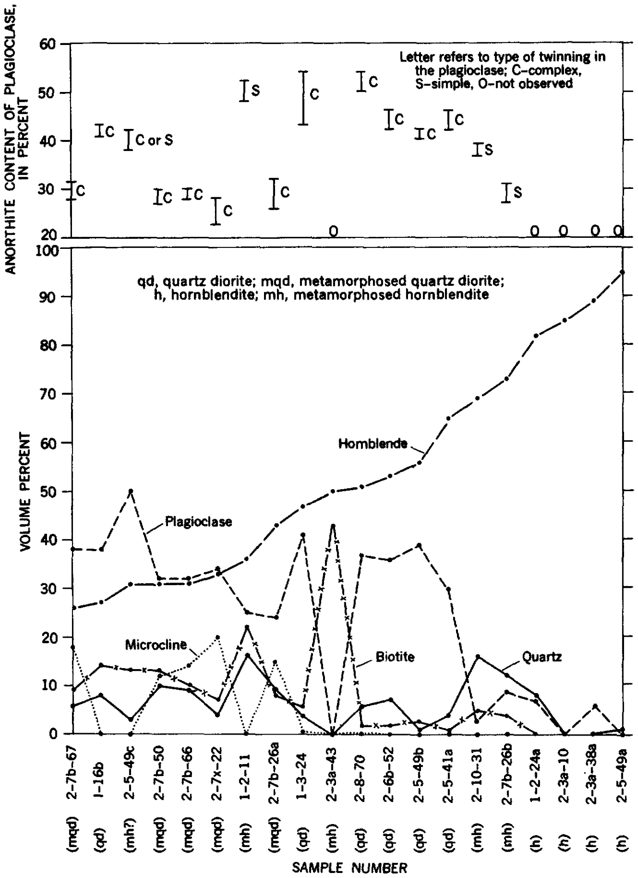

FIGURE 6.—Variation diagram showing mineral content and type of plagioclase in samples of quartz diorite and associated hornblendite.

metamorphosed rock appears to be greater, and the iron—and magnesium(?)—content appears to be less than that of the original intrusive quartz diorite.

3. The original hornblendite is massive and contains, in addition to dominant hornblende, a small amount of plagioclase, inferred to be labradorite, that was complexly twinned, and some quartz. It is represented by specimens 1–2–24a, 2–3a–10, 2–3a–38a, and 2–5–49a, which represent a fairly broad range of original composition.

4. The metamorphosed hornblendite is foliated, and it contains simply twinned or untwinned plagioclase of composition ranging from An_{28} to An_{54}, from 5 to 40 percent biotite, and less hornblende than the massive hornblendite. The amount of biotite in the foliated hornblendite varies directly with an increase in the perfection of the gneissic structure and varies inversely with the hornblende content. The metamorphosed hornblendite is represented by specimens 1–2–11, 2–3a–43, 2–10–31, 2–5–49c(?), and 2–7b–26b. The mineralogic changes shown by these rocks are similar, in part, to those shown by the metamorphosed quartz diorite. An increase in potash is indicated in these rocks by an increase in biotite instead of an increase of microcline as in the metamorphosed quartz diorites. Biotite as the potassic phase may represent the stable mineral in an iron-rich environment as opposed to microcline and biotite as the potassic phases in a less iron-rich environment. The plagioclase tends to have simple twins, but the anorthite content in all samples has not been reduced to oligoclase-andesine. This is possibly a reflection of disequilibrium in the metamorphosed hornblendites, and the lack of such evidences in the metamorphosed quartz diorites may indicate either that the intrusive quartz diorite contained a mineral assemblage that was more easily or quickly brought to the regional metamorphic grade or that the hornblendite was more difficult to metamorphose because of its nearly monomineralic composition or its resistance to shear.

In summary, the quartz diorite and associated hornblendite were intruded as plugs, sills, and dikes. Originally these rocks contained a very poorly developed flow structure or were massive. Subsequent to their intrusion, some of these rocks were metamorphosed. The prominent layering now present in the rocks resulted from recrystallization and some metasomatism—a retrogression of the rocks toward regional grade of metamorphism. The metamorphosed quartz diorite appears to have approached the regional grade of metamorphism more quickly than the metamorphosed hornblendite, possibly because it was texturally or chemically more adapted to a rapid rate of approach to equilibrium.

BIOTITE-MUSCOVITE GRANITE

The youngest major Precambrian rock unit in the Chicago Creek area is relatively undeformed biotite-muscovite granite. It occupies about 10 percent of the mapped area (pl. 1) and is well exposed on Alps Mountain and in Maximillian Gulch near Chicago Creek. Excellent exposures of dikes of this granite can be seen underground in the Dixie (pl. 4) and Beaver (pl. 3) mines. The biotite-muscovite granite is similar in fabric, mineralogy, and color to Silver Plume granite from the type area at Silver Plume, Colo. (Ball, 1906).

Some of the bodies of biotite-muscovite granite in the mapped area are concordant and others are discordant. The concordant bodies form phacoliths or sheets that are subparallel to foliation in the host rocks along parts of their extent. (See pl. 1.) The discordant bodies form stocks, irregular masses, and dikes cutting all Precambrian rocks except certain pegmatites (pl. 1). Most of the larger bodies of this rock contain granite pegmatite dikes, commonly about 1 foot wide, along joints in the granite.

Contacts between biotite-muscovite granite and other Precambrian rock units are generally sharp, but many have a few inches to a few feet of pegmatite along them.

The granite varies from a nearly massive to a well-foliated, fine- to medium-grained rock. Foliation in the fine-grained facies results from alinement of biotite flakes, and foliation in the medium-grained facies results from nearly parallel arrangements of tabular microcline crystals and some of the biotite laths. The foliation is subparallel to the contacts of the granite bodies, which at places are irregular and discordant. A lineation is defined in some parts of the well-foliated fine-grained facies by alinement of biotite crystals in streaks along the foliation planes.

Subparallel fractures that commonly are spaced as close as 3 millimeters are prominent at many exposures of the biotite-muscovite granite. In some outcrops these fractures are not visible or only faintly visible megascopically, but they are prominent in thin section. These fractures have been referred to as incipient fractures (Harrison and Wells, 1956). At localities where the incipient fractures are best developed, the surfaces of the fractures have slickensides marked by ¼- to 1-inch-wide streaks of biotite, muscovite and, less commonly, chlorite; figure 7 is a plot showing the general bearing and plunge of these slickenside lineations. The structural significance of these lineations will be discussed in a later section of this report. The incipient fractures parallel the foliation in some outcrops and cut across it in others. At outcrops where the incipient fractures are visible, individual crystals and planes of crystals are disrupted, with the result that the foliation imparted by microcline and (or) biotite alinement is at places nearly or completely destroyed.

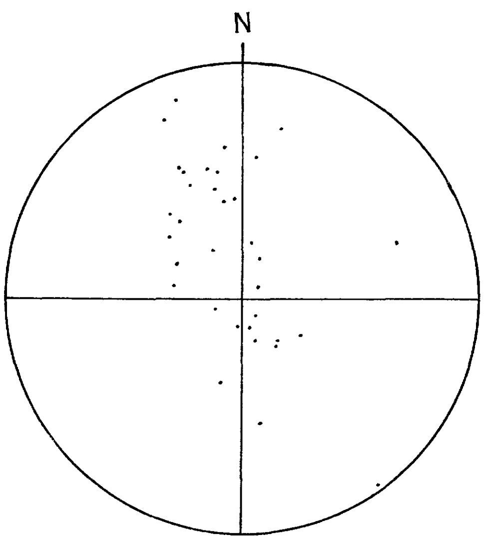

FIGURE 7.—Lower hemisphere Schmidt net plot of slickenside lineations on incipient fracture surfaces in the biotite-muscovite granite.

In the Chicago Creek area, the fresh biotite-muscovite granite is a gray to mottled gray and pink, fine- to medium-grained rock that has a seriate porphyritic texture; weathered outcrops are buff to reddish brown. At places a fine-grained equigranular facies forms dikes or small, irregular bodies within the seriate porphyritic facies. Certain dikelike masses of this rock contain vaguely defined patches of leucogranite or pegmatite or grade into pegmatite along their strike. A dark-gray fine-grained variety of biotite-muscovite granite is peculiar to dikes that crosscut granodiorite and quartz diorite. All the varieties are composed principally of microcline, oligoclase, and quartz; biotite and muscovite are minor constituents, and magnetite, monazite, apatite, and zircon are common accessory minerals (table 9). The ratio of the principal mineral constituents in all facies of the granite is remarkably consistent, as is indicated by figure 8, which shows modes of all facies of the granite ranging from that in dikes as small as 4 inches wide to that in stocks as large as three-fourths of a mile in diameter.

In thin section the undeformed granite is shown to be hypidiomorphic granular and seriate porphyritic. Fresh microcline in anhedral to subhedral laths commonly forms crystals 6 millimeters long; altered plagioclase and quartz form crystals from 1 to 3 millimeters in diameter; and quartz, plagioclase, and biotite at places intergrown with muscovite occur in the fine-grained groundmass. Opaque hair-

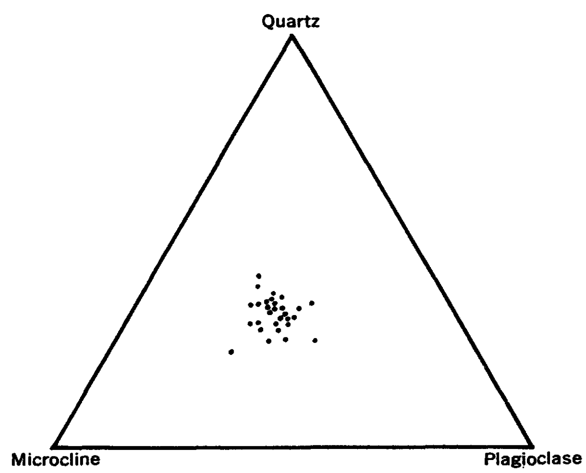

FIGURE 8.—Triangular diagram showing variations in composition (volume percent) of the biotite-muscovite granite.

TABLE 9.—*Modes (volume percent) of biotite-muscovite granite*

Mineral	Mode (volume percent) of specimen—									
	1-3-64b	1-3-70	1-7b-8a	2-3b-3	2-3b-9	2-3b-14	2-3b-32	2-3b-49a	2-3b-49b	2-3b-58
Microcline	35	30	33	31	32	31	34	34	41	24
Oligoclase	26	39	29	18	28	31	28	26	31	33
Quartz	35	24	29	34	30	28	33	30	26	30
Biotite	3	4	6	6	4	4	2	5	Tr.	6
Muscovite	.9	1.6	1.0	10	5	4	2	3	1.3	6
Magnetite	Tr.	1.3	1.9	.6	.8	1.5	.9	.3		.4
Monazite		Tr.		.4	.7	.5		1.9		.8
Apatite	Tr.				Tr.	Tr.		Tr.		Tr.
Zircon	Tr.									Tr.
Sphene										Tr.
Chlorite								Tr.		
Allanite		Tr.								

Mineral	Mode (volume percent) of specimen—									
	2-7a-42	2-7a-48	2-7a-50	2-7a-52	2-7a-54	2-7b-17	2-7b-36	2-7b-53	2-7b-87	2-7x-11b
Microcline	27	34	30	37	35	31	33	34	37	39
Oligoclase	30	26	26	25	32	25	20	29	24	24
Quartz	28	29	32	27	24	33	35	28	31	32
Biotite	6	4	6	4	3	5	5	3	3	2
Muscovite	7	6	5	6	5	5	7	6	2	2
Magnetite	.5	.4	.9	Tr.	1.0	.6	Tr.	Tr.	1.3	.4
Monazite	1.2	.5	.3	.8	.4	Tr.		Tr.	.7	.4
Apatite	Tr.	.4	Tr.	.3	Tr.					Tr.
Zircon							Tr.			
Sphene										
Chlorite				Tr.						
Allanite									.6	

Mineral	Mode (volume percent) of specimen—									Average
	2-8-14b	2-8-58b	2-11-42	2-12-1b	2-12-32	2-12-39	Dx-5	JDW-1	JDW-2	
Microcline	37	35	41	46	34	37	35	38	35	34.4
Oligoclase	32	32	28	23	35	28	27	24	29	27.8
Quartz	27	31	28	21	30	35	34	27	27	29.6
Biotite	1.8	2	1.3	4		Tr.	1.7	4	4	3.4
Muscovite	1.8		1.1	5	1.5	.4	1.5	5	4	3.2
Magnetite	.6	Tr.	Tr.	.3	Tr.	Tr.	.6	1.1	.9	.6
Monazite	Tr.			.3	Tr.	Tr.	.5	Tr.	Tr.	.4
Apatite	.4	Tr.		Tr.	Tr.	Tr.	Tr.	Tr.		Tr.
Zircon		Tr.		Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Sphene							Tr.			
Chlorite										
Allanite		Tr.		Tr.						

1-3-64b. Foliated granite from 2-foot dike in granodiorite on slope north of Ute Creek near west edge of area.
1-3-70. Foliated, fine-grained gray granite on slope north of Ute Creek near west edge of area.
1-7b-8a. Foliated, fine-grained granite from 5-foot dike in granodiorite outcrop on slope north of Ute Creek at west edge of area.
2-3b-3, -9, -14, -49a, -58.; 2-7a-42, -48, -50, -52, -54.; 2-7b-36, -53. } Systematic samples of Alps Mountain stock; sample interval about 500 feet; 1 east-west traverse and 2 north-south traverses.
2-3b-32. Fine-grained buff granite from 6-foot dike in metasedimentary rocks on east shoulder of Alps Mountain. Sample located about 500 feet along dike from its junction with the Alps Mountain stock.
2-3b-49b. Alaskitic, dikelike mass in biotite-muscovite granite near contact with metasedimentary rocks on south slope of Alps Mountain.
2-7b-17. Sheared granite from 60-foot dike in Eclipse Gulch.
2-7b-87. Cataclastically deformed, well-foliated granite from slope west of Eclipse Gulch.
2-7x-11b. Cataclastically deformed granite from dike in granodiorite on slope west of Maximillian Gulch.
2-8-14b. Granite from 18-inch dike in granodiorite near contact between granodiorite and metasedimentary rocks along lower Ute Creek road.
2-8-58b. Granite from 12-inch dike in granodiorite crosscutting granodiorite and associated aplitic dikes at outcrop in gulch on slope north of lower Ute Creek.
2-11-42. Alaskitic granite from 50-foot dike on southwest-trending ridge south-southeast of Lamartine.
2-12-1b. Well-foliated, unsheared granite from 4-inch dike in granodiorite along Ute Creek road.
2-12-32. Alaskitic granite from crest of ridge north of loop in Ute Creek road.
2-12-39. Highly sheared granite from outcrop 400 feet north of source of specimen 2-12-32.
Dx-5. Fresh granite from 20-foot dike in granodiorite in Dixie mine.
JDW-1. Fine-grained, well-foliated granite from 20-foot dike in granodiorite along lower Ute Creek road.
JDW-2. Fine-grained, well-foliated granite from 300-foot dike in granodiorite on crest of ridge south of lower Ute Creek near south edge of area.

like inclusions (rutile?) are abundant in most of the larger quartz crystals and in some of the feldspar crystals. Albitic borders occur on some of the oligoclase grains, and myrmekite is common at the edges of plagioclase crystals where they contact microcline. Some of the muscovite is in poikilitic plates grading into sericitic shreds on altered plagioclase grains. Quartz and altered plagioclase are the rounded blebs enclosed poikilitically in the muscovite.

The deformed granite is allotriomorphic to hypidiomorphic granular and contains a weakly to strongly developed mortar structure. The distribution of the mineral grains is similar to that of the undeformed granite except in the cataclastically deformed areas. The mortar structures contain fine broken fragments of quartz and feldspar and larger crystals of biotite intergrown with muscovite. In general, the deformed granite contains more muscovite than the undeformed granite.

The granite and its associated dikes have a high radioactivity. George Phair, of the Geological Survey, has done mineral separations on samples of the granite and one pegmatite. He reports (oral communication, 1953) that the radioactivity of the granite is associated with monazite and the radioactivity of the one pegmatite, possibly related to the granite, was associated with tiny cubes of uraninite.

ORIGIN

The biotite-muscovite granite is of probable magmatic origin, as suggested by (1) the planes of crystals that parallel irregular contacts which crosscut older foliated rocks, and (2) the dike patterns, such as those developed in the quartz diorite bodies on the ridge between Maximillian Gulch and Eclipse Gulch.

The writers have tentatively concluded that the granite was emplaced by relatively passive processes that included some stoping but no assimilation in the parts of the bodies now exposed. The Alps Mountain stock is in part phacolithic on the fold system trending north-northeast and in part cuts across these folds. Rocks adjacent to the stock do not appear to be deformed around it. The pattern of close spaced intersecting dikes and isolated blocks of host rock seen in the larger bodies of quartz diorite and granodiorite is suggestive of stoping. The granite is, however, relatively uncontaminated, and the few inclusions are angular, unchanged, and have sharp contacts. The quartz-feldspar ratio in all phases of the granite, including the peculiar dark phase found adjacent to quartz diorite or granodiorite, is remarkably consistent.

Relation of the granite to two recognizable fold systems is relatively clear cut. The granite is phacolithic and crosscutting in its relations to the oldest fold system, and it is cataclastically deformed by fractures whose surfaces show lineations of the younger fold system. These data are interpreted as indicating that the granite was emplaced late in the period of older folding and was cataclastically deformed at a later time.

GRANITE PEGMATITE

The rocks shown on the geologic map (pl. 1) as granite pegmatite are probably not all of the same age. Part of these dikes are related to biotite-muscovite granite; certain of the bodies could not be identified as to source.

Pegmatites included in this map unit that are associated with biotite-muscovite granite commonly occur in dikes that contain vaguely defined patches of typical biotite-muscovite granite. These dikes may have also parts, tens of feet long and dike width, that are typical biotite-muscovite granite. These parts grade along the dike into pink granite pegmatite composed principally of perthitic microcline, albite, and quartz in about equal amounts; minor amounts of coarse book biotite and (or) small grains of magnetite are locally present in the pegmatite.

The pegmatites included in this map unit that could not be identified as to source contain only quartz, plagioclase, and microcline. This mineral composition is characteristic of some of the pegmatites associated with, and having age relations similar to, biotite-muscovite granite, granodiorite, and granite gneiss and pegmatite.

TERTIARY INTRUSIVE ROCKS

Eight kinds of Tertiary intrusive rocks have been recognized in the Chicago Creek area. Mentioned in the inferred order of intrusion they are quartz monzonite, alaskite, granite, monzonite, bostonite, quartz bostonite, trachytic granite, and biotite-quartz latite. These rocks have been intruded into the Precambrian rocks in the form of dikes and small plugs in all but the southwest corner of the area (pl. 1). The dikes range in length from a few hundred feet to about 1½ miles; they range in width from a few feet to a few tens of feet, most being about 15 feet.

The intrusive rocks are early Tertiary in age (Lovering and Goddard, 1950, p. 47) and all except the biotite-quartz latite were intruded prior to the vein formation. The age of veins in the Central City district, about 5 miles northeast of the Chicago Creek area, has been indicated by lead-uranium determinations to be about 60 million years, or early Tertiary (Holmes, 1946; Phair, 1952).

Sequence of intrusion of the dike types cannot be demonstrated in the Chicago Creek area, although some age relations are known. The order as listed above is based on information taken from the Chicago Creek area, Lovering and Goddard (1950, p. 44–47), and Phair (1952, p. 20–22).

Most of the dikes strike northeast; others strike northwest or nearly north. Generally the dikes dip from 65° to 80° NW., but one north-striking dike dips 33° E. The foliation and axial planes of folds in the metamorphic rocks are the dominant controls of strike and dip of the dikes. Some dikes follow preexisting dikes, joints, and possible faults. The Precambrian granodiorite appears to have been unfavorable for Tertiary dike intrusion, for the dikes penetrate only the margin of the body.

Outcrops along the dikes are widely spaced and poorly expose the rock. The outcrop shows well-jointed usually altered dikes, commonly with a few inches of chilled margin. The alteration, probably deuteric, has removed the ferromagnesian minerals and changed the feldspars partly or completely to clay.

The intrusive rocks are highly radioactive and the range in the amounts of radioactivity is more or less characteristic of the dike type. The range of radioactivity is given for each type in table 10.

The Tertiary intrusive rocks of the general area covered by this report have been studied by Spurr, Garrey, and Ball (1908, p. 67–83), Lovering and Goddard (1938, p. 35–68; 1950, p. 43–50), and Phair (1952). In the early work the rocks were classified on megascopic and microscopic characteristics, and the mapping, which was on a scale of 1:62,500, was necessarily generalized. Lovering and Goddard supplemented Ball's work with additional petrographic work and a few chemical analyses, but they made no essential changes in the rock classification. Phair's work supplements the previous work with some petrography and chemical analyses of selected fresh specimens that were collected only from dikes and plugs shown on 1:62,500 scale maps.

The writers feel that rock units described should be mappable units that can be distinguished and correlated by simple methods. For that reason the rocks are described in terms of megascopic, microscopic, and simple chemical characteristics. The sodium cobaltinitrite stain for potassium (Gabriel and Cox, 1929) and the malachite green stain for feldspar (Russell, 1935) were used together in one operation to distinguish potash from lime-soda feldspars, particularly in the groundmass.

In this report the scale of mapping is such that the details of geographic distribution of the dikes can be shown. Because of this detail, more dikes have been mapped than were previously known and every dike had to be classified no matter how well exposed, how highly altered, or how typical of any rock type.

CLASSIFICATION

Classification and correlation of the Tertiary intrusive rocks have been made more on the basis of qualitative mineralogy and textural characteristics than on quantitative mineralogic composition. The diagnostic range in radioactivity is used as an aid in the classification of some dikes. Petrographic characteristics commonly used to distinguish the rock types are (1) groundmass texture, (2) qualitative mineralogy, (3) approximate quantitative mineralogy, (4) color, (5) character of the phenocrysts, and (6) character of the fracture.

Two general classes of rock types are recognized on the basis of groundmass texture—trachytic and granular groundmass rocks. The trachytic rocks include quartz bostonite, bostonite, and trachytic granite porphyries. The granular groundmass rocks include quartz monzonite, monzonite, alaskite, granite, and biotite-quartz latite porphyries. Hand-specimen color, although not reliable because of variations caused by alteration, is more or less characteristic of the two groups of rocks. The trachytic rocks are shades of pink and red and the granular rocks are shades of gray. One notable exception is pink-colored quartz monzonite, which may be distinguished from the trachytic rocks by a "glassy-appearing" groundmass that tends to have a smooth flaky fracture observable with a hand lens.

Among the trachytic group of rocks the bostonites are distinguished from the trachytic granite porphyry because the bostonites have bostonitic texture—interlocking subhedral to anhedral alkali feldspar laths in the groundmass—and the trachytic granite has stubby, euhedral, noninterlocking plagioclase laths. Megascopically, the coarse-grained trachytic granite porphyry is easily recognized by the large rounded white feldspar grains, but the finer grained phase cannot be distinguished from the bostonites with certainty without a microscope.

The two bostonites are distinguished by the presence of polysynthetically twinned plagioclase phenocrysts in the bostonite and by quartz existing in quantities greater than 5 percent in the quartz bostonite. The quartz grains have characteristic poikilitic inclusions of feldspar in the groundmass. Megascopically, the quartz bostonite has pink feldspar and the bostonite white feldspar phenocrysts.

Of the Tertiary intrusive rocks with granular groundmass texture, only the alaskite porphyry is lacking in both plagioclase and ferromagnesian minerals. This serves to distinguish the alaskite from the similar-appearing granite porphyry which also has no ferromagnesian minerals but contains polysynthetically twinned plagioclase phenocrysts. Megascopically, the less porphyritic phase of alaskite closely resembles the granite porphyry because both have conchoidal flinty fractures and few phenocrysts. Also, the phenocrysts in both weather out, leaving a pitted surface. The quartz monzonite porphyry is distinguished from the more porphyritic phase of the alaskite porphyry because the phenocrysts of the quartz monzonite are mostly plagioclase and ferromagnesian minerals. Megascopically, the alaskite has the pitted weathered surface and lacks ferromagnesian minerals. The monzonite porphyry is distinguished microscopically by the low quartz content and megascopically by the inconspicuous feldspar phenocrysts and granular appearance. Biotite-quartz latite porphyry is distinguished by the biotite flakes, small feldspar phenocrysts, and generally darker gray color.

Table 10 gives a summary of the characteristics of the different Tertiary rock types in the Chicago Creek area.

QUARTZ MONZONITE PORPHYRY

Quartz monzonite porphyry in the Chicago Creek area is limited to a steep-dipping northeast-striking dike in the north-central part of the area (pl. 2).

The rock is seriate porphyritic, has a brown-gray aphanitic groundmass, and contains phenocrysts of white equidimensional ⅛-inch feldspar crystals and black ferromagnesian mineral laths. The phenocrysts comprise about 40 percent of the rock. The groundmass fractures with an irregular porcellainous surface.

Microscopically, the groundmass texture is allotriomorphic granular, consisting of interlocking quartz grains with poikilitic inclusions of subhedral to euhedral potash feldspar crystals. The feldspar phenocrysts are albite-twinned euhedral oligoclase plates and crystal aggregates. Euhedral ferromagnesian crystals have been entirely replaced by chlorite and magnetite. The quartz monzonite porphyry contains about 30 percent quartz, 15 percent potash feldspar, 45 percent plagioclase, and 10 percent ferromagnesian mineral. Trace amounts of apatite, magnetite, sphene, and zircon occur in the rock.

The radioactivity of the quartz monzonite dike in the Chicago Creek area is 0.003 percent equivalent uranium.

ALASKITE PORPHYRY

Alaskite porphyry is exposed in the Maxmillian Gulch-Eclipse Gulch area about 4,000 feet north of Chicago Creek, northeast of the "N" tunnel portal, and near Spring Gulch in the north-central part of the area (pl. 2). The rock is exposed as dikes that strike about N. 70° E., and dip about 65° NW.

Two varieties of the alaskite porphyry are present in the Chicago Creek area. The first variety of

TABLE 10.—*Characteristics of the Tertiary intrusive rocks*

[Mineral content: Where quantity is characteristic, a percentage figure is given. Where presence or absence is characteristic, abbreviations are given: A, absent; P, present; P–A, present to absent. Size of phenocrysts: S, small (<⅛ inch); M, medium (>⅛ and <¼ inch); L, large (>¼ inch)]

Rock name	Equivalent uranium (percent)	Microscopic characteristics								
		Groundmass					Phenocrysts			
		Texture	Quartz (percent)	Plagioclase	Potash feldspar	Ferro-magnesian	Quartz	Plagioclase	Potash feldspar	Ferro-magnesian
Bostonite porphyry	0.003–0.009	Trachytic (bostonitic)	<5	P	P	A	A	P	P	P–A
Garnetiferous bostonite porphyry	.003– .009	do	<5	P	P	P	A	P	P	P
Quartz bostonite porphyry [1]	[2].007– .014	do	<5	A	P	A	A	A	P	A–P
Trachytic granite porphyry	.003– .008	Trachytic	<5	P [4]	P	A	A	P	P	P
Quartz monzonite porphyry	[2].002– .007	Granular	<5	P	P	A	A	P	P	P
Monzonite porphyry	.005	do	<5	P	P	A	A	P	P	P
Alaskite porphyry [5]	.006– .011	do	<5	A	P	A	P–A	A	P	A
Granite porphyry	.004– .008	do	<5	P	P	A	A	P	P	P
Biotite-quartz latite porphyry	.003– .005	do	<5	P	P	A	A	P	P	P [6]

Rock name	Equivalent uranium (percent)	Megascopic characteristics						
		Groundmass			Phenocrysts			
		Texture	Color	Fracture	Feldspar	Ferro-magnesian	Size	Quantity (percent)
Bostonite porphyry	0.003–0.009	Aphanitic	Pink	Irregular granular	P	P–A	M	5–20
Garnetiferous bostonite porphyry	.003– .009	do	Red-brown	Irregular granular; Garnet is present.	P	P	M–L	50
Quartz bostonite porphyry [1]	[2].007– .014	do	Lilac to reddish-brown		P [3]	A	M	5–25
Trachytic granite porphyry	.003– .008	do	do	Irregular granular	P	P	M–L	10–25
Quartz monzonite porphyry	[2].002– .007	do	Brown-gray	Irregular porcellainous	P	P	M	40
Monzonite porphyry	.005	do	Light pinkish-gray	Irregular granular	P	P	M–S	40
Alaskite porphyry [5]	.006– .011	do	Gray to pinkish-gray	Conchoidal porcellainous to flinty.	P	A	M	5–20
Granite porphyry	.004– .008	do	do	Irregular granular to conchoidal porcellainous to flinty.	P	P	M	5
Biotite-quartz latite porphyry	.003– .005	do	Greenish-gray to dark-gray and brown-gray.	Irregular to smooth conchoidal flinty.	P	P [6]	S	5–50

[1] Microscopic quartz grains have poikilitic inclusions of feldspar.
[2] Range from Harrison and Wells, 1956, table 8, p. 58.
[3] Pink.
[4] Stubby laths.
[5] Megascopic phenocrysts weather out, leaving pitted surface.
[6] Biotite.

alaskite porphyry in the central Chicago Creek area has a gray to pinkish-gray aphanitic groundmass that has a porcellainous to flinty conchoidal fracture. The phenocrysts comprise from about 5 to 10 percent of the rock and are quartz and pink feldspar; the feldspar is commonly altered to white clay. Weathered surfaces are tan and are pitted by the removal of the feldspar phenocrysts. The second variety of alaskite porphyry is represented by the dike in the north-central part of the area. It resembles the other alaskite except that it has more feldspar phenocrysts and no quartz phenocrysts. This rock is the same as that described in the Freeland-Lemartine area (Harrison and Wells, 1956).

Microscopically, the groundmass of both varieties of alaskite is allotriomorphic granular and consists of about equal amounts of anhedral 0.02- to 0.1-millimeter quartz and potash feldspar grains. The potash feldspar phenocrysts are euhedral 1- to 3-millimeter plates, some of which show Carlsbad twinning. The quartz phenocrysts present in the dikes in the central part of the area are 0.5- to 2-millimeter anhedral grains that have been deeply embayed by corrosion; the embayments are filled by the groundmass. No accessory minerals were observed in the specimens. The alaskite porphyry consists of about 50 percent quartz and 50 percent potash feldspar. Radioactivity of the alaskite porphyry ranges from 0.006 to 0.011 percent equivalent uranium.

GRANITE PORPHYRY

The granite porphyry in the Chicago Creek area occurs as narrow discontinuous dikes near the road along Chicago Creek and on the slope north of Chicago Creek in the vicinity of Cottonwood Gulch. Most of the dikes strike from N. 65° to 70° E. and dip from 70° to 75° NW.

The granite porphyry has an aphanitic gray to pinkish-gray groundmass that has an irregular granular to conchoidal porcellainous or flinty fracture. The phenocrysts are pinkish-gray feldspar and comprise about 5 percent of the rock. Some specimens have small reddish-brown pseudomorphs, probably after ferromagnesian minerals. Weathered surfaces are tan and are pitted by the removal of phenocrysts. Granite porphyry closely resembles alaskite porphyry in hand specimens but can be distinguished because of generally fewer phenocrysts and absence of quartz phenocrysts in the granite porphyry. Microscopically, the rock is distinguished from the alaskite porphyry by the presence of twinned albite-oligoclase as well as orthoclase phenocrysts.

Under the microscope the groundmass texture is seen to be hypidiomorphic granular and made up of subhedral to anhedral laths, plates and irregular grains of quartz and alkali feldspar that range from 0.04 to 0.1 millimeter in length. The phenocrysts are albite-oligoclase, orthoclase, and, in some specimens, a ferromagnesian mineral. The albite-oligoclase is in euhedral, albite-pericline-twinned laths that range from 0.4 to 5 millimeters in length. Orthoclase phenocrysts are subhedral laths and plates that range from 0.5 to 3 millimeters in length. The orthoclase and plagioclase are commonly intergrown. Aggregates of clay, magnetite, and limonite fill euhedral forms from 0.3 to 1 millimeter long that were probably ferromagnesian minerals.

The granite porphyry contains approximately 20 percent quartz, 45 percent potash feldspar, 34 percent plagioclase, and 1 percent ferromagnesian mineral. Trace amounts of euhedral, altered sphene and of magnetite are present in the rock.

The radioactivity of the granite porphyry ranges from 0.004 to 0.008 percent equivalent uranium.

MONZONITE PORPHYRY

Monzonite porphyry occurs in the northeast corner of the area as a dike that extends out of the area to the northeast. The strike is east-northeast and the dip is steep to the northwest.

The monzonite porphyry is a light pinkish-gray seriate porphyritic rock having an aphanitic groundmass and containing feldspar phenocrysts. Phenocrysts as long as three-sixteenths inch comprise about 40 percent of the rock but are not conspicuous because they are the same color as the groundmass. Scattered dark grains of mafic minerals are present. The rock has an irregular granular fracture and weathers tan.

Microscopically, the groundmass is allotriomorphic granular, consisting of irregular quartz and potash feldspar grains. Oligoclase phenocrysts are euhedral laths and plates as much as 3.5 millimeters long that show pericline-albite twinning. The potash feldspar grains are smaller, as much as 0.4-millimeter-long, anhedral grains. Sericite, magnetite, and limonite replace euhedral grains as much as 1 millimeter long that were probably a ferromagnesian mineral. Some specimens have an appreciable quantity of calcite.

The approximate composition of the rock is 5 percent quartz, 45 percent potash feldspar, 40 percent plagioclase, 5 percent ferromagnesian mineral. Accessory minerals are ilmenite, apatite, and zircon. The radioactivity of the monzonite porphyry dike is 0.005 percent equivalent uranium.

BOSTONITE AND GARNETIFEROUS BOSTONITE PORPHYRY

Bostonite porphyry, which is a leucocratic alkali-syenite with a trachytic texture, and garnetiferous bostonite porphyry dikes are exposed in the Chicago Creek area. The bostonite porphyry dikes are mostly east of Golden Glen Gulch (pl. 2). Most of them strike northeast to nearly east and have dips ranging from 65° to 75° NW., but a dike crossing the head of King Solomon Gulch strikes N. 20° E. and dips 33° SE. The garnetiferous bostonite porphyry is a branching dike series in the northwest corner of the area that strikes nearly east and dips approximately 30° SE.

The two varieties, although the same in most characteristics, have significant differences in mineralogy, color, and grain size and they will be described separately.

BOSTONITE PORPHYRY

The bostonite porphyry is a seriate porphyritic rock that has a pink aphanitic groundmass, white feldspar phenocrysts, and in some specimens small phenocrysts of bladed ferromagnesian minerals. The phenocrysts comprise from 5 to 20 percent of the rock; feldspar crystals are laths and X-shaped aggregates as long as one-half inch, and the ferromagnesian minerals are mostly altered to brown pseudomorphs. Some feldspar crystals have been altered to gray-green clay bordered by white clay. The gray-green clay has been identified by X-ray powder diffraction methods[5] as illite, and the white clay has been identified as sericite. The dike crossing the head of King Solomon Gulch contains altered wall-rock fragments, a peculiarity not usually exhibited by the bostonites. The groundmass has an irregular fracture that produces a gritty or granular fracture surface. Upon weathering, the surfaces become tan and the ferromagnesian minerals are removed.

Microscopically, the groundmass texture is bostonitic—subhedral to anhedral interlocking feldspar laths with imperfect parallel orientation. The plagioclase grains are anhedral to subhedral laths in the groundmass and euhedral laths as phenocrysts generally less than 0.5 centimeter but as much as 1 centimeter long. The grains show albite and Carlsbad-albite twinning. Although accurate determinations could not be made, the plagioclase is probably albite. The potash feldspar is mostly restricted to the groundmass, occurring as subhedral to anhedral grains between the plagioclase laths. Some specimens have sparse phenocrysts of sanidine. The ferromagnesian phenocrysts, rounded to bladed aggregates ranging from 0.4 to 2 millimeters in length, are entirely altered and replaced by quartz, magnetite, and serpentine. The ferromagnesian mineral is presumed to be aegirine-augite because the mineral has been identified in the less altered garnetiferous variety. Quartz occurs as irregular grains in the groundmass, forming as much as 3 percent of some specimens. Trace amounts of sphene, apatite, and zircon occur. The sphene is in euhedral wedge-shaped grains usually altered to leucoxene.

The bostonite contains variable amounts of plagioclase, alkali feldspar, and a ferromagnesian mineral, probably aegirine-augite. Accessory minerals are sphene, apatite, magnetite, quartz, and in some specimens calcite. The approximate quantity of essential minerals is plagioclase, from 20 to 45 percent; potassium feldspar, from 55 to 80 percent; aegirine-augite, from 1 to 10 percent. The radioactivity of the bostonite porphyry in the Chicago Creek area ranges from 0.003 to 0.011 percent equivalent uranium. All the samples except 1 have less than 0.008 percent equivalent uranium.

GARNETIFEROUS BOSTONITE PORPHYRY

The garnetiferous bostonite porphyry is a seriate porphyritic rock that has a reddish-brown aphanitic groundmass, white to pink zoned feldspar phenocrysts, black garnet, and aegirine-augite. The feldspar phenocrysts, as much as one-half inch but generally about one-eighth inch long, comprise about 50 percent of the rock. The groundmass has an irregular granular-appearing fracture. Weathered specimens are darker reddish-brown; the garnet and aegirine-augite weather to limonitic pseudomorphs.

Feldspar in the rock is generally of 3 types: (1) Albite- and pericline-twinned crystals of zoned oligoclase-albite comprising most of the feldspar phenocrysts; (2) untwinned albite, occurring as irregular small phenocrysts and laths in the groundmass; and (3) untwinned potash feldspar occurring as rims around the larger plagioclase phenocrysts and as groundmass material between the albite laths. Some of the twinned plagioclase phenocrysts are euhedral, stubby laths as much as 3 millimeters long that have sharp contacts. Others as much as 2 centimeters long show euhedral growth zones but have a sutured detailed outline because the potash feldspar overgrowth is intergrown with the laths of the groundmass. The plagioclase near the margins of the larger crystals is more albitic than that with the smaller crystals. The smaller grains range from calcic oligoclase in the center to sodic oligoclase on the margins.

Garnet is in euhedral crystals that range from 0.5 to 1.5 millimeters across and that contain inclusions

[5] Determination by A. J. Gude 3d, U. S. Geological Survey.

of sphene and aegirine-augite crystals. X-ray and refractive index determinations show the garnet to be andraditic. Aegirine-augite occurs as small anhedral grains in the groundmass and euhedral blades as long as 1.5 millimeters as phenocrysts. The accessory minerals occur as small, generally euhedral grains scattered through the rock.

The approximate mineralogic composition is plagioclase, 45 percent; alkali feldspar, about 20 percent; potash feldspar, about 25 percent; andradite, 4 percent; and aegirine-augite, 3 percent. Accessory minerals are sphene, apatite, zircon, and quartz. Radioactivity of the garnetiferous bostonite porphyry in the Chicago Creek area ranges from 0.003 to 0.011 percent equivalent uranium. All the samples but 1 have radioactivity less than 0.008 percent equivalent uranium.

QUARTZ BOSTONITE PORPHYRY

Quartz bostonite porphyry is exposed in the northeast part of the Chicago Creek area (pl. 2). The rock occurs as a small plug and as nearly east- to northwest-striking dikes that dip to the north. A fine-grained bleached quartz bostonite with few phenocrysts is exposed along the Little Mattie vein.

The quartz bostonite porphyry in the Chicago Creek area is seriate porphyritic rock that has a pale pink aphanitic groundmass and pink feldspar phenocrysts. The phenocrysts, as much as one-fourth inch long, generally comprise about 25 percent of the rock, but the quantity may be as low as 5 percent. Some specimens have irregular brown areas that were probably ferromagnesian minerals.

Microscopically, the groundmass has a bostonitic texture consisting essentially of anhedral to subhedral feldspar laths and plates and scattered irregular quartz grains with poikilitic inclusions of the feldspar laths. The feldspar laths generally have Carlsbad twinning. The potash feldspar phenocrysts are euhedral to subhedral zoned plates and laths as much as 5 millimeters long; these crystals tend to be in aggregates. The quartz bostonite porphyry contains from 5 to 20 percent quartz, from 70 to 80 percent potash feldspar, and from 0 to 10 percent ferromagnesian minerals. Trace amounts of magnetite, zircon, and fluorite are present. The radioactivity of the quartz bostonite porphyry ranges from 0.007 to 0.015 percent equivalent uranium.

TRACHYTIC GRANITE PORPHYRY

The trachytic granite porphyry is exposed as a small plug and a series of dikes from lower Ute Creek northeastward to Spring Gulch (pl. 2). The dikes strike northeast to east and dip from 60° to 80° NW. In general appearance the trachytic granite porphyry is much like the bostonites, but the granite does not have a bostonitic groundmass and contains more plagioclase.

The trachytic granite porphyry has two variations, one of which has more abundant larger phenocrysts, and the other has less abundant smaller phenocrysts. Both varieties are seriate porphyritic, have an aphanitic lilac to reddish-brown groundmass, and contain pink to white feldspar phenocrysts. In the coarse-grained phase the feldspar phenocrysts comprise about 25 percent of the rock and are as much as three-fourths of an inch long; the phenocrysts in the finer grained phase comprise about 10 percent of the rock and are as long as one-fourth inch. Brown ferromagnesian minerals or their alteration product are present as small grains. The rock has an irregular granular-appearing fracture.

Microscopically, the groundmass is hypidiomorphic granular, consisting of stubby euhedral plagioclase laths, subhedral potash feldspar grains, and anhedral quartz grains that fill the interstices between the feldspar grains. Plagioclase phenocrysts are euhedral plates and crystal aggregates. The plagioclase is compositionally zoned with middle oligoclase in the center and albite on the margin of the crystals. Polysynthetic twinning is generally poorly developed. Euhedral potash feldspar phenocrysts and crystal aggregates as large as 3 millimeters are present. Euhedral pseudomorphs, from 0.8 to 1.5 millimeters long, of quartz, magnetite, and clay minerals replace a ferromagnesian mineral. Euhedral grains of sphene are altered to magnetite and leucoxene.

The rock is made up of about 8 percent quartz, 51 percent potash feldspar, 35 percent plagioclase, 5 percent ferromagnesian mineral, and trace amounts of sphene, magnetite, apatite, and zircon.

Radioactivity of the trachytic granite porphyry ranges from 0.003 to 0.008 percent equivalent uranium.

BIOTITE-QUARTZ LATITE PORPHYRY

Biotite-quartz latite porphyry dikes crop out between the mouths of Eclipse and Golden Glen Gulches and in the vicinity of Cottonwood Gulch. The rock has been seen underground in the Dorit and King Solomon mines. The dikes strike northeast and have a moderately steep northwest dip.

Two textural varieties of biotite-quartz latite porphyry occur in the Chicago Creek area—a very fine-grained variety with few phenocrysts, and a coarser grained variety with abundant phenocrysts. Although these two varieties are probably gradational, individual dikes are characteristic of one or the other type. Both types have seriate porphyritic texture. The very fine-grained variety has a greenish-gray to dark-gray aphanitic groundmass and phenocrysts of biotite flakes and irregular feldspar crystals as much as one-eighth inch across; the phenocrysts comprise about 5 percent of the rock. The coarser grained type has a brown-gray aphanitic groundmass and white altered feldspar phenocrysts, comprising about 50 percent of the rock. The feldspar laths are generally one-sixteenth inch long, but some are as much as half an inch long. Considerable limonite alteration has replaced probable biotite in the samples of the coarser grained dike. The fracture of both phases is irregular to smooth conchoidal with a flinty surface. Weathered surfaces are reddish tan.

Microscopically, the groundmass texture is allotriomorphic to hypidiomorphic granular; some specimens have a felty appearance because of conspicuous plagioclase laths. Grain size ranges from 0.1 millimeter to cryptocrystalline. The groundmass consists essentially of irregular grains and anhedral laths of potash feldspar surrounded by irregular quartz grains. In the felty varieties, oligoclase-andesine laths make up a conspicuous part of the groundmass. Phenocrysts are euhedral oligoclase-andesine laths and plates that have albite and combined Carlsbad-albite twinning and biotite flakes. In the most altered specimens, the biotite is completely replaced by limonite, magnetite, quartz, and chlorite.

The approximate mineral composition of the biotite-quartz latite porphyry is 35 percent quartz, 40 percent plagioclase, 20 percent potash feldspar, and 5 percent biotite. Accessory minerals are magnetite, sphene, apatite, and zircon.

Age relations between the biotite-quartz latite porphyry, other dike types, and veins are shown in the Chicago Creek area by crosscutting relations, fault relations, and inclusions. The biotite-quartz latite porphyry is younger than the granite porphyry, quartz bostonite porphyry, and some of the veins, and it is older than other veins. Biotite-quartz latite porphyry cuts the granite porphyry in the area due south of the Newton shaft and cuts the quartz bostonite porphyry in the area due east of the Newton shaft. Near the mouth of Eclipse Gulch the granite porphyry is offset by a fault which does not offset the biotite-quartz latite porphyry. In the Dorit mine the biotite-quartz latite porphyry contains inclusions of sulfide vein material and is cut by minor mineralized fractures. Similar latite porphyry-vein relations have been described in the Stanley mine (Spurr, Garrey, and Ball, 1908, p. 344–345). Radioactivity of the biotite-quartz latite porphyry ranges from 0.003 to 0.005 percent equivalent uranium.

ORIGIN

The Tertiary intrusive rocks appear to have been intruded passively or under weak force from a differentiating magma source as small plugs and dikes oriented by the fabric of the Precambrian country rock.

Virtual lack of offset displacement of the walls of dikes indicates that the dike fractures were opened by tensional and not shearing forces. In an area of tension relatively small magmatic pressures could then cause magmas to widen and occupy existing fractures or open and occupy incipient fractures in a manner similar to that described by Anderson (1942, p. 22–28).

Some sort of differentiation must have operated in this area to account for different rock types being intruded into similar structures in essentially the same geographic area within a short geologic time interval. Available data do not indicate any of the details of a differentiation process.

QUATERNARY DEPOSITS

Three types of unconsolidated Quaternary deposits were mapped in the Chicago Creek area—debris deposits, mixed deposits of talus and solifluction debris, and alluvium. The solifluction debris forms sheets filling high basins, covering some of the steep slopes, and filling parts of some of the valleys. The talus covers the surface of the high basins and valleys on the south side of Alps Mountain and is mixed with solifluction debris at most places. Alluvium occurs in the valley flat of Chicago Creek and parts of the valley bottoms of Ute Creek and Maximillian Gulch (pl. 1).

SOLIFLUCTION DEBRIS

The debris deposits are composed of unsorted heterogeneous rock fragments, ranging in size from boulders to silt, that have been derived from the surrounding slopes and ridges. These deposits of colluvial and slump material are at places more than 20 feet thick. Mr. Gerald Richmond, U. S. Geological Survey, who has studied the Pleistocene geology of parts of the Front Range, states (oral communication, 1953) that solifluction debris sheets at the elevation of those at the head of Ute Creek and Maximillian Gulch are Wisconsin in age and are probably early Wisconsin in age.

TALUS AND SOLIFLUCTION DEBRIS

The talus is composed principally of angular blocks of biotite-muscovite granite and covers the surface of the high basins on the south side of Alps Mountain. This material appears to rest on solifluction debris. At most places talus is mixed with solifluction debris and forms topographic ridges in the central part of the valleys immediately south of the talus-covered basins. These ridges commonly have a relief of 20 feet, are 200 feet wide, grade into talus or mixed talus and solifluction debris on the north end, and taper out on the south end. Smaller ridges occur in some of the valleys below basins covered with solifluction debris, but only the larger ridges, all of which contain talus blocks, have been mapped. All of these ridges are probably the result of movement of water-saturated talus and slump debris. These deposits, according to Richmond (oral communication, 1953), are also Wisconsin, probably early Wisconsin, in age.

ALLUVIUM

A thin cover of Recent and (or) Pleistocene alluvium is present along the valley flats of the larger streams and gulches. Chicago Creek flows in the bottom of a U-shaped glaciated trough. The alluvium along Chicago Creek covers outwash gravels in part and is probably Recent in age. The alluvium along Ute Creek and Maximillian Gulch has been at places cut through or mostly stripped off. This stripping is primarily in the lower parts of the valleys near their junction with Chicago Creek. This suggests that the alluvium in the valleys tributary to Chicago Creek may represent deposits caused by damming of their mouths in the late stages of Pleistocene glaciation. The stripping of the alluvium is still in progress and began after removal of the dams, possibly as the glacier retreated up Chicago Creek valley.

STRUCTURE

The bedrock in the Chicago Creek area is composed of igneous rocks and a generally conformable series of metamorphic rocks. The rocks were folded during Precambrian time, and many of the folds are now outlined by the lithologic layering. The metamorphic rocks are generally well foliated, and the foliation trends northeast except in local areas on fold noses where it trends east or slightly south of east. All the rocks are jointed and are cut by numerous faults of Laramide age; some of the joints now contain granite or pegmatite of Precambrian age or porphyry intrusives of Tertiary age, and many of the faults locally contain ores of gold, silver, copper, lead, zinc, and uranium of Tertiary age.

The structural history of the bedrock is complex. Several elements involved in creating the present structural pattern cannot be dated with much accuracy. A general summary of the structural history shows the following events:

1. Precambrian plastic deformation causing major folds with north-northeast-trending axes accompanied by intrusion of granodiorite and then quartz diorite.
2. Intrusion of biotite-muscovite granite near the end of the north-northeast-trending period of folding.
3. Precambrian deformation, largely cataclastic, causing crushing and granulation in the more massive rocks, and minor (generally less than 50 feet wide) terrace, monoclinal, or chevron folds in the more gneissic rocks.
4. Early Laramide(?) arching resulting in the development of a regional joint pattern superposed on Precambrian joint patterns.
5. Tertiary fracturing and faulting accompanied or followed by intrusion of dikes and deposition of hydrothermal veins.

MAJOR FOLD SYSTEMS

Two fold systems can be recognized in outcrops in the mapped area. Broad arcuate patterns of some of the rock units serve to outline some of the larger open folds; zigzag patterns serve to delineate some of the smaller folds; small bends of lithologic units on broad open folds serve to locate some of the younger folds. Traces of axial planes of the traceable folds are shown on the geologic map (pl. 1).

It is convenient to refer the geometry of the folds and the associated planar and linear features to a coordinate system similar to that in common usage (Cloos, 1946, p. 5). The axes a and b are in the movement plane, c is normal to it; b is parallel and a is at a large angle to principal fold axes. Both a and b are defined by linear elements in the rocks.

The older and most prominent fold system trends north-northeast to northeast, and the axis of this system is called b_1, in this report. The selection of b_1 is based upon evidence of a strong crumpling of the rocks into upright and overturned folds trending in a north-northeast direction, and b_1 is here defined as the axis of any fold of this system.

A younger fold system that is superposed on b_1 folds trends east-northeast, and the axes of folds of this system are called b_2 in this report. The selection of b_2 is based on evidence of folding in the b_2 direction and warping and slickensiding in the a_2 direction; both b_1 and a_1 lineations are deflected in many outcrops by folds or warps in b_2 or a_2 directions. The characteristics of the b_2 folding have led the writers to the conclusion that this fold system is related to faulting and that the folds probably reflect at depth structures that were faults nearer the surface.

The 2 major fold systems give rise to lineations of various kinds in 4 directions, and at some outcrops all

4 linear directions can be measured. The types of lineations present include mineral alinement, streaks, slickensides, crinkles (small crenulations whose amplitude-to-wave-length ratio is about 1 :1), warps (crenulations whose amplitude-to-wave-length ratio is about 1:2 or smaller), and axes of rounded-crest drag folds, chevron drag folds, and terrace folds. All of these lineations are in the plane of the foliation. The kinds of lineations and relative abundance in the b and a directions on both fold systems are shown on table 11.

TABLE 11.—*Types of lineations present in the two fold systems*

[Boldface, very common; italic, common; other, less common]

Linear direction—			
b_1 (N. 23° E.)	a_1 (N. 60° W.)	b_2 (N. 55° E.)	a_2 (N. 27° W.)
Mineral alinement *Warps and crinkles* *Rounded-crest drag folds.* Chevron drag folds	*Warps and crinkles* *Mineral alinement* Rounded-crest drag folds. Streaks	**Terrace folds** **Warps** *Monoclinal folds* *Chevron drag folds* Crinkles Mineral alinement Rounded-crest drag folds.	**Warps** **Slickensides** *Mineral alinement* Rounded-crest drag folds. Streaks

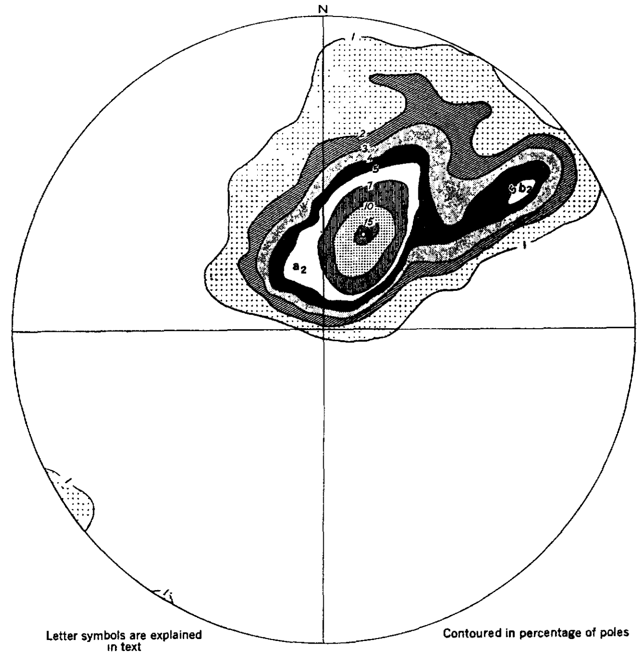

FIGURE 9.—Contour diagram of lineations, lower hemisphere plot of 1,005 poles.

This table points up the fact that only terrace folds and monoclinal folds are unique to 1 linear direction; the other types of linear elements are found in all 4 directions. With the exception of the 2 unique kinds of linear elements, the recognition of whether a lineation should be called b_1, b_2, a_1, or a_2, depends entirely on its direction. The relative abundance of types of lineations in each of the 4 directions shown on this table helps to bring out the field observation that b_1 is a direction of folding and recrystallization, a_1 is primarily a direction of warping and recrystallization, b_2 is primarily a direction of folding accompanied by little recrystallization, and a_2 is a direction of warping, shearing, and some recrystallization.

All lineations measured in surface outcrops were plotted on the lower hemisphere of a Schmidt equal-area net. The net was then contoured, and the resulting diagram is shown in figure 9. Both b_1 and b_2 are represented by prominent highs on this diagram; a_2 is represented by a bulge on the southwest side of the b_1 high; and a_1 possibly is indicated by a bulge in the 1- and 2-percent contours in the area west of the a_2 high. The diagram indicates that in the Chicago Creek area the average plunge of b_1 folds is 62° N. 23° E.; the average plunge of b_2 folds is 22° N. 55° E., and the approximate plunge of a_2 lineations is 72° N. 27° W. Because of the proximity and overlap in space of the range in direction and amount of plunge of b_1 and a_2 lineations, the average plunges derived from the diagram for these linear directions are probably not quite correct. The mechanics of taking overlapping averages in a 1-percent area used to count the plotted data causes some a_2 lineations to be counted and used in contouring the b_1 high, and vice versa. The area between these highs is thus built up in the counting process, and contours are thus "pulled" away from their true position toward the area between the highs. As an a_2 lineation cannot always be distinguished from a b_1 lineation in the field, this overlap in counting and consequent slight shift in true position of highs is a necessary evil for the diagram shown.

CHARACTERISTICS OF THE "1" SYSTEM

The older fold system is the dominant control of the rock patterns and foliations of the metamorphosed rocks mapped (pl. 1). The lithologic layering and foliation attitudes outline large to small folds that trend north-northeast to northeast. Related to these folds are linear features parallel to their axes (b_1 lineations) and those approximately at right angles to their axes (a_1 lineations).

LINEATIONS AND FOLDS IN b_1

Linear features present in the b_1 direction (about N. 23° E.) include mineral alinement, warps and crinkles, and fold axes. The most prominent and widespread linear feature is mineral alinement. Rocks containing hornblende, sillimanite, and biotite commonly show b_1 alinements in foliation planes of the rocks. These alinements are shown by parallelism of the long dimension of hornblende and sillimanite crystals and by streaks of fine-grained biotite plates. Muscovite, if present, commonly is alined with the biotite except in sillimanitic rocks where it commonly occurs with the sillimanite and, along with quartz, forms rods or pods in the b_1 direction. Warps are common in all the layered rocks, and crinkles are common in the micaceous rocks near crests of folds. The fold axes that can be measured in the field are all minor features. Most commonly these folds are in the biotite-rich gneisses and are rounded-crest drag folds that have a wave length and amplitude of a foot or less. Chevron drag folds in these same rocks and of the same size are much less common.

The larger folds whose axial planes can be traced out along b_1 trends include broad upright folds, upright to overturned tight folds, recumbent folds, and chevron folds. Broad upright folds in the b_1 direction are outlined by lithologic layering in the easternmost and northernmost parts of the mapped area (pl. 1). The broad syncline and an associated anticline seen in the northern part of the area along Spring Gulch is the largest b_1 fold recognized in the area. This fold has a wave length of about 5,000 feet along Spring Gulch, can be traced southwest along the trace of the axial plane of the syncline, and is seen to tighten up and overturn south of Alps Mountain where the wave length of the syncline is probably less than 1,500 feet. This large fold appears to be asymmetric and may be a drag fold indicating a larger anticlinal structure to the east. This variation from open to tight and overturned folds along an axis is common in the areas mapped in this part of the Front Range. Smaller asymmetric tight folds that have a wave length and amplitude of a few hundred feet are abundant in the area between the synclinal axis described above and the first anticlinal axis of the open structure in the easternmost part of the mapped area (pl. 1). Traces of axial planes of many of these lesser folds are shown on the geologic map, but perhaps only 30 percent of the folds mappable on a scale of 1:6,000 are traceable for more than a few hundred feet. These lesser folds are interpreted as rounded-crest and chevron drag folds on the northwest flank of the larger anticlinal structure mapped at the eastern edge of the area. Recumbent folds are confined to the crests or troughs of the more open folds. Most of the recumbent folds are only a few inches wide in amplitude and wave length, but a few are larger. The largest recumbent fold seen has a 500-foot amplitude and was mapped along the southwest part of the anticlinal structure at the east edge of the map.

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LINEATIONS AND FOLDS IN a_1

Linear features present in the a_1 direction (about N. 60° W.) include warps and crinkles, mineral alinement, streaks, and fold axes. The warps, crinkles, and mineral alinement are similar in occurrence to those described in b_1 but are much less common. The axes of a few rounded-crest drag folds that have a wave length and amplitude of about a foot were measured in biotite-quartz-plagioclase gneiss.

Opposing dips of foliation planes containing a prominent mineral alinement in a_1 outline larger (500-foot) folds in metasedimentary rocks on the northeast shoulder of Alps Mountain. These larger folds are shown in section on plate 1 and are about at right angles to the axes of a broad open b_1 syncline. The asymmetry of these folds suggests that they are drag folds related to a slippage or shortening parallel to b_1. The rocks above may have moved as a plate southwest parallel to b_1 or the b_1 syncline may have been steepened at a late stage in b_1 formation; steepening would result in local compressional stresses in the bent area.

REVERSED DRAG FOLDS

Certain local areas on flanks of folds contain a few drag folds that show relative movements reversed to that expected for drag folds on the flanks of the major b_1 folds. Many of these reversed drag folds are in layers adjacent to other layers containing normal (in sense) drag folds of the same order of magnitude.

The writers believe that two varieties of these reversed drag folds formed in the rocks. The first variety is found on relatively undeformed flanks of broad open b_1 folds. The reversal of the drag folds is believed due to gross competency factors involving groups of layers. As illustrated on figure 10, movements of groups of beds on the flank of a large fold may set up local differential movements reverse to those of the major movement. Such reversed shearing stresses could result in reversed drag folds in a layer between two particular groups of beds. Several variations of the diagram shown are possible, but they all depend for reversal of drag folds upon gross relative competency of groups of beds. Reversed drag folds believed to be of this general type are locally abundant on the southeast flank of the syncline on the southeast flank of the Alps Mountain.

The second variety of reversed drag folds is found as 3- to 10-foot-wide folds on the underside of larger overturned b_1 folds, near the axial plane of the larger fold. The reversal of these drag folds is believed related to overturning and stretching of the fold as illustrated on figure 10. As the larger drag fold is overturned and tightened up under the same continued

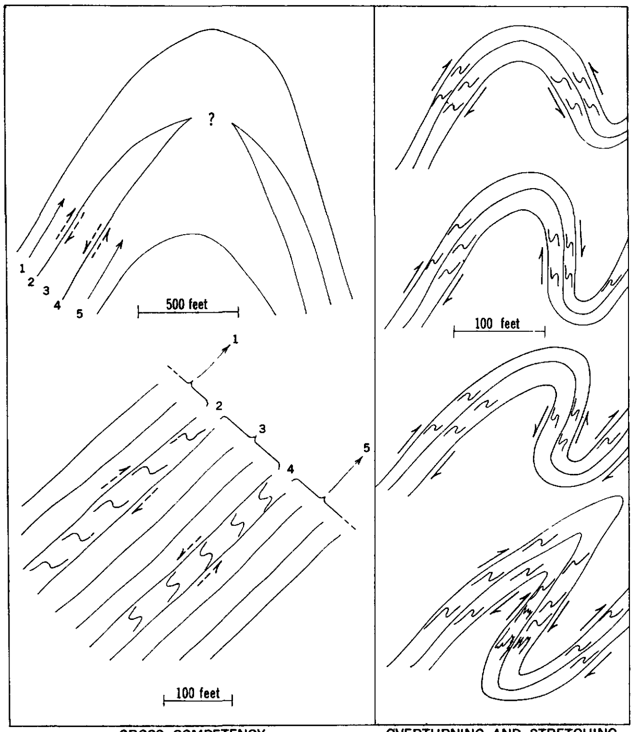


FIGURE 10.—Possible methods of formation of reversed drag folds on the b_1 fold system.

stress, it eventually becomes so tight that the shear stress on the short limb is the same as that on the long limb. These drag folds commonly are found where the rock has the appearance of pulled taffy and where drag folds that appear to be stretched and deformed are prominent. (See sketch in lower right corner of fig. 10.) Drag folds formed during the stretching probably are found also on the upper side of the overturned fold, but as they show the expected differential movement for that flank of the fold they are not readily distinguished from drag folds formed during the folding and before stretching. Reversed drag folds believed to be of this general type are sparse in the mapped area, but a few of them occur in the tightly folded metasedimentary rocks south of Alps Mountain. Some of the "reversed" drag folds seen in the area may be normal drag folds on the flank of an unrecognized subisoclinal fold.

Certain b_2 folds that are found on the underside of overturned b_1 folds and appear to be reversed drag folds will be described in the following section.

CHARACTERISTICS OF THE "2" SYSTEM

The younger fold system is less prominent than the older fold system in the area mapped. The largest of the younger folds mapped has an amplitude of about 200 feet and a wave length of about 50 feet; most folds are smaller. The distortion of foliation by most of these folds is slight and is limited to a few feet on either side of the axial plane of the fold. Thus at the scale of the geologic map (pl. 1) most of the folds of the younger fold system do not appear to deflect the lithologic layering.

Related to the younger folds are linear features parallel to their axes (b_2 lineations) and those approximately at right angles to their axes (a_2 lineations). All of these lineations in the metamorphic rocks are in the plane of the foliation.

LINEATIONS AND FOLDS IN b_2

Linear features present in the b_2 direction (about N. 55° E.) include mineral alinement, crinkles, warps, and fold axes. Mineral alinement, though rare, is at places expressed by coarse crystals of biotite and (or) sillimanite in rocks containing those minerals. Crinkles, commonly consisting of close-spaced chevron folds about half an inch in size, are common in micaceous rocks near the crests of folds. Warps are common in all the layered rocks, and at many places they are the only recognizable indication of the second deformation. Because most of the b_2 folds are relatively small, their axes can be measured in the field. These folds are apparently limited to the gneissic rocks in the Chicago Creek area and have not been seen in granodiorite, quartz diorite, or biotite-muscovite granite.

The kinds of folds characteristic of the b_2 system include terrace folds, monoclinal folds, chevron folds, and a few rounded-crest drag folds and recumbent folds. The 3 principal types of folds commonly are less than 100 feet across and most of them are from 10 to 30 feet across. Many of them can be recognized in outcrop as being b_2 folds because of their sharp deflection of the general foliation trend and because terrace and monoclinal folds are found only in the b_2 direction. All of these folds in the Chicago Creek area show the same relative movements in section; the northwest side has been raised relative to the southeast side. These types of folds may grade into each other vertically and horizontally along the trace of a single axial plane.

Traces of axial planes of b_2 folds are vertical or nearly vertical in section and remarkably straight in plan (pl. 1). The number of traceable b_2 fold axes increases markedly from northwest to southeast across the mapped area.

The type of b_2 fold formed and the direction and amount of plunge of these folds are dependent upon (1) the attitude of the foliation on a b_1 fold that existed prior to the formation of b_2 folds, and (2) the amount and direction of relative movement across the axial area of the b_2 fold. A simplified diagram is shown in figure 11 to aid in the explanation of these factors.

The diagram has been constructed as simply as possible to bring out the effects of superposing b_2 folds on b_1 folds. The simplifications include the following points: (1) the b_1 structure is a broad fold plunging 30° N. 30° E.; (2) the axial planes of the b_2 folds are vertical; (3) the amount of relative raising across all the b_2 fold areas is the same; and (4) the relative movement is essentially vertical. The diagram shows the trace of 2 axial planes, 1 at each bend, where the geologic map (pl. 1) shows only 1 located midway between the 2 bends; the single trace of axial plane is necessary on the geologic map because of scale. The diagram (fig. 11) illustrates the point that the terrace, chevron, and monoclinal folds characteristic of the b_2 fold direction can grade into each other along the trace of an axial plane and that the type of fold formed depends on the attitude of preexisting foliation. If the reader will picture twice the amount of movement shown in the section, then the location of the terrace folds shown in the section will move down and their place will be taken by chevron folds. The diagram also illustrates that b_2 folds on the northwest side of an open and upright b_1 fold will be chevron or terrace folds, whereas those on the southwest side will be monoclines.

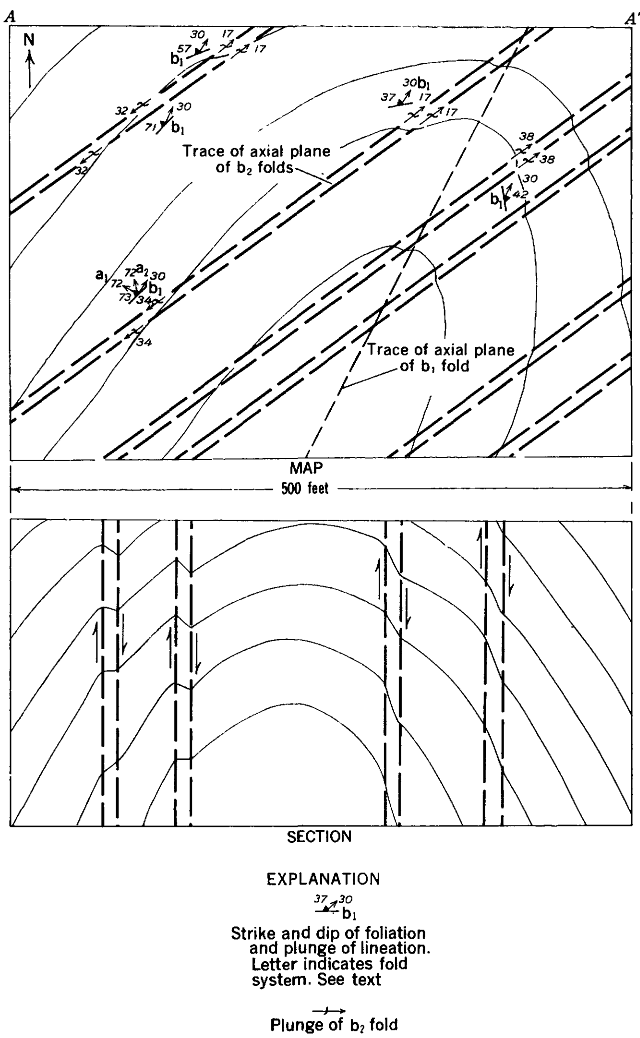


Figure 11.—Diagram illustrating effects of superposing b_2 folds on b_1 folds.

It follows that terrace and chevron folds will be found in section views of both sides of an overturned b_1 fold, for both flanks are then dipping northwest in the Chicago Creek area. Because the b_2 folds all have the same relative directions of movement, a b_2 fold on the underside of an overturned b_1 fold looks like a reversed drag fold but can be recognized because the direction of plunge is N. 55° E. rather than N. 30° E. parallel to the major fold. The direction and amount of plunge of the b_2 folds is the angle of intersection between the axial plane of the b_2 fold and the plane of the preexisting b_1 foliation. Because the axial plane of b_2 folds is essentially vertical, the direction of plunge of the b_2 folds is either about N. 55° E. or S. 55° W. The amount of plunge and whether it is northeast or southwest is dependent on the strike and dip of the foliation on a b_1 fold. Some examples of plunge of the b_2 folds are shown in the plan on figure 11. The b_2 fold shown near the northwest corner of the plan was constructed to illustrate the particular field observations that the plunge of the fold can change from northeast to southwest in a very few feet along the axis.

Another observation not illustrated directly is that if the foliation is changing strike rapidly on a b_1 fold and the b_2 fold is relatively broad, then the plunge of the bend on each side of the fold need not be the same amount or even the same direction. Note also, in the left center of the plan, that the a_2 lineation (perhaps alinement of coarse flakes of biotite) is in the plane of the foliation.

LINEATIONS AND FOLDS IN a_2

Linear features present in the a_2 direction (most at about N. 27° W., a few at about S. 27° E.) include warps, mineral alinement, slickensides, streaks, and fold axes. Warps are most common in the more gneissic rocks. Mineral alinement is in the plane of the foliation and is commonly expressed by coarse crystals of biotite and (or) sillimanite. Slickensides on fracture surfaces express the a_2 direction in parts of the granite gneiss and pegmatite and in biotite-muscovite granite. (See fig. 11.) And streaks or rodlike ovoids of magnetite or quartz-feldspar express a_2 in parts of the granite gneiss and pegmatite, quartz diorite, and granodiorite. The slickensides and streaks in a_2 are in the more massive rocks, and where these linear elements are found the rock contains visible fractures in outcrop and (or) mortar structures in thin section. The megascopic fractures are best developed in biotite-muscovite granite and parts of the granite gneiss and pegmatite. These fractures were described in detail in the section on biotite-muscovite granite and are called incipient fractures. Where these fractures exist, a_2 is in the plane of the fracture.

The fracture planes containing the a_2 lineation were observed carefully in the biotite-muscovite granite stock on Alps Mountain. Parts of the stock are visibly cataclastically deformed along the fractures, and other parts are apparently undeformed; but some of the thin sections from apparently undeformed rocks contain recemented fractures as indicated by a weakly developed mortar structure, and some of them show no evidence of cataclasis. Because some of the apparently undeformed rocks show a weakly developed deformed texture in thin section, megascopic observations concerning this deformation cannot be precise. The writers believe, however, that the field and laboratory data combine to show that parts of the stock are deformed, parts are much less deformed, and parts are undeformed. Field observation suggests that the deformed and less deformed or undeformed areas form alternating zones that are a few hundred feet in width. The general strike of the fractures is northeast about parallel to b_2, and the fractures maintain the trend even where the flow layers do not parallel them. The alternating layers of deformed and undeformed granite probably strike northeast. The fractures and probably the cataclastically deformed layers dip northwest and steeply southeast.

Folds in the a_2 direction are sparse; the few seen were in biotite-quartz-plagioclase gneiss and were small rounded-crest drag folds or small recumbent folds.

SUMMARY AND CONCLUSIONS

Folds and lineations of the "1" system represent a folding that was plastic. The folds are large open and upright to tight and overturned structures that have many drag folds on the flanks; these folds have no cataclastic characteristics where "2" structures are absent. Lineations in b_1 resulted from the plastic deformation of the folded rocks and from recrystallization. Lineations in a_1 formed mostly by growth of elongate minerals in that direction, though some plastic deformation formed folds. Fine-grained biotite, muscovite, hornblende, and sillimanite show preferred orientation on the "1" fold system. The writers infer that the grade of metamorphism during this folding was high.

Folds and lineations of the "2" system are believed to be reflections at depth of faulting nearer the surface. The structures resulting from the "2" stresses are plastic in part and cataclastic in part. Folds are nearly completely restricted to the b_2 direction, and recrystallization is nearly completely restricted to the a_2 direction. The folds are structures whose effects generally are limited to a hundred feet in width in the more gneissic rocks. Incipient fractures containing the a_2 lineation show up in some of the more massive rocks and probably in layers a few hundred feet wide that alternate with layers of undeformed rocks. Streaks of biotite and rodlike masses of quartz and feldspar define a_2 in granodiorite and quartz diorite; these rocks do not show the incipient fracture of less mafic more massive rocks, but they do show the mortar structures in thin section. The a_2 lineation is in foliation planes or fracture surfaces subparallel to foliation. Slippage accompanying the folding thus was confined to layering in the metamorphic rocks and to fracture surfaces in the massive rocks *regardless of the attitude of these surfaces.* Traces of axial planes of b_2 folds are remarkably straight and trend about N. 55° E.; the rocks on the northwest side of these folds have been lifted up relative to those on the southeast side. Because b_1 structures show little or no tilting on the northwest flanks of b_2 folds, the writers infer that the movement across the folds has been essentially vertical. The character of the folds and accompanying cataclastic deformation suggests that the "2" fold system is related to faulting at such depth that the more easily deformed rocks slipped on foliation planes, bent, and recrystallized in part; the less easily deformed rocks slipped slightly on foliation planes and recrystallized in part; and the more resistant rocks fractured, slipped on the fracture surfaces, and recrystallized sufficiently to form slickensides on the fracture surfaces.

Coarse-grained biotite and (or) sillimanite with quartz and muscovite show preferred orientation on the "2" fold system in the layered rocks that normally contain these minerals. Fine-grained muscovite and chlorite show preferred orientation on the "2" system in biotite-muscovite granite. Some of the hornblende-bearing rocks show "1" lineations in hornblende alinement and "2" lineations in biotite alinement. The writers infer that the second folding caused retrograde metamorphism, but that the grade was still moderately high.

The type of faulting that caused the folding and cataclasis characteristics of the "2" system is difficult to define. Anderson (1942, p. 187–189) concluded that earth forces are not strong enough to cause vertical thrust faulting. The axial planes of the "fault-folds" are steep to vertical, and they must represent, according to Anderson, either normal or wrench (essentially tear) faults. If the movement is nearly dip slip, as it seems to be, then the faults are probably normal faults and the downthrown block was the one that moved. Normal faults are tensional structures, and so the implication is that during later Precambrian time (following the formation of the biotite-muscovite granite) the crust of the earth was arched or uplifted over the mapped area. Arching and removal of cover would bring the rocks up from a deeper zone of plastic deformation into a shallower zone of part plastic and part cataclastic deformation that prevailed at the time of deformation on the second fold system.

AGE RELATIONS OF THE FOLDING

Dating of the folding is based on which rocks have been plastically and (or) cataclastically deformed and which rocks have been intruded into the folds. Granodiorite contains inclusions of folded metasedimentary rocks, yet it has foliation planes containing a strong b_1 mineral alinement. The foliation planes are superposed on the granodiorite. These data are interpreted as indicating that the granodiorite was intruded during the north-northeast folding. All the rocks older than biotite-muscovite granite contain lineations belonging to both fold systems. The biotite-muscovite granite has been intruded in part concordantly in b_1 folds and in part crosscutting b_1 folds, but it contains lineations and cataclastic structures characteristic of the "2" fold system. These data are interpreted as indicating that part of the biotite-muscovite granite was intruded into fold crests and troughs late in the north-northeast folding and part was intruded after the folding. Some of the pegmatites associated with granite gneiss and pegmatite and with biotite-muscovite granite are swelled on the crests of b_2 folds. These rocks are not visibly cataclastically deformed, and the age of the pegmatite related to the granite gneiss and pegmatite unit appears younger than the bulk of that unit; that is, some of the undeformed pegmatites traceable into granite gneiss and pegmatite cut rocks younger than the granite gneiss unit where the effects of the "2" fold system are most prominent. These pegmatites are believed to have been recrystallized and remobilized during "2" time and thus to have taken on the relative age of the structures in which they occur.

FAULTS

Most of the faults in the Chicago Creek area are zones of subparallel fractures along which repeated movement has occurred. The fault zones range in width from an inch to a few feet. Most of the faults show a marked tendency to split and branch. Most of the faults have been mineralized, and they are indicated on plates 1 and 2 and figure 12 by the traces of the veins that occupy them.

Apparent movement along the faults has been mostly northwest block to the northeast and hanging wall down, but a few of the flat-dipping faults show apparent reverse movement. The amount of movement generally has been small. Many veins of the district cross without noticeable displacement.

The attitude of many of the faults is controlled by the gross fabric or grain of the bedrock. Many faults are subparallel to foliation, axial planes of tight folds, contacts between rock units, or preexisting joints. As the gross fabric of most of the bedrock in the Chicago Creek area trends northeast, most of the faults trend northeast.

Most of the faults are Tertiary in age (Lovering and Goddard, 1950, p. 44–47), but a few of them are older. In general, faults trending northeast to east cut through, offset, or follow along the Tertiary intrusive rocks, but near Idaho Springs a large fault trending northwest is at places followed by or cut by the Tertiary rocks and (or) the northeast-trending veins (R. H. Moench, oral communication, 1955). These northwest-trending faults are called the "breccia-reef" fault system by Lovering and Goddard (1950, p. 79), who infer them to be Laramide in age. Movement during Tertiary time on small faults in the Chicago Creek area belonging to this older system is recorded by offset of some of the Tertiary dikes and veins along the northwest-trending faults. As a rule the northwest-trending faults have been mineralized very little and only where reopened by movement during Tertiary time.

TYPES OF FAULTS

The Tertiary faults are probably wrench faults[6] and, less commonly, thrust faults. Too few northwest-trending faults are exposed in the area to allow an analysis of their type or types.

The Tertiary faults have 3 principal trends that are about N. 40° E., N. 65° E., and N. 75° E.–N. 75°W. (many about due east). These trends are shown on figure 12, where traces of the major veins

[6] Wrench faults are used here as used by Anderson (1942, p. 13–21), who defines them essentially as steeply dipping strike-slip faults.

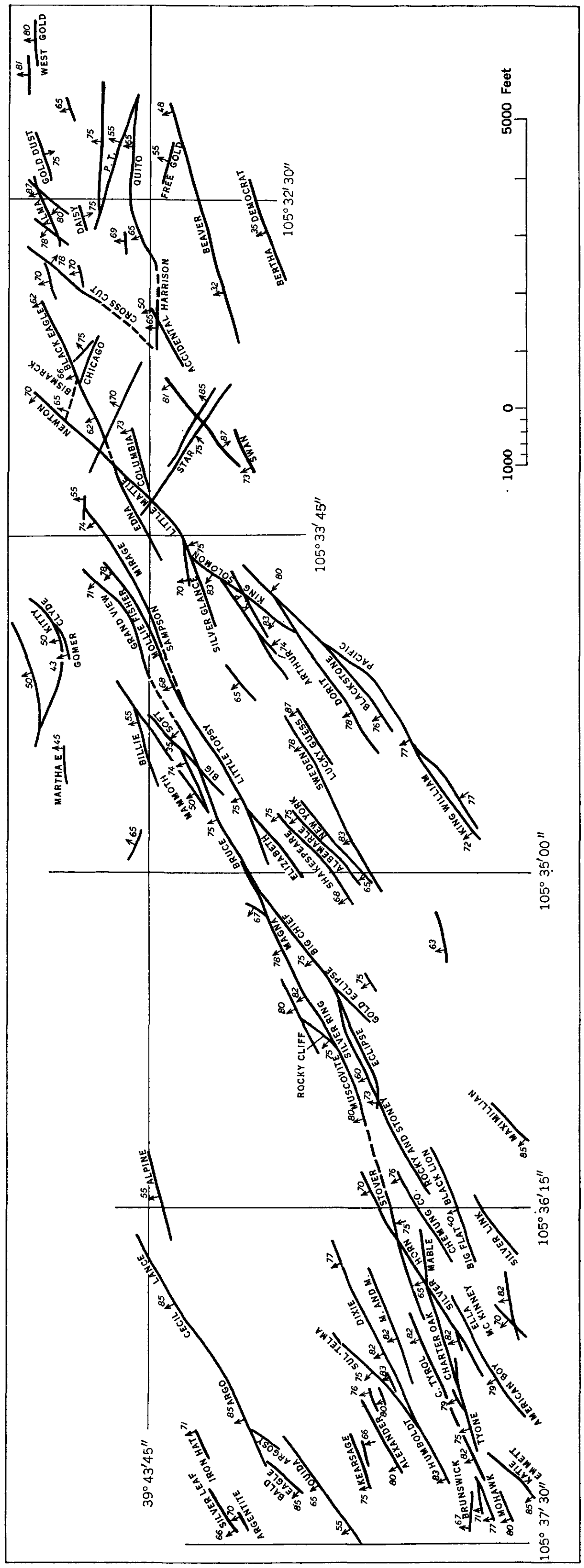


FIGURE 12.—Traces of major veins in the Chicago Creek area projected to 9,000 feet elevation.

along the faults have been projected to a horizontal plane at 9,000 feet elevation. Most of the faults dip steeply northwest, a few dip vertically to steeply southeast, and a few dip relatively flatly (less than 50°) northeast or southwest.

The horizontal component of the relative movement on the steeply dipping northeast-trending faults appears to have been northwest block to the northeast. This relative horizontal movement can be demonstrated, however, along only the faults containing the Dixie, the Silver Horn, and the Black Eagle veins. This relative movement is also common in the adjacent Freeland-Lamartine district (Harrison and Wells, 1956). The steeply dipping northeast-trending faults are probably wrench faults.

Some of the flat-dipping northeast- to east-trending faults have an apparent relative vertical movement of hanging wall up. In the Beaver mine several of these faults containing veins show apparent reverse dip-slip movement. The thickening of the ore on the flatter parts of the *a* vein (pl. 3 and p. 50) suggests reverse movement on the fault containing that vein. Near the portal of the Black Swan tunnel (fig. 24) faults that offset steeply dipping wall rock and the drift vein show apparent reverse dip-slip movement. In the P.T. and Free Gold mines the wider parts of the vein are on the flatter parts of the vein.

The association of flat thrust faults and steeply dipping faults suggests that the steeply dipping faults are wrench faults. According to Anderson (1942, p. 20), thrust planes and normal faults cannot form in association, but thrust and wrench faults can.

AGE RELATIONS AMONG THE FAULTS

Only limited data on relative ages of the faults are known for the Chicago Creek area. As has been mentioned, the northwest-trending faults are probably Laramide in age. Only a few junctions between the northeast- to east-trending Tertiary faults have been observed where age relations were clear. In general, the flat-dipping faults tend to join or cut through the steeply dipping faults seemingly regardless of the trend of either group. Clear age relations between steeply dipping faults were seen in only 2 places: (1) the Dixie vein (N. 60° E. fault) is cut by an east-trending fault on the second level of the Dixie mine (pl. 4), and (2) the Little Mattie vein (N. 40° E. fault) is cut by the Black Eagle vein (N. 60° E. fault) near the Decatur shaft on the tunnel level of the Little Mattie mine (pl. 8).

JOINTS

Joints are present in all the rocks in the Chicago Creek area. Some of the joints are followed by Precambrian igneous dikes, and others transect these dikes and their host rock; some joints are followed by Tertiary dikes that are also jointed; certain joints are most abundant near Tertiary veins and commonly are stained by limonite or have scattered crystals of pyrite along them.

The writers infer from the data gathered that several joint systems of different ages can be recognized at places in the rocks of the area. Each of the Precambrian and Tertiary magmatic rocks contains joints believed to represent fractures formed during cooling of the rocks. The Precambrian metamorphic rocks contain joints believed to be related to folding of these rocks during two periods of deformation; some of these folding joints have been superposed on the Precambrian intrusive rocks. A widely distributed "regional" joint system appears to have been superposed on all Precambrian rocks, possibly during Laramide time. Some mineralized joints may be Tertiary in age and related to the stresses that caused Tertiary faults.

The writers wish to emphasize that at most outcrops joints that may be middle Precambrian cannot be distinguished from joints that may be later Precambrian or Laramide in age. At some outcrops, however, the field relations seem clear, and consistent data from these outcrops encourage the writers to attempt an explanation of the complex joint pattern.

Such a complex joint group might be expected to contain certain joints that are essentially parallel in each succeedingly younger joint system. At places it is difficult or impossible to determine whether a joint is new or whether it represents a reopening or extension of a preexisting plane of weakness. A simple example of parallelism of succeeding joints is shown by dikes that intrude older rocks along joints or axial planes of tight folds. Longitudinal joints in the dikes (Balk, 1937, p. 34–36) are subparallel to the flow structure, which in turn is subparallel to the wall of the dike, which in turn is parallel to an older joint in the host rock. If a dike should be intruded along an axial plane, possibly along a longitudinal fold joint, and should move approximately up-plunge on the fold, then both longitudinal joints and cross joints in the dike and in the folded rocks would be subparallel. As the gross fabric of the rocks in the Chicago Creek area has a northeast trend and a steep dip, the writers are not surprised to find that joints whose field relations suggest that they range in age from Precambrian to Laramide trend northeast and dip steeply northwest or southeast.

PRECAMBRIAN JOINTS

Joints of the Precambrian include 2 types—primary joints in intrusive rocks and joints related to 2 periods of Precambrian folding.

Primary igneous joints, commonly containing pegmatite or granitic dikes, are characteristic of granodiorite, quartz diorite, and biotite-muscovite granite. Figures 13 and 14 show a diagram of joints in the granodiorite and of Precambrian dikes in the same rock. The dikes are of two ages; some are related to the granodiorite (p. 12), and others are related to biotite-muscovite granite that intrudes the granodiorite and its related dikes. The steeply dipping joints in the granodiorite are believed to represent primary joints; the flatly dipping joints may be primary joints or may be sheeting joints. Dikes of biotite-muscovite granite are limited to joints trending east-northeast and dipping steeply north. Some of these joints also contain leucocratic granodiorite, and the joint direction is, therefore, considered to be a primary igneous direction of weakness. The dike pattern shown by dikes of biotite-muscovite granite that intrude the quartz diorite bodies on the ridge between Maximillian Gulch and Eclipse Gulch (pl. 1) is suggestive of a joint system that may be inherent to the quartz diorite. The quartz diorite has been metamorphosed,

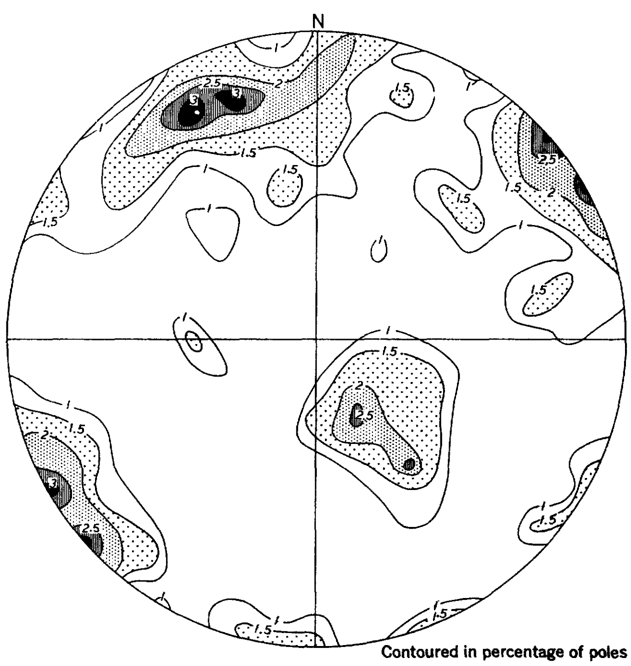


FIGURE 15.—Contour diagram of joints upper hemisphere plot of 1,127 poles. Contoured on number of poles.

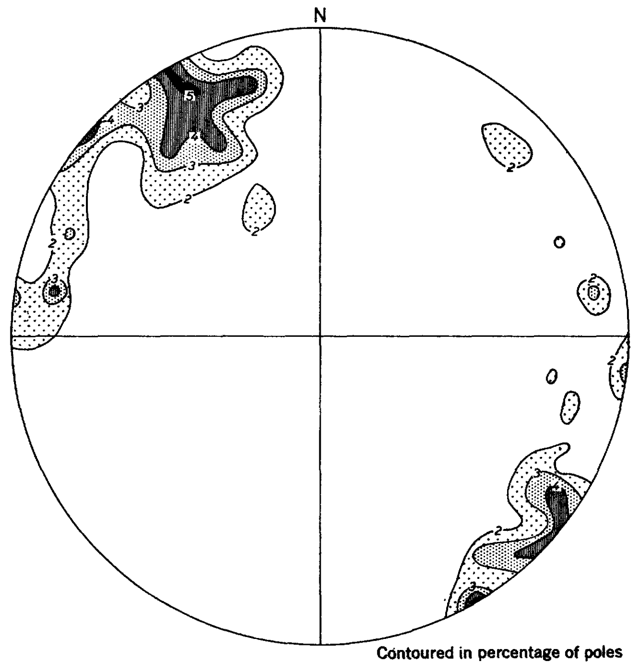


FIGURE 14.—Contour diagram of planes of Precambrian granitic dikes in granodiorite, upper hemisphere plot of 153 poles.

however, and the joint pattern may be secondary rather than primary. The biotite-muscovite granite in the stock at Alps Mountain (pl. 1) contains pegmatite along some of the joints. These joints may be primary igneous joints.

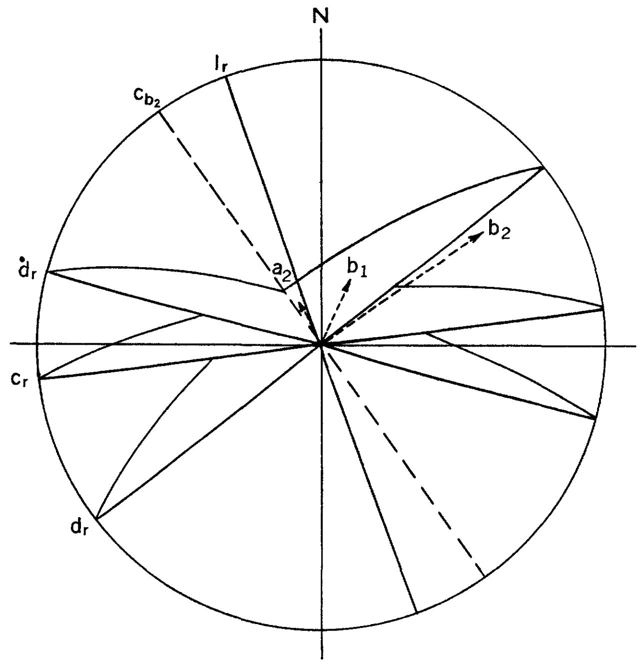
Joints related to Precambrian folding are recognized at places in the metasedimentary rocks. Some of these joints contain dikes of biotite-muscovite granite or pegmatite and thus probably formed during folding on the b_1 system. Other joints and fractures cut the biotite-muscovite granite dikes and the host rocks, and some contain slickensides formed during b_2 folding. One of the joints in the Precambrian rocks is probably a cross joint related to b_1 folding. This joint is particularly evident in the tightly folded rocks where it forms planes of parting at right angles to the b_1 lineation measured at the outcrop. As the plunge of b_1 is steep in the Chicago Creek area, the b_1 cross joint is flat. The strike of small relatively flat surfaces is difficult to determine accurately, and consequently the strike direction recorded ranges widely. The readings plotted on a Schmidt net are not concentrated sufficiently to give a prominent high, although field observation suggests that such a joint is present. In the adjacent Freeland-Lamartine district the plunge of the b_1 folds is about 30°; the b_1 cross joint is steep and shows up clearly on the Schmidt net plot of the joints (Harrison and Wells, 1956).

All joints measured in folded Precambrian rocks were plotted on the upper hemisphere of a Schmidt equal-area net. The net was then contoured and the resulting diagram is shown in figure 15. Seven "highs" are believed to be recognizable, 2 of which (V_1 and V_2) are commonly found only near veins and are weakly mineralized. The other 5 highs have been plotted on a stereographic net and the principal linear directions have been added (fig. 16). The stereographic diagram suggests that none of the prominent highs shown on the joint diagram are related to b_1 folds. Two of the highs, c_{b2} and d_r, may represent cross and longitudinal joints related to b_2 folds. The d_r joint that about parallels b_2 in trend, however, may be in part 1 of 4 joints in a system apparently not related to Precambrian folding.

POST-PRECAMBRIAN JOINTS

Joints that are possibly younger than Precambrian include (1) a "regional" joint system composed of 4 joints, (2) joints in the Tertiary dikes, and (3) joints that are found only near veins, are weakly mineralized, and cut Tertiary and Precambrian rocks.

A "regional" set of joints has been proposed and discussed by the writers in a previous report (Harrison and Wells, 1956). This group of joints was first recognized in the adjacent Freeland-Lamartine district. These joint directions show up on figures 15 and 16 and are labeled l_r, c_r, and two d_r's. They are believed to represent a joint system consisting of a longitudinal, a cross, and two diagonal joints superimposed on the Precambrian rocks possibly during Laramide arching that raised the Front Range highland (fig. 1). The longitudinal and cross joints of this system are particularly persistent. That l_r is distinct from c_{b2} is indicated by two distinct highs for the joints in the granodiorite (fig. 13), and by the appearance of c_{b2} on the diagram for the Chicago Creek area where b_2 is well developed. On the diagram for the Freeland-Lamartine district (Harrison and Wells, 1956), where b_2 is weakly developed c_{b2} is apparently absent.



l_r—regional longitudinal joint; d_r—regional diagonal joints; c_r—regional cross joint; c_{b_2}—cross joint related to b_2; b_1—oldest Precambrian fold axis; b_2—younger Precambrian fold axis; a_2—warp axis related to b_2

FIGURE 16.—Stereographic diagram showing main joint sets and principal fold axes.

A group of two or more joints is commonly developed in dikes of Tertiary age. Most outcrops of these dikes contain at least a joint parallel to the dike and one at right angles to it. These joints are confined to the dike and are probably primary igneous longitudinal and cross joints.

Two joint directions (V_1 and V_2 on fig. 15) are most common in Precambrian and Tertiary rocks near veins. These joints commonly are limonite stained or contain traces of pyrite. They form a complementary set of steep to vertical joints trending about north and about east. The writers infer that these joints are related to the Tertiary faults.

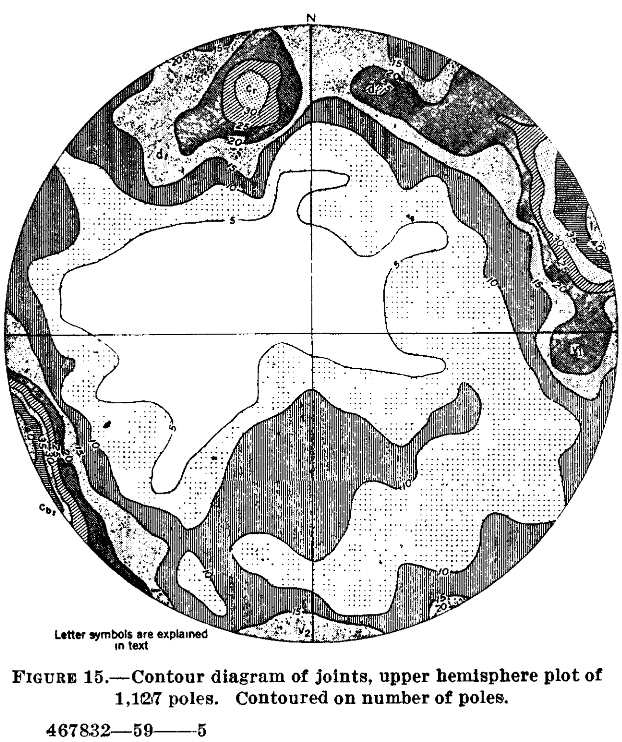


FIGURE 15.—Contour diagram of joints, upper hemisphere plot of 1,127 poles. Contoured on number of poles.

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ORE DEPOSITS

The Chicago Creek area contains veins that bear gold, silver, copper, lead, zinc, and uranium; these deposits were formed as hydrothermal fillings in fault fissures. Replacement of the wall rocks by the ore minerals was unimportant as a method of formation of the ore deposits. Most of the veins have smooth walls; some are lodes, inasmuch as they have a footwall vein and a hanging-wall vein separated by a few feet of altered wall rock that at places contains stringers of vein minerals. Slickensides are abundant, and most are nearly horizontal. The vein fractures are fairly regular in strike and dip, and irregularities, where present, commonly provided favorable structures for the deposition of the ore minerals. Repeated opening of the veins is shown by brecciated gangue and sulfides that are cemented by later gangue and sulfides which at places are of different composition from the earlier vein minerals. Vugs, though not uncommon, are generally small, and the veins tend to be filled completely even where they have been fractured and reopened several times. The vein zones, from fresh wall rock on one wall to fresh wall rock on the other, are generally less than 3 feet wide although some, such as the Little Mattie, are as much as 8 feet wide. The metallic ore minerals exclusive of disseminated pyrite commonly are confined to less than 8 inches of the vein zone.

The principal ore minerals are sulfides and sulfosalts of iron, copper, silver, lead, and zinc. Those that are less abundant but common in the area include native gold, native silver, and hydrous uranium phosphates. Ore minerals that have been mined but are rare in the area include tellurides of mercury or of gold and silver and oxides of uranium.

The gangue minerals include several varieties of quartz and several kinds of carbonate minerals. The most abundant gangue mineral is vein quartz, but locally a very fine-grained variety, called chalcedonic quartz in this report, forms a major part of the gangue. The chalcedonic quartz commonly is colored tan, brown, or black. Small amounts of opal have been reported from a few mines in the area. Carbonates of calcium, iron, magnesium, barium, or manganese form a small part of the gangue in many mines.

Five principal types and one subtype of veins have been recognized in the area on the basis of quantitative mineralogy. (See fig. 17.) In general, pyritic types are mined for gold and galena-sphalerite types are mined for lead and silver. Mixtures of 2 or more of the 5 principal types in a reopened vein or in a lode has resulted in some ore bodies that have been mined for gold, silver, and lead. No veins have been mined specifically for copper or zinc, although these metals have been recovered during processing of many of the ores. One vein (shear zone) has been mined for uranium. In general, all types of veins occur in similar vein structures in all types of host rocks.

The Pb/U determinations on pitchblende from veins in the Central City district (about 5 miles northeast of the Chicago Creek area), made by Holmes (1946) and Phair (1952), indicate an age for those veins of about 60 million years, or early Tertiary. As the veins in the Chicago Creek area are in the same geologic setting as the veins in the Central City district, these two groups of veins are probably the same age.

PRODUCTION

Production from the area has been compiled from several sources, but complete records for all mines were not available. Most of the data have come from records kept by the U. S. Bureau of Mines. These records are nearly complete for the period from 1900 to 1954. Data on production prior to 1900 have come principally from reports of the Director of the Mint on production of gold and silver in the United States. Production for the period from 1885 through 1892 is fairly well recorded in the reports by Kimball (1886, 1887, 1888, 1889) and Leech (1890, 1891, 1892, 1893). Some information on production comes from the geological report by Spurr, Garrey, and Ball (1908) and some from the records of the Idaho Springs Sampling Works. The production figures given in this report should be considered as minimum values, particularly for mines operated prior to 1900.

The total recorded production of zinc is probably less than half of the total taken from the mines. Sphalerite was thrown out on the dumps of the earliest mines and was not paid for consistently at the smelter until about 1910. Most of the mines containing galena contain as much or more sphalerite, but the yield of metals recorded from these mines commonly lists less than half as much zinc as lead.

The total recorded yield of metals from the area to 1955 has been approximately 88,300 ounces of gold, 1,100,000 ounces of silver, 23 tons of copper, 668 tons of lead, 250 tons of zinc, and 4 pounds of uranium. The value of this ore at average 1954 market prices is about $4,500,000. Almost half of the total recorded yield from the area has come from the Little Mattie group of mines.

VEINS AND LODES

CLASSIFICATION

Spurr, Garrey, and Ball (1908, p. 97–101) recognized two types of veins in the Georgetown quadrangle—silver-bearing veins without important amounts of "gold," "galena-blende ores," and gold-bearing veins with or without silver, "pyritic ores." They also recognized (p. 100) that at places both types of ores occurred together.

The writers and their colleagues who have been working in adjacent areas of the Front Range find that the classification used by Spurr, Garrey, and Ball is not adequate to describe all vein types. A classification is used in this report that has pyritic and galena-sphalerite veins as two of the principal vein types. The other three principal types of veins contain conspicuous amounts of copper and silver sulfides and sulfosalts in varying proportions. A graphic representation of this classification is shown in figure 17, where the veins are arbitrarily divided into five types on the basis of quantitative mineralogy. Assay values of ores believed to be representative of some of these vein types are shown on table 12.

The pyritic type of vein, type 1, consists predominantly of pyrite, auriferous pyrite, and quartz. Minor amounts of chalcopyrite, tetrahedrite-tennantite, galena, sphalerite, and carbonate are present in a few of these veins. Type 1 ore is commonly massive, but locally it is weakly layered. The pyritic type of vein is represented by the American Boy and Ella McKinney veins, and possibly the vein at the portal of the P. T. tunnel.

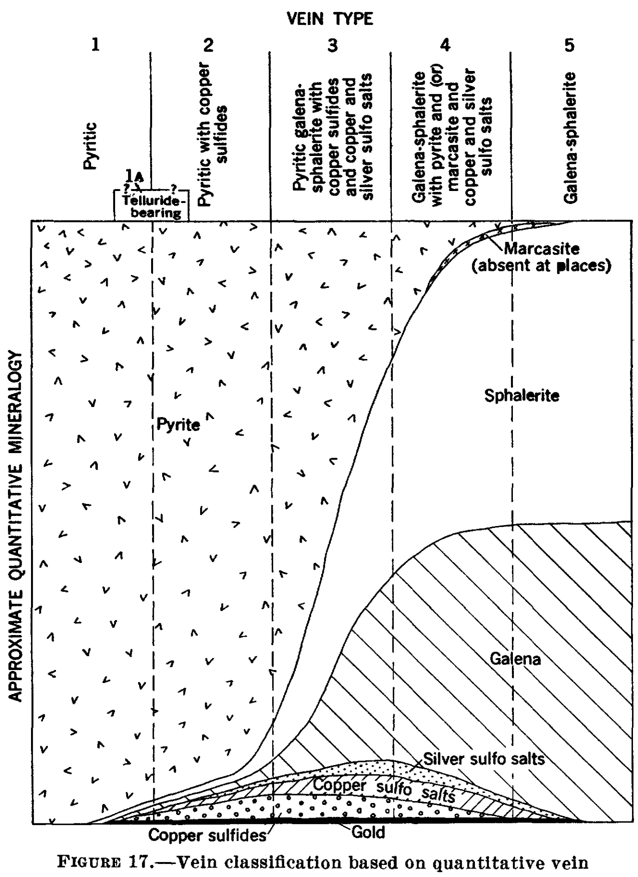


FIGURE 17.—Vein classification based on quantitative vein mineralogy.

A subtype of pyritic vein, type 1*A*, consists predominantly of quartz and pyrite and is telluride bearing. The minor amounts of gold and silver tellurides and of native gold in the ore allow this vein type to be mined economically. Trace amounts of galena and sphalerite have been reported in a vein of this type, and minor amounts of chalcopyrite were seen in polished surfaces of some specimens of some of this ore. The telluride-bearing pyritic type of vein is represented by the West Gold vein.

Type 2 veins, pyritic with copper sulfides, consist predominantly of quartz, pyrite, auriferous pyrite, and chalcopyrite. Minor amounts of carbonate minerals, free gold, tetrahedrite-tennantite, galena, sphalerite, and polybasite are common constituents of these veins. Traces of bournonite, pyrargyrite, and pearceite are found in some of these veins. This vein type is most easily recognized by the abundance of pyrite, its relative lack of galena and sphalerite, and its copper content. Chalcanthite, azurite, and malachite occur in fractures in the vein or cover exposures of the vein in mine workings. The best examples of this vein type are the P. T. and Free Gold veins.

Type 3 veins, pyritic galena-sphalerite with copper sulfides and copper and silver sulfosalts, consist predominantly of quartz, carbonate minerals, pyrite, chalcopyrite, tetrahedrite-tennantite, galena, and sphalerite. Minor amounts of free gold, polybasite, pyrargyrite, pearceite, and argentite are found at places in these veins. This type of vein is commonly well layered and has pyrite as the outer layers and the other sulfide and sulfosalts in the center. Only one vein, the Kitty Clyde, in the Chicago Creek area is of this type.

Type 4 veins, galena-sphalerite with copper and silver sulfosalts and pyrite and (or) marcasite, are the most common in the Chicago Creek area. These veins consist chiefly of quartz, carbonate minerals, galena, sphalerite, pyrite and (or) marcasite, tetrahedrite-tennantite, and polybasite. Minor amounts of flake gold, wire silver, pyrargyrite, pearceite, argentite, and chalcopyrite are common constituents of these veins. Type 4 veins are mined principally for lead and silver. Good examples of this vein type are exposed in the Beaver, Dorit, and King Solomon mines.

TABLE 12.—*Assay values of ores typical of various vein types*

[For explanation of vein type, see fig. 17 and text. Items marked with an asterisk (*) were obtained from assay records of the Idaho Springs Sampling Works; other items were calculated from production records furnished by the U. S. Bureau of Mines. All records are published with permission]

Vein type	Mine name	Year	Gold (oz per ton)	Silver (oz per ton)	Copper (percent)	Lead (percent)	Zinc (percent)
1*A* (telluride-bearing)	West Gold	1926	0.69				
		1927	.66	0.15			
		1928	1.12	.21			
		1930	.07	.06			
		1931	.08	.05			
		1933	1.66	2.39	0.18	1.63	
		1937	.50	.45			
		1940	.10	.17			Trace
2	P. T.	1911	.68	3.60	.60		
		1913	.51	1.77	.20		
		1927*	1.16	3.80			
			.60	8.00	1.27		4.16
		1934*	1.91	5.52	.10	.86	1.98
		1936	.14	.58	.17	.07	
		1940	.16	.86	.17	.10	.23
3	Kitty Clyde	1908	1.63	12.50	2.94	24.30	
		1910	.58	17.00	1.85	31.60	11.80
		1911	.75	12.00	1.90	8.20	3.00
		1912	.82	9.40	.92	5.80	5.30
		1923*	.86	10.80	.50	21.00	11.14
4	Beaver	1902	.80	100.00		35.00	
		1905	.21	3.28		2.62	
		1912	.31	67.00		32.40	14.50
		1916	.29	105.38		19.70	
		1919*	.31	202.51		43.50	17.00
		1935*	.24	40.00		32.60	24.30
		1938	.06	4.20	.23	1.75	3.30
	Black Eagle-Bismarck	1908	.34	14.20	.05		
		1910	.46	32.60	.27	1.09	
		1913	.18	10.60			
		1919*	.49	12.40	.10	8.50	1.50
		1920*	.27	14.75	1.20	29.39	15.20
		1926*	.28	12.87		.50	2.10
		1934*	1.60	40.35		2.40	4.05
		1935*	2.51	74.75	1.00	6.92	8.40
			2.68	45.50	.85	4.40	7.10
			.19	8.35		1.05	1.50
5	Dixie	1939	.71	3.08	Trace	.21	.41
		1945	.52	1.40	Trace	.09	.09
		1951	.83	1.56	Trace	.17	
	Humboldt	1909	.27	.12		.22	.06
		1913	.66	1.27	Trace		
		1934*	.52	1.70		.65	3.80
		1940	.14	.58	.05	.08	.55
		1943	.50	1.05	.64	9.35	11.10
		1951	1.16	2.32		.26	

The galena-sphalerite type of vein, type 5, consists predominantly of quartz, carbonate minerals, galena, and sphalerite. Minor amounts of pyrite and (or) marcasite, polybasite, electrum, tetrahedrite-tennantite, and chalcopyrite are common constituents of these veins. These veins in the Chicago Creek area are mined principally for gold, silver, and lead. The Dixie, Mary Foster, and Humboldt veins are good examples of this vein type even though the veins are narrow and the amount of lead and zinc in the mill ore is only a small part of the total rock tonnage put into the mill. (See table 12.)

The division of the veins into five principal types is artificial, although most veins appear to fall into one of these major groups. Some veins have a quantitative mineralogy that, when plotted on figure 17, is near or on the line separating two types of veins. This is particularly true of many veins in the Chicago Creek area that have been classified as galena-sphalerite with copper and silver sulfosalts and pyrite and (or) marcasite. Some of these veins that do not contain marcasite might as well be classified as pyritic galena-sphalerite with copper sulfides and copper and silver sulfosalts.

Gangue minerals are slightly different in the various vein types. Primary carbonate minerals are most common in the second, fourth, and fifth vein types; they are less common in the third and subtype veins, and they are rare in the first type. Quartz is common in all the types of veins. Coarse-grained quartz is more common, however, in the pyrite-rich ores, and chalcedonic quartz is more common in the galena-sphalerite-rich ores.

The veins are shown on plate 2 as classified into the five principal types and the subtype. As the data for some veins were insufficient to assign them to one of the principal types, they are reported as "type not known." The data on which the division into the vein types is based are set forth in this report in the section dealing with the description of individual mines. These data include some or all of the following: observations from mapping of the mines, assays of ore samples, study of polished surfaces of vein specimens, and production figures of the individual mines.

Mineralization of the vein fractures appears to have taken place in at least two principal stages. Many of the veins showing two stages have a more pyritic vein that has been broken and cemented by less pyritic ores. These veins might be called mixed in that they consist of two types of ores, one cementing breccia fragments or forming stringers crosscutting the other. Two kinds of mixed veins of this type have been seen. One kind, best exposed in the P. T. and Free Gold mines, contains major amounts of quartz, pyrite, and auriferous pyrite that have been brecciated and cemented by pyrite and chalcopyrite accompanied by minor amounts of tetrahedrite-tennantite, polybasite, quartz, carbonate minerals, and auriferous pyrite and trace amounts of galena and sphalerite. Another type of multiple stage vein might be termed mixed lode. This type of vein, exemplified by the Little Mattie, has at places a footwall vein and a hanging-wall vein that are of different vein types. Both the footwall and hanging-wall veins cement broken fragments of quartz and pyrite. At some places, particularly evident in the area along the tunnel 2,100 to 2,400 feet from the portal, the footwall vein is mostly galena, sphalerite, copper sulfides, and copper sulfosalts; but the hanging-wall vein is mostly galena and sphalerite without copper minerals.

PARAGENESIS OF THE VEINS AND VEIN MINERALS

VEIN MINERALOGY

Forty vein minerals, exclusive of the clay minerals in the altered wall rock, have been identified or reported from veins in the Chicago Creek area. These minerals and their chemical compositions are listed in table 13.

TABLE 13.—*Names and chemical composition of vein minerals mentioned in this report*

Name	*Composition*
Altaite	$PbTe$
Ankerite	$Ca(Mg,Fe)(CO_3)_2$
Argentite	Ag_2S
Autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 10\text{–}12H_2O$
Azurite	$2CuCO_3 \cdot Cu(OH)_2$
Barite	$BaSO_4$
Bournonite	$Cu_2S \cdot 2PbS \cdot Sb_2S_3$
Calcite	$CaCO_3$
Cerussite	$PbCO_3$
Chalcanthite	$CuSO_4 \cdot 5H_2O$
Chalcopyrite	$CuFeS_2$
Coloradoite	$HgTe$
Covellite	CuS
Dolomite	$CaMg(CO_3)_2$
Electrum	$Ag \cdot Au$
Freibergite	$5(Cu,Ag)_2S \cdot 2(Cu,Fe)S \cdot 2Sb_2S_3$
Galena	PbS
Gold	Au
Hematite	Fe_2O_3
Krennerite	$(Au,Ag)Te_2$
"Limonite"	$Fe_2O_3 \cdot nH_2O$
Malachite	$CuCO_3 \cdot Cu(OH)_2$
Marcasite	FeS_2
Opal	$SiO_2 \cdot nH_2O$
Pearceite	$8Ag_2S \cdot As_2S_3$
Petzite	$(Ag,Au)_2Te$
Pitchblende	See uraninite.
Polybasite	$8Ag_2S \cdot Sb_2S_3$
Pyrargyrite	$3Ag_2S \cdot Sb_2S_3$
Pyrite	FeS_2
Quartz	SiO_2
Rhodochrosite	$MnCO_3$
Siderite	$FeCO_3$
Silver	Ag
Sphalerite	ZnS
Sylvanite	$AuAgTe_4$
Tennantite	$5Cu_2S \cdot 2(Cu,Fe)S \cdot 2As_2S_3$
Tetrahedrite	$5Cu_2S \cdot 2(Cu,Fe)S \cdot 2Sb_2S_3$
Torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$
Uraninite (pitchblende)	Ideally UO_2, commonly contains UO_3.
Wulfenite	$PbMoO_4$

The most common primary metallic minerals in the veins are pyrite, chalcopyrite, sphalerite, tetrahedrite-tennantite, polybasite, galena, marcasite, and free gold or electrum. Pyrite forms fine- to coarse-grained cubes, pyritohedrons, and subhedral to anhedral grains in those parts of the veins that are not fractured or sheared. Most of the pyrite is weakly to moderately anisotropic and shows polarization colors of pale red to pinkish green. Chalcopyrite forms tiny blebs in sphalerite and occurs in veinlets and patches scattered through many of the ores. Sphalerite has two distinct colors; most commonly it is dark brown to black, but in some ores it has a distinctive red-brown color. Both types of sphalerite form medium- to coarse-grained masses, pods, and veinlets. Tetrahedrite-tennantite occurs in veinlets and patches scattered through the ores and as blebs in sphalerite and (or) galena. Some of the tetrahedrite is probably freibergite, the silver-bearing variety of tetrahedrite. Polybasite is common in silver-bearing ores and forms irregular patches scattered through the ore and tiny blebs in sphalerite, tetrahedrite-tennantite, and galena. Most galena forms coarse grains or granular aggregates in discontinuous stringers, patches, or pods. Marcasite commonly is in tiny blades or aggregates of blades and is at places intergrown with pyrite. Free gold and electrum commonly occur in blebs in pyrite, marcasite, and sphalerite; less commonly they form irregular patches along grain boundaries or occur in veinlets with galena or sphalerite. Some electrum in the Dixie mine forms in vugs as flakes as large as half an inch in diameter; these flakes commonly are coated by a veneer of clear quartz.

The most common secondary minerals in the veins are covellite, azurite, malachite, and chalcanthite in the copper-bearing veins; "limonite" and hematite in the pyritic veins; cerussite and wulfenite in some of the lead-bearing veins; and torbernite, autunite, and sooty pitchblende in uranium-bearing veins. Some of the silver-bearing veins contain argentite and polybasite that may be supergene in origin. Only the secondary uranium minerals and possibly secondary silver minerals are of economic importance in the ores of the Chicago Creek area.

Gangue minerals in the veins are mostly forms of silica and various carbonates. In general, the more pyritic veins contain clear to white coarse- to fine-grained quartz as the principal gangue mineral; siderite, ankerite, and calcite form a small part of the gangue in these veins. The less pyritic veins that are richer in galena and sphalerite contain coarse-grained to chalcedonic quartz and, commonly, calcite, dolomite, ankerite, and rhodochrosite. In all the veins, quartz commonly cements fragments of brecciated sulfide ore. The brecciation and cementation is particularly evident in galena-sphalerite-rich ores that may contain clear quartz and 2 or 3 different colors of chalcedonic quartz; each succeeding color of quartz may cement broken fragments of preceding quartz and sulfides.

PARAGENETIC SEQUENCE

The paragenetic sequence of the vein minerals for individual veins, based on field and laboratory observations is given in this report with the description of individual mines (pp. 47–88). The general statements made in this section are based on the more detailed descriptions presented in the later section.

The paragenetic sequence of the primary vein minerals is consistent throughout the area. Single veins or individual components of a mixed lode show the following sequence of deposition: (1) quartz intergrown with pyrite and (or) marcasite; (2) sphalerite commonly containing blebs of chalcopyrite; (3) chalcopyrite, tetrahedrite-tennantite, and polybasite—commonly, but not always, in that order; and (4) galena. This sequence is reflected by a pronounced layering in many veins.

Several paragenetic trends and slight differences exist among the various vein types. As is indicated on figure 17, marcasite is uncommon in all but the galena-sphalerite-rich veins. Primary carbonate minerals are most common in the second, fourth, and fifth types of veins where they are generally intergrown with quartz and pyrite but at places are postsphalerite. Quartz trends from coarse grained through fine grained to chalcedonic where more than one generation is present in any vein. Coarse-grained quartz is more common in the pyrite-rich ores, and chalcedonic quartz is more common in the galena-sphalerite-rich ores. Sphalerite tends to contain abundant blebs of chalcopyrite in the pyrite-rich ores, but it contains few or no blebs of chalcopyrite in the galena-sphalerite-rich ores. Limited data on the occurrence of free gold suggest that most of the gold is early in the paragenetic sequence in pyrite-rich ores and late in the sequence in galena-sphalerite-rich ores. Gold tends to be in blebs in pyrite in the pyrite-rich ores but is in veinlets with sphalerite or tennantite in some of the less pyritic ores and is in veinlets with galena, or embays and corrodes galena, in some of the most galena-sphalerite-rich ores.

GENESIS OF THE VEINS

The writers believe that the veins are the result of 2 processes that occurred practically simultaneously—(1) repeated fracturing that at places resulted in younger fractures parallel to older fractures and at other places resulted in younger fractures at some slight angle to older fractures; and (2) mineralization by solutions that filled the fractures as they were formed and whose chemical composition changed in character from iron depositing to lead-zinc depositing with time.

Fracturing and refracturing, apparent along most veins in the area, is shown by brecciation and cementation of wall rock and ore. The brecciated ore may be cemented by similar or quite different ore and gangue minerals. At places the younger minerals are undeformed and follow fractures that are parallel to one wall of a deformed vein, down the center of a deformed vein, or cut sharply across a deformed vein. In a few places one fracture is clearly offset by the other, but at most places no offset is recognizable.

The filling of fractures as they were formed is inferred from two observations. The veins contain little or no open space. Where refracturing, at some places multiple refracturing, is across or parallel to one wall of an older vein, the undeformed older parts are solid.

The change in character of the ore solutions with time is suggested by the mineralogic characteristics of the composite veins. In every multiple-stage vein where age relations are clear, the older parts are more pyritic than the younger parts. The two most common varieties of multiple-stage veins are those containing abundant copper minerals that cement fractured pyritic ore and those containing predominantly lead and zinc minerals that cement fractured pyritic ore. The type of vein classified as pyritic with copper sulfides has never been seen where it was not multiple stage. In some of the mixed-lode type of veins, 2 kinds of lead-zinc-rich veins occur, 1 on the foot wall and 1 on the hanging wall. Because both of the lode veins are in the same kind of structures and the same kinds of host rocks, the writers infer that these different kinds of veins represent deposition from ore solutions of somewhat different character. These lode veins cross at places but are not well enough exposed in critical areas to show age relations. The fact that they do cross but are different in character suggests that they were deposited at different times.

Determination of the exact nature of the ore-forming fluids is beyond the scope of this study, but certain conclusions regarding apparent changes seem worth mentioning. If the ore solutions changed with time and if the component parts of the multiple-stage veins represent this change, then the solutions changed from iron depositing through copper depositing to lead-zinc depositing in character. Vertical lines drawn through figure 17 do not necessarily represent either an ore stage or the components in solution at any given time because the three middle vein types are, or may be, multiple-stage veins formed by repeated fracturing and mineralization. Thus the quantity of any given mineral in a multiple-stage vein or mixed lode depends on the amount of "stage one" minerals mixed with "stage two" minerals and is, therefore, a function of the amount of open space formed by reopening of a vein as well as a function of the nature of solution that deposited minerals in that open space. The observation that any undeformed vein or stringer contains all, or nearly all, of the common vein-forming minerals in a remarkably uniform paragenetic sequence suggests to the writers that principal differences in "ore stages" were primarily differences in quantitative mineralogy and not qualitative mineralogy.

In general, all types of veins occur in similar vein structures in all types of host rocks. The writers infer from this observation that in the Chicago Creek area the structure, or open space, was more important in controlling mineral deposition than was the chemical composition of the host rock. The general geographic distribution of the vein types shown on plate 2 where the pyrite-rich veins are shown to be concentrated in the northeast part of the area may, therefore, have significance in showing a hypogene zoning of the ore deposits.

Further evidence of such a zoning needs to come from areas adjacent to that mapped for this report, and no further discussion of such a zoning seems warranted at this time.

The following genesis is inferred for the veins of the Chicago Creek area:

1. The mineralization was by fluids continuously leaving a source that changed quantitatively with time at the source from predominantly iron-depositing through predominantly copper-depositing to predominantly lead-zinc-depositing solutions.

2. The fractures were filled as they were formed; early fractures were filled with pyritic ores, later fractures with cupriferous ores, and still later fractures with galena-sphalerite ores.

3. The formation of multiple-stage veins or mixed lodes was caused by one or more reopenings of a filled fissure and by deposition of the minerals characteristic of the source fluids. These fluids changed at the source with time so that the relative quantities of minerals deposited in a fissure were dependent on the time of opening of that fissure.

This interpretation of data leads to the conclusion that the vein type at any given place in the Chicago Creek area and at any given place along a given vein depends upon (1) the time of first opening of the fracture and the chemical composition of the hydrothermal solution at that time, (2) what parts of the fracture were reopened and at what time in the "differentiation" of the vein fluids, and (3) how much open space was formed during any reopening.

Because of the close spatial relationship between the Tertiary intrusive rocks and the veins in the Front Range mineral belt, Lovering and Goddard (1950, p. 75–76) have inferred that the Tertiary magmas were the source of the solutions that deposited the ores.

WALL-ROCK ALTERATION

A detailed study of the wall-rock alteration in many mines of Gilpin and Clear Creek Counties, Colo.—including several mines in the Chicago Creek area—is in progress while this report is being written. The methods of study and a few of the preliminary results have been reported by Tooker (1955). The statements made here are generalized from field observations of the writers and from Tooker's preliminary data.

The vein zone, meaning the area between fresh rock on one wall and fresh rock on the other, most commonly consists of successive, but variable, alteration "envelopes" around a vein. In general, the vein zone contains an outer argillized zone, an inner sericitized and silicified zone, and a more or less centrally located vein. If the vein zone is a lode, the central part is commonly a horse (country rock) between two veins. The horse, if narrow, is generally silicified and sericitized; if it is wide, it may also be argillized or perhaps contain nearly fresh country rock in its center. Generally, the horses are strongly pyritized and at places contain stringers of ore. The alteration along minor fractures outside of the principal vein zones duplicates, in miniature, the alteration along the principal vein zones.

Most of the wall rocks found in the Chicago Creek area contain abundant silica and iron in the form of quartz, feldspar, biotite, and (or) hornblende, and magnetite. It seems reasonable to believe that part of the silica and iron found in the veins has been derived from the wall rock by metasomatic processes. Many small fractures in wall rock outside of the principal vein zones contain traces of quartz and pyrite regardless of the vein type with which they are associated. These minor amounts of quartz and pyrite in small fractures and some of the quartz and pyrite in the principal vein zones may have had their silica and iron derived from the wall rock in which they occur by processes that added, at least, water and a small amount of sulfur to the wall rock.

ABNORMAL RADIOACTIVITY OF VEINS AND ROCKS

No large amount of uranium had been produced from the Chicago Creek area by 1955, but several shows of radioactivity from relatively low-grade materials have been found in the area. Only one mine, the Martha E, containing a significant amount of radioactivity has had any exploration work done. Veins containing radioactivity tend to have greater concentrations of uranium-bearing minerals than the rocks in the Chicago Creek area. Certain of the Precambrian and Tertiary rocks, however, do have a nearly uniform and characteristic radioactivity and are potential sources for very large tonnages of very low-grade ore.

Significant amounts of abnormal radioactivity and the occurrence of uranium-bearing minerals in veins appear to be limited to galena-sphalerite-rich veins and to one vein or vein system in a group of subparallel veins. Four veins or vein systems, the Bruce-Eclipse-Muscovite, the Martha E-Gomer, the Chicago-Bismarck, and the Dixie-Humboldt, contain most of the abnormal radioactivity. Each of these vein systems is a member of a group of similar subparallel veins, but the others in the group contain no abnormal radioactivity. No apparent relation exists between the vein systems containing the abnormal radioactivity, the host rocks of these veins, or the geographic distribution of the radioactivity.

The biotite-muscovite granite and its associated pegmatite are highly radioactive relative to the other Precambrian rocks. Abnormally radioactive pegmatites were noted in several mines or on several mine dumps. Some of the secondary uranium minerals and abnormal radioactivity noted along veins in the area may be due to deposition of uranium minerals from ground water that leached uranium from the granite or pegmatite. The characteristic radioactivity of the Tertiary rocks is shown in table 10.

The mines and mine dumps that contain radioactivity of at least twice the background on a rate meter with a 6-inch beta-gamma probe are listed on the following pages in alphabetical order; the assay data have been condensed in table 14.

In the following descriptions, the number in parentheses after the property name refers to the location on plate 2.

Alpine (7).—One sample of radioactive limonitic vein material assaying 0.008 percent equivalent uranium and 0.002 percent uranium was taken from the Alpine dump. About 1 percent, 28 square feet, of the surface area of the dump is radioactive.

Bismarck (160).—A few cubic feet of radioactive vein material was found under the ore bin. This material had radioactivity of about twice background.

Blackwood (11).—The dump of the small shaft contained a small area, about 3 square feet, of radioactive limonitic vein material. A sample taken from this area assayed 0.011 percent equivalent uranium and 0.005 percent uranium.

Bruce (94).—Abnormal radioactivity was found on the main Bruce shaft dump and on the dump of a small prospect shaft about 2,000 feet to the east. On the main dump the anomaly was somewhat less than twice background on an area of about 10 square feet.

TABLE 14.—*Radioactivity of samples collected from mines and mine dumps*

[All samples are grab samples. Analysts: S. P. Furman, R. F. Dufour, J. S. Wahlberg, Wayne Mountjoy, J. P. Schuch, H. I. Peterson, M. T. Finch, G. W. Boyes, Jr, J. E. Wilson, J. E. Johnson, and J. L. McGurk, all of the U. S. Geological Survey]

Mine no. (pl. 2)	Mine name	Material sampled	Sample no.	Equivalent uranium (percent)	Uranium (percent)
7	Alpine	Limonitic vein material on dump	Alp-1	0.008	0.002
11	Blackwood	Limonitic vein material on dump	JEH-419-1	.011	.005
94	Bruce	Limonitic vein material on dump	JEH-406-1	.009	.007
45	Brunswick	Limonitic vein material on dump	KE-1	.006	.002
161	Chicago	Footwall of friction breccia	Ch-2	.032	.033
40	Dixie	Limonitic vein material on dump	Dix-1	.012	.009
77	Eclipse	Limonitic vein material on dump	Ecl-1	.006	.003
129	Gomer	Vein material (mostly sphalerite) on dump	JEH-1	.068	.072
42	Humboldt	Brecciated vein material containing scattered flakes of torbernite and thin coatings of sooty pitchblende.	MF-1	.10	.012
48	Katie Emmett	Limonitic vein material on dump	JEH-428-1	.018	.004
125	Martha E	18-inch shear zone to 8-inch-thick pod of sooty pitchblende and altered wall rock.	WWW-40 to ME-A	.003 to .55	.002 to .91
75	Muscovite	Altered granite containing flakes of torbernite on dump.	Mus-1	.047	.046
102	Orinoco	Pegmatite on dump	GG-1	.18	.22
63	Silver Link	Limonitic vein material on dump	EM-1	.007	.002
87	Silver Ring	Limonitic vein material on dump	Sil-1	.028	.028
26	Wallace	Limonitic vein material on dump	Arg-1	.014	.006

A sample of limonitic vein material was taken from the dump of the prospect shaft. This material assayed 0.009 percent equivalent uranium and 0.007 percent uranium. One-third of the dump, 65 square feet, showed anomalous radioactivity.

Brunswick (45).—About one-fourth of the Brunswick tunnel dump is abnormally radioactive. A sample of limonitic vein material collected from the dump assayed 0.006 percent equivalent uranium and 0.002 percent uranium. No abnormal radioactivity was found underground, but only a very small part of the mine was accessible.

Chemung County (71).—The dumps of the shaft, the tunnel to the east, and the prospect shaft to the west show abnormal radioactivity in the order of twice background. Only small areas of vein material on each dump were radioactive.

Chicago (161).—One area of abnormally radioactive material was found about 120 feet from the portal of the mine. The area was at the junction between a friction breccia and a gougy pyritic and copper-stained vein. A 9-inch chip sample from the footwall of the friction breccia assayed 0.032 percent equivalent uranium and 0.033 percent uranium. (See fig. 23 for location.) No discrete uranium minerals could be identified.

Columbia (143).—About 20 square feet of vein material on the dump was found to be radioactive to the extent of slightly more than twice background.

Dixie (40).—The radioactive material was found on about 200 square feet of the dump of the Dixie tunnel. A sample of the limonitic vein material assayed 0.012 percent equivalent uranium and 0.009 percent uranium. No abnormal radioactivity was found underground on the accessible parts of the vein.

Eclipse (77).—About one-fourth of the dump surface is abnormally radioactive. A sample of vein material taken from this area assayed 0.006 percent equivalent uranium and 0.003 percent uranium.

Gomer (129).—About half of the dump surface shows abnormal radioactivity. The radioactivity is associated with the vein material, which consists principally of sphalerite and quartz with minor amounts of pyrite and galena. A grab sample of the radioactive vein material assayed 0.068 percent equivalent uranium and 0.072 percent uranium. No discrete uranium minerals could be identified.

Humboldt (42).—Two areas containing abnormal radioactivity were found on the third level of the Humboldt mine. One of the areas begins 465 feet from the portal and extends about 30 feet southwest (fig. 35). The first 5 feet shows the highest radioactivity. A grab sample (MF-2) of brecciated quartz, chalcedony, and pyrite assayed 0.045 percent equivalent uranium and 0.003 percent uranium. The other radioactive area begins about 566 feet from the portal and extends 4 feet to the southwest; the radioactive area is about 8 feet high. A grab sample (MF-1) of brecciated and vuggy quartz, chalcedony, and pyrite containing scattered flakes of torbernite and thin coatings of sooty pitchblende assayed 0.10 percent equivalent uranium and 0.012 percent uranium.

Katie Emmett (48).—A small area, about 200 square feet, of radioactive limonitic vein material was found on the dump of the lower tunnel. A sample of this material assayed 0.018 percent equivalent uranium and 0.004 percent uranium.

In a subsequent underground examination, a radioactive portion of the vein was found in the lower tunnel at an intersection of two weakly mineralized limonitic gouge veins 210 feet from the portal. (See fig. 37.) No uranium minerals were identified.

Martha E (125).—The Martha E mine and the radioactivity of the shear zone exposed in the mine will be discussed more fully in the section of this report containing the description of individual mines. The uranium minerals found in the mine include torbernite, autunite, and sooty pitchblende. Assays of channel samples collected during a systematic sampling of the winze are shown on plate 10.

Muscovite (75).—About half of the surface of the upper dump shows abnormal radioactivity. This radioactivity is apparently confined to fractured fragments of biotite-muscovite granite that contains torbernite along fractures and disseminated through the rock with biotite. A grab sample of this radioactive material assayed 0.047 percent equivalent uranium and 0.046 percent uranium.

Orinoco (102).—The abnormal radioactivity of the Orinoco dump is limited to a 10- by 10-foot area near the portal. The radioactive material is pegmatite and not associated with vein material. A grab sample from the dump assayed 0.18 percent equivalent uranium and 0.22 percent uranium. After the results of the assay were known, the surface above the tunnel —the tunnel was inaccessible because of bad air— was examined for radioactivity. During this examination, a radioactive pegmatite dike was found in outcrop about 200 feet up the slope from the portal. The pegmatite is believed to be associated with the biotite-muscovite granite.

"Q" shaft (64).—Abnormal radioactivity of slightly more than twice background was found in the small area where the oxidized galena, sphalerite, tetrahedrite, pyrite, and quartz ore was dumped.

Rhoda (37).—The abnormal radioactivity on the dump is about twice background from a small area of limonitic vein material.

Silver Bell (85).—One small area in the Silver Bell mine showed abnormal radioactivity of about twice background. The radioactive area, about 3 feet long, is along the Eclipse vein 30 feet southwest of its junction with the Gold Eclipse vein (fig. 43). No discrete uranium mineral could be identified.

Silver Link (63).—The abnormal radioactivity is limited to a small area of limonitic vein material on the dump. A grab sample taken from this area assayed 0.007 percent equivalent uranium and 0.002 percent uranium.

Silver Ring (87).—An area about 10 feet long and 3 feet wide on the lower tunnel dump showed abnormal radioactivity. A sample of the limonitic vein material assayed 0.028 percent equivalent uranium and 0.028 percent uranium.

Stover (72).—Limonitic vein material on the dumps of the pits has abnormal radioactivity of about twice background.

Sulitelma (35).—Abnormal radioactivity in the order of twice background occurs on the tunnel dump. The radioactivity is with vein material on a small part of the dump.

Thirty Second (73).—A small amount of radioactive limonitic vein material is on the dump of the tunnel in the valley of Maximillian Gulch. The abnormal radioactivity is about twice background.

Tyone (50).—A small amount of radioactive material is on the lower tunnel level about 680 feet from the portal (fig. 45). A fracture at the end of a short crosscut tunnel contains a film of black radioactive material tentatively identified as sooty pitchblende. On the wall a few feet beyond the crosscut tunnel is a small area of radioactive, recently formed, limonitic precipitate.

Viking (69).—A small pile of limonitic vein material on the dump has about twice background abnormal radioactivity.

Wallace (26).—A few abnormally radioactive limonitic vein fragments were found on the dump of the Wallace tunnel. A sample of the material assayed 0.014 percent equivalent uranium and 0.006 percent uranium. No abnormally radioactive areas were found underground along the accessible parts of the veins.

LOCALIZATION OF THE ORE BODIES

Because the ore bodies are within the veins which are in the faults, the location of the ore bodies is related to the location of the veins and faults. The veins and faults tend to be subparallel to the gross fabric of the bedrock; that is, subparallel to foliation, axial planes of tight folds, contacts between rock units, or preexisting joints. The veins containing the widest alteration zone and generally the larger ore shoots, however, are those in the northeast-trending Tertiary fractures that cut across the fabric of the Precambrian rocks. These crosscutting veins, such as the Little Mattie, may follow contacts between Tertiary dikes and Precambrian gneisses. The next widest veins are those that are subparallel to axial planes of tight folds. Less wide are those that follow preexisting joints or contacts between Precambrian rock units. The narrowest veins are those that are along foliation planes; these veins widen perceptibly where they cut across the foliation or cut through a tight fold. In summary, the veins that are the least related to the folds described in detail (pp. 27–33) are the better prospects for ore; those that follow the folds by following the foliation of the rocks outlining the folds are the poorest prospects for ore.

Information on localization of the individual ore bodies within the veins in the Chicago Creek area is sparse inasmuch as many of the former producing mines are mostly or completely caved. Most of the ore bodies occur as shoots, lenses, or pods and are probably localized by structural features. Sufficient data have been gathered on a few ore bodies to indicate that vein intersections, changes in strike or dip of veins, deflections in the vein where the fault enters a rock of different competency, or a combination of these factors have served to localize ore bodies. A chemical control related to the type of wall rock apparently was unimportant as a factor localizing ore bodies.

ORE BODIES AT VEIN INTERSECTIONS

Vein intersections appear to have localized ore bodies in the Black Eagle group of mines, in the Columbia mine, and in the Quito mine. In the Black Eagle group of mines the 3 main ore bodies are at vein junctions (figs. 22 and 23); 1 is at the junction of the Chicago and Black Eagle veins, 1 at the junction of the Chicago and Bismarck veins, and the third is in the Chicago tunnel at the junction of the Chicago vein and a series of northeast-trending fractures. The principal ore body in the Columbia mine is in the area where 2 branches of the Columbia vein join (Spurr, Garrey, and Ball, 1908, p. 366). The stoped area in the Quito mine (fig. 42) appears limited to the vicinity of the junction of the Quito and P. T. veins.

On a smaller scale, vein intersections are also sites of wider ore. Ore is thicker at some splits in veins and is commonly thicker at the edges of a horse where individual splits of a branching vein rejoin.

ORE BODIES ALONG DEFLECTIONS IN DIP OF VEINS

Ore bodies localized along deflections in dip of veins are present in the Free Gold and the P. T. mines. The stoped area in the Free Gold mine is limited to the part of the main vein that dips less than 50°. The ore body mined near the P. T. shaft obviously was also on the flatter part of the vein. This body, however, may also be related in position to vein deflection through a rock of different competency.

ORE BODIES ALONG DEFLECTIONS IN STRIKE OF VEINS

The principal ore bodies in the Dixie, Humboldt, and West Gold mines appear to be localized along deflections in strike of veins. Ore bodies along the Dixie-Humboldt vein have been found principally on the east-northeast-trending parts of the vein and are rare on the north-northeast-trending part (pl. 4 and fig. 34). The apparent horizontal offset along the fault containing the Dixie-Humboldt vein has been northwest block to the northeast, and this movement is in accord with the concept (Newhouse, 1940) that open space would be formed along the more easterly-trending parts of the fault. Some of the stoped areas above the fifth level of the Dixie, however, are not clearly related to deflection in strike and may be related to deflection in dip or a combination of deflection in strike and dip. The principal ore body in the West Gold mine is limited to the east-trending part of the vein (fig. 48), but vein intersections might have helped localize the ore body too.

ORE BODIES ALONG FAULT DEFLECTIONS DUE TO ROCK TYPE

The ore bodies along the Beaver and Washington veins apparently are limited to the parts of the vein that cut through a dike of biotite-muscovite granite. Deflection of the vein through the dike is shown in the workings of the Beaver mine (pl. 3). The dike is a more brittle rock than the micaceous gneisses that it transects. Newhouse (1942) has summarized observations of several geologists on this type of fault deflection. According to theory, the fault containing the Beaver vein is probably a reverse fault because it flattens in dip upon entering the dike, and the vein is wider in the dike.

DESCRIPTION OF INDIVIDUAL MINES

About 60 mines are scattered throughout the Chicago Creek area. They range in size from those having only a few hundred feet of drifts to those having several miles of drifts. The largest mine in the area is the Little Mattie, which consists of more than 2,200 feet of shafts and 5 miles of drifts. The average size of the larger mines is on the order of a few thousand feet of workings; these larger mines include the Beaver, Big Forty, Black Eagle group, Cecil-Argo group, Dixie, Dorit, Humboldt, King Solomon, Kitty Clyde, Little Mattie group, P. T., Silver Ring-Muscovite, and West Gold. The deepest of these is the Little Mattie, which has workings that are more than 1,200 feet below the surface. Many of the mines were driven as crosscuts to the north or northwest to intercept the numerous northeast-trending veins, particularly to intercept what were thought to be southeast extensions of the rich Little Mattie vein. During 1953, 1954, and the first half of 1955 only the Dixie mine was in continual operation; the Humboldt, Martha E, and West Gold mines each had a small amount of exploration work done in them.

Because many of the mines in the Chicago Creek area were partly or completely inaccessible during 1953–55, much of the underground geology was not available for study by the writers. Information on the underground workings of inaccessible mines was obtained from several sources and is acknowledged on the appropriate maps. Some of the accessible mines had been flooded in previous years, and the mine walls were coated by thick accumulations of blasting dust, muck, and limonitic slime which allowed only sketchy observation in the mines.

The mining terms used in this report are those that are in general usage by the local miners. Any nearly horizontal passageway from the surface is called a tunnel in this report; as none of these passageways extend completely through a hill, they are preferably called adits. Any inclined passageway used as a main haulageway for ore is called a shaft regardless of whether the collar is at the surface or in the underground workings. A mine is any underground workings of moderate extent regardless of whether the property has ever had ore produced from it; tunnel is used commonly in the name of the property if it has had little or no ore produced from it and if its main haulageway is an adit.

In the following descriptions, the number in parentheses after the mine name refers to the location in plate 2.

ALEXANDER TUNNEL (33)

The portal of the Alexander tunnel, at an altitude of 9,630 feet, is on the valley slopes southwest of Ute Creek about 4,600 feet S. 10° W. of Lamartine (pl. 2). The workings consist of a 356-foot tunnel trending about S. 65° W. and a water-filled winze 35 feet from the portal (fig. 18). No stoping has been done above the tunnel level.

Although no record of production could be found for the years prior to 1907, Spurr and Garrey (Spurr, Garrey, and Ball, 1908) visited the mine in 1906 and state (p. 371) that "a little ore running between 200 and 300 ounces in silver to the ton" had been obtained from the mine. The available records show that the mine was operated in 1907, in 1917, and 1925–30. During these periods of operation 46 tons of ore was shipped; this ore yielded 21.77 ounces of gold, 892 ounces of silver, 53 pounds of copper, 3,331 pounds of lead, and 3,796 pounds of zinc. This ore presumably was mined through the winze and came from below the tunnel level.

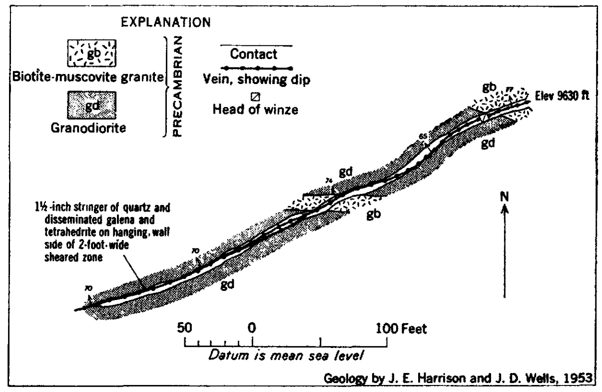


FIGURE 18.—Geologic map of the Alexander tunnel.

The wall rock is predominantly granodiorite that is cut by dikes of biotite-muscovite granite and pegmatite.

The vein on the tunnel level strikes about N. 65° E. and dips 65°–77° NW. It consists of a 2-foot sheared zone that at places contains thin stringers of quartz, galena, and tetrahedrite on the hanging-wall side of the lode zone. Some brown chalcedonic quartz stringers were noted near the tunnel portal. The production records suggest that sphalerite was present along the vein where the ore was obtained.

ALPINE MINE (7)

The collar of the Alpine shaft, at an altitude of 10,315 feet, is near the saddle in Alps Mountain (pl. 2). At the time of the writers' visit, the shaft was caved and the mine inaccessible. The mine workings in 1902 consisted of a shaft that connected with drifts on two levels (fig. 19).

Spurr, Garrey, and Ball (1908, p. 333) report that considerable ore was produced from the mine before a fire (in 1906) destroyed the shaft house. The only record of production from the mine is that given by Leech (1892) for the year 1891. During 1891, ore from the mine yielded 25 ounces of gold and 1,550 ounces of silver.

The vein, which strikes about N. 65° E. and dips about 62° NW., is in biotite-muscovite granite. The vein probably extends to the southwest as the vein seen at the Roca shaft and to the northeast, into the Freeland-Lamartine district, as the vein seen in the Miller tunnel. Ore from the ore bin contained galena

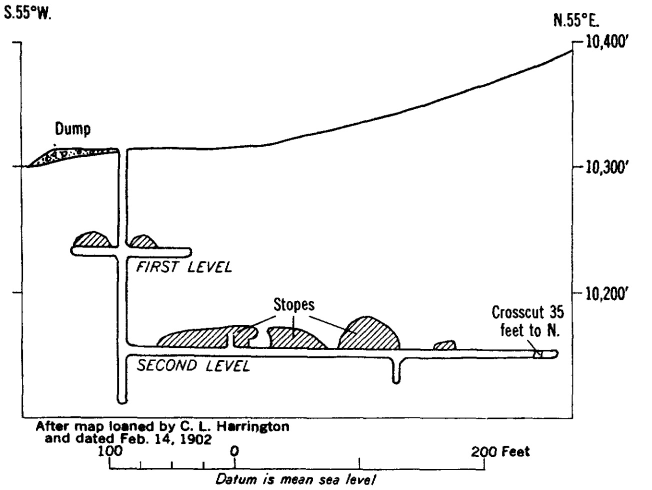


FIGURE 19.—Vertical longitudinal section of the Alpine mine.

and sphalerite with minor amounts of pyrite, tetrahedrite, and argentite (Spurr, Garrey, and Ball, 1908, p. 333).

ARTHUR MINE (113)

The collar of the Arthur shaft, at an altitude of 8,447 feet, is on the northwest slope of Chicago Creek valley and is about due north of the prominent bend in Chicago Creek (pl. 2). At the time of the writers' visit the mine was inaccessible.

According to Spurr, Garrey, and Ball (1908, p. 363), the mine consists of a shaft connecting with several levels and a tunnel that begins near the shaft house and extends about 450 feet northeast along the vein. Some stoping was done above the tunnel level, and somewhat more stoping was done in the shaft workings.

The only record of production for the mine was found in the files of the U. S. Bureau of Mines. This record shows a shipment of 3 tons of ore in 1916 and 1 ton of ore in 1925. This ore yielded 0.95 ounce of gold and 141 ounces of silver.

The Arthur vein, which strikes about N. 52° E. and dips about 75° NW., is probably one of several southwest-extending branches of the Little Mattie vein (pl. 2). The vein is in granite gneiss and pegmatite and consists of "crushed gneiss, pegmatite, and clay, 6 inches to 2 feet wide, which gives way in places to a silicified gneiss or quartz streak of the same width carrying some galena and zinc blende" (Spurr, Garrey, and Ball, 1908, p. 363).

BEAVER MINE (154)

The collar of the Beaver shaft, at an altitude of 8,007 feet, is in the second gulch east of Cottonwood Gulch (pl. 2). The mine workings consist of an inclined shaft about 250 feet deep and more than 1,100 feet of levels and winzes connecting with the shaft (pl. 3). The tortuous character of the mine workings is due to the intersecting of veins of opposing dip and to the gently rolling character of the Beaver vein (*a* on pl. 3).

Records of the Bureau of Mines on production from the Beaver mine are complete for the years 1901–55. The mine was being worked, however, before adequate records were kept and considerable stoping had been done prior to 1904, when the mine was mapped by Spurr (Spurr, Garrey, and Ball, 1908, fig. 144). The available records indicate that the mine was worked almost continuously from 1901 to 1920, and then again from 1934 to 1938. During these periods of operation, 1,116 tons of ore was shipped. This ore yielded 454.22 ounces of gold, 28,519 ounces of silver, 2,152 pounds of copper, 273,501 pounds of lead, and 13,587 pounds of zinc.

The wall rock in the mine consists of biotite-muscovite granite and biotite-quartz-plagioclase gneiss that is locally migmatitic and (or) sillimanitic. The gneiss is tightly folded and contorted; one fold axis can be traced through the mine workings (pl. 3) and possibly correlates with a similar type of axis found on the surface (pl. 1). The biotite-muscovite granite in the mine is probably the dike seen on the surface, but faulting, folding, and possible branching of this dike make positive correlation difficult.

The mine has developed a group of intersecting veins that strike northeast to east and dip from south through horizontal to north. In general, the veins can be divided into two groups on the basis of their attitudes; one group strikes northeast and dips 30°–55° SE., the other strikes northeast to east and dips from 18° S. through horizontal to 54° N. (pl. 3). The two main veins are called the Beaver vein and the Washington vein. The Washington vein appears to offset the Beaver vein west of the shaft but to join it at the shaft. Surface traces of these veins have been mapped more than half a mile northeast from the shaft collar and several hundred feet southwest of it (pl. 2). Although the veins have been prospected along their exposed length, no extensive development has been done other than that in the Beaver mine and through a shaft in the first gulch east of Cottonwood Gulch.

All of these veins are sheared and altered zones 2 to 24 inches wide, containing stringers of ore. These stringers commonly are half an inch to 2 inches wide and uncommonly are as much as 5 inches wide. They consist principally of quartz, pyrite, galena, black sphalerite, and (or) red-brown sphalerite. At places minor amounts of chalcopyrite were noted in the mine, and traces of tennantite, polybasite, covellite, marcasite, pyrargyrite, and free gold were seen in polished surfaces of the ore. A suite of polished surfaces of ores from the Beaver and *c* veins yielded the following information on paragenesis of the vein minerals. Pyrite, at places intergrown with minor amounts of marcasite, commonly is intergrown with coarse-grained quartz. Sphalerite containing abundant blebs of chalcopyrite coats and embays pyrite. Tennantite and polybasite, at places with chalcopyrite, vein and fill fractures in pyrite and sphalerite. Galena, some of which appears deformed, fills fractures in pyrite and sphalerite and contains blebs and irregular patches of polybasite, pyrargyrite, and tennantite. One bleb of free gold was seen along a contact between pyrite and sphalerite. Quartz and covellite fill some fractures in galena; cerussite, in fractures cutting through early quartz and all sulfides, forms dendritic and interlocking netlike patterns in galena. The paragenetic sequence is shown diagrammatically in figure 20.

The location of certain of the ore bodies and offsets of certain rock units and veins suggest that most of the veins occupy faults formed by reverse movement. On the third level of the mine, the Beaver vein reverses its dip at the contact between biotite-muscovite granite and biotite-quartz-plagioclase gneiss. The position of the stopes suggests that the ore was better on the south-dipping part of the vein. Thicker ore in such a structural position along the vein is in accord with the concept of flattening of a reverse fault upon entering a more brittle rock. The Beaver vein is offset about 8 feet in apparent dip-slip displacement by reverse movement on the Washington vein

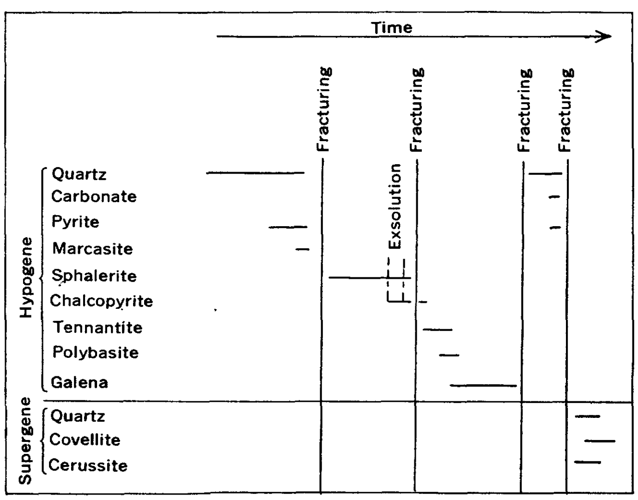


FIGURE 20.—Paragenetic diagram for the vein minerals of the Beaver vein.

(pl. 3). Vein *h* offsets vein *g* about 2 inches in apparent reverse dip slip; and vein *b* or *c* appears to have offset the biotite-muscovite granite dike several feet in apparent reverse dip slip. In general, the group of veins that strikes northeast and dips about 45° SE. appears to cut through or cut off the other group of veins.

Certain structural controls of the ore deposits can be inferred from the data available. The biotite-muscovite granite dike obviously influenced the location of some of the ore in the Beaver mine. The stoped areas along the Beaver and Washington veins are essentially confined to the dike. Along the surface trace of the vein, the only other extensive development of the vein is through a shaft whose collar is on the dike where the vein cuts through. Vein *c*, which is the only other extensively stoped vein in the Beaver mine, is not exposed in the dike. The writers infer, on geologic grounds, that vein *c* may become wider where it cuts through the dike above the first level (pl. 3*B*). Although the area is highly fractured, vein intersections are not areas of thicker ore. Vein deflection seems to have been more important as an ore control than the gross brecciation of the rocks.

BIG FORTY MINE (81)

The portal of the Big Forty mine is near the mouth of Maximillian Gulch at an altitude of 8,315 feet (pl. 2). The workings consist of a 978-foot crosscut tunnel trending N. 45° W. (fig. 21). Near the middle of the crosscut are 2 short drifts and near the portal is a 175-foot drift on the First vein.

Little work has been done in the mine since Spurr reported that the crosscut tunnel was 550 feet long (Spurr, Garrey, and Ball, 1908, p. 376–377). In 1934 and 1935, 12 tons of ore yielded 1.03 ounce of gold and 14 ounces of silver.

The wall rock of the mine is mostly biotite-quartz-plagioclase gneiss that is at places sillimanitic or garnetiferous; small amounts of biotite-muscovite granite, pegmatite, amphibolite, and quartzite also are exposed in the workings. These rocks have been folded into a series of north-northeast- and northeast-trending synclines and anticlines. The north-northeast-trending folds have been deflected by terrace folds that trend northeast.

Although three veins were prospected in the mine, only the fault containing the First vein was mineralized to any extent. The First vein is on the southwest end of the Little Mattie vein system and strikes about N. 70° E. and dips about 70° NW. The First vein has many weakly mineralized splits. Vein min-

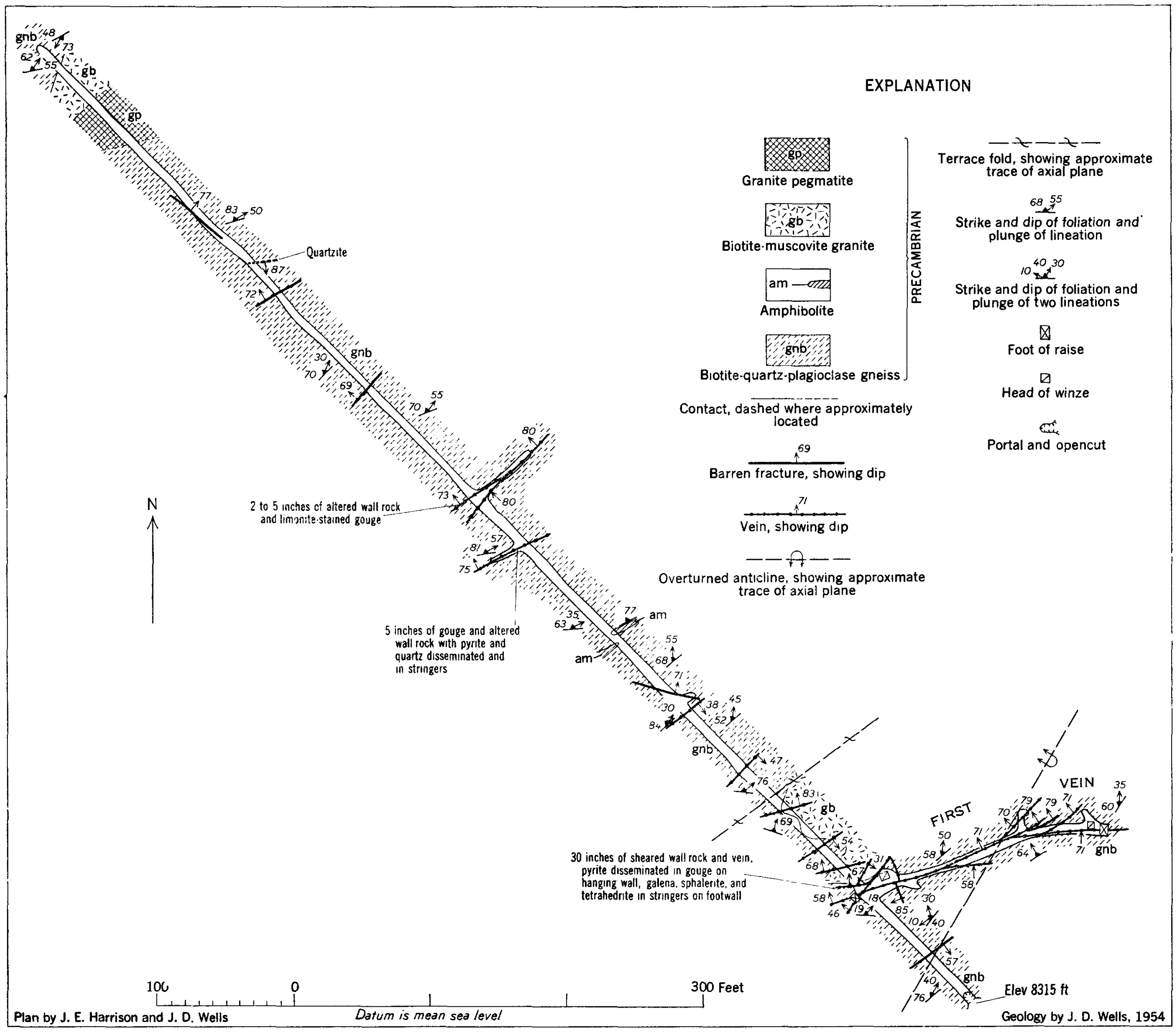


FIGURE 21.—Geologic map of the Big Forty tunnel.

erals are galena, sphalerite, tetrahedrite, pyrite, and quartz.

Two prospected veins near the middle of the crosscut tunnel strike N. 60° E. and N. 45° E., respectively, and dip at about 75° NW. These veins contain limonite-stained gouge with small amounts of pyrite and quartz.

BLACK EAGLE GROUP OF MINES (159, 160, 161)

The Black Eagle group of mines includes the Black Eagle, the Bismarck, and the Chicago mines. The principal openings to the mines, at an altitude of about 8,500 feet, are on a prominent ridge in the northeastern part of the mapped area (pl. 2).

Mine workings.—The workings of the Bismarck and Black Eagle mines are connected on the third and fourth levels (fig. 22); most of the mine development has been done through the Black Eagle shaft. The Chicago tunnel, if extended, would connect approximately with the second level of the Black Eagle-Bismarck workings. At the time of the writers' visit only the Chicago tunnel and part of the Black Eagle shaft were accessible.

Production.—Production records for the Black Eagle and Bismarck mines are believed nearly complete for the period 1905–55. However, considerable development of the mines occurred prior to 1905 (Spurr, Garrey, and Ball, 1908, p. 367–368), and the

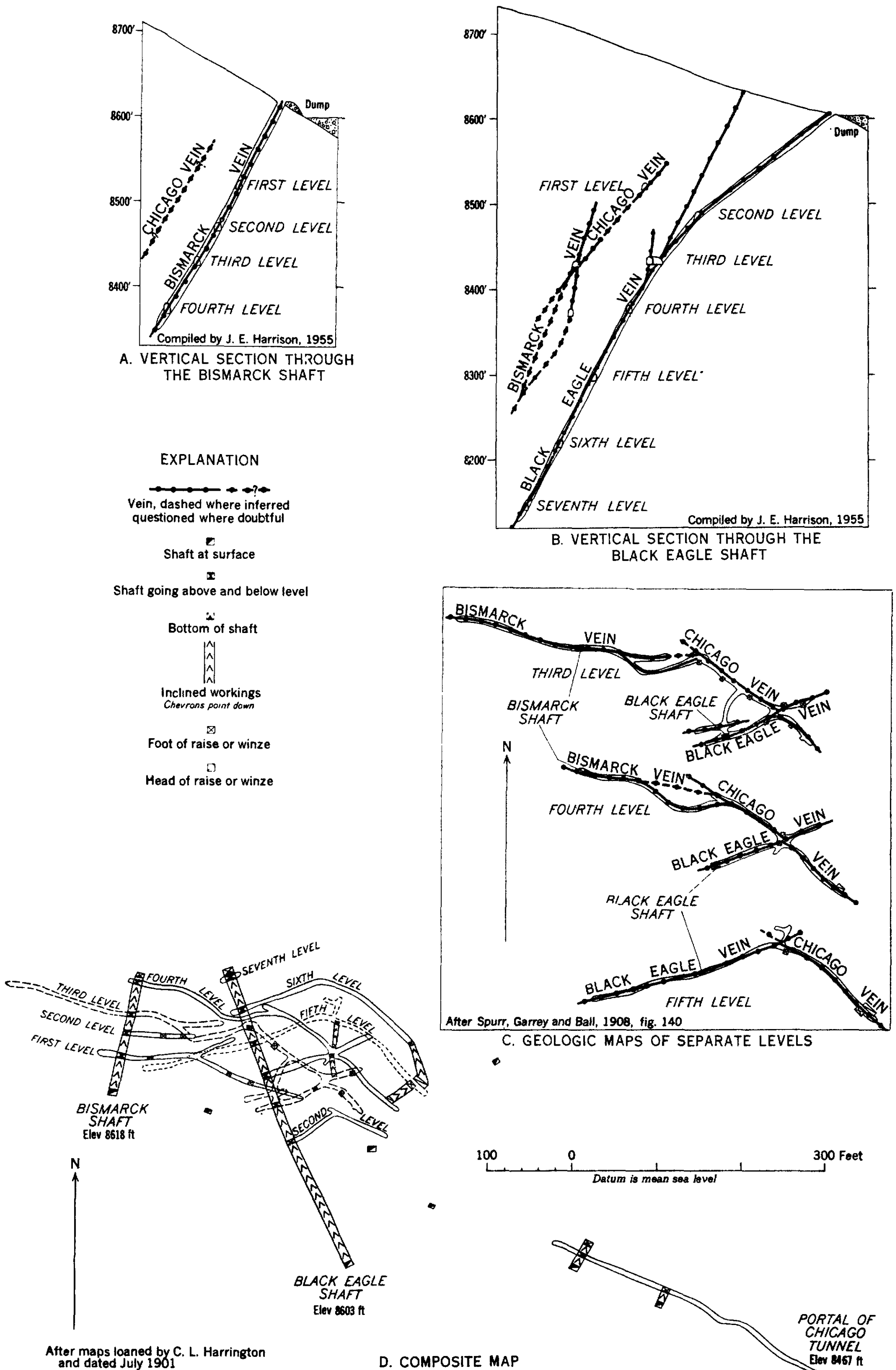


FIGURE 22.—Sketch map, sections, and geologic maps of the Black Eagle-Bismarck mine.

figures given here should be considered minima. The records of the Bureau of Mines indicate that the mines were operated from 1905 to 1923, from 1929 to 1940, and in 1949. During these periods of operation 43,697 tons of ore was shipped. This ore yielded 5,419.66 ounces of gold, 253,382 ounces of silver, 13,041 pounds of copper, 238,831 pounds of lead, and 61,673 pounds of zinc.

Production records for the Chicago mine are believed to be complete. According to the records of the Bureau of Mines, this mine was operated from 1912 to 1924 and from 1941 to 1943. During these periods of operation 607 tons of ore was shipped from the mine. This ore yielded 129.1 ounces of gold, 9,293 ounces of silver, 148 pounds of copper, 12,920 pounds of lead, and 123 pounds of zinc.

Wall rock.—The wall rock in the Chicago tunnel is mostly granitic gneiss and pegmatite (fig. 23), and that in the Black Eagle-Bismarck mines is mostly "micaceous gneiss and pegmatite" (Spurr, Garrey, and Ball, 1908, p. 368). Layers of quartz monzonite gneiss and amphibolite were mapped on the surface near the collar of the Black Eagle shaft and probably were found in the shaft.

Veins.—The Black Eagle group of mines develops a group of intersecting northeast-trending and northwest-trending veins (figs. 22 and 23). The principal veins are the Black Eagle, which trends northeast, and the Bismarck and Chicago which trend northwest. The Black Eagle vein strikes about N. 67° E. and dips about 62° NW. It probably extends to the northeast as the vein seen in the "H" shaft and extends to the southwest, crosses the Little Mattie vein near the collar of the Decatur shaft, and passes through the Edna shaft (pl. 2). The Bismarck vein strikes about N. 75° W. and dips about 65° NE. It joins the Chicago vein to the southeast and is reported (Spurr, Garrey, and Ball, 1908, p. 362) to cross the Little Mattie vein several hundred feet northeast of the Newton shaft. The Chicago vein strikes N. 55°–65° W. and dips 60°–72° NE. It probably extends to the northwest beyond the junction with the Bismarck vein, but it is not traceable on the surface. It extends to the southeast in the Chicago tunnel to a point about 120 feet from the portal, where it is intersected by a series of northeast-trending veins and is no longer identifiable (fig. 23). The Bismarck and Chicago veins are probably along premineral faults belonging to the "breccia reef" system.

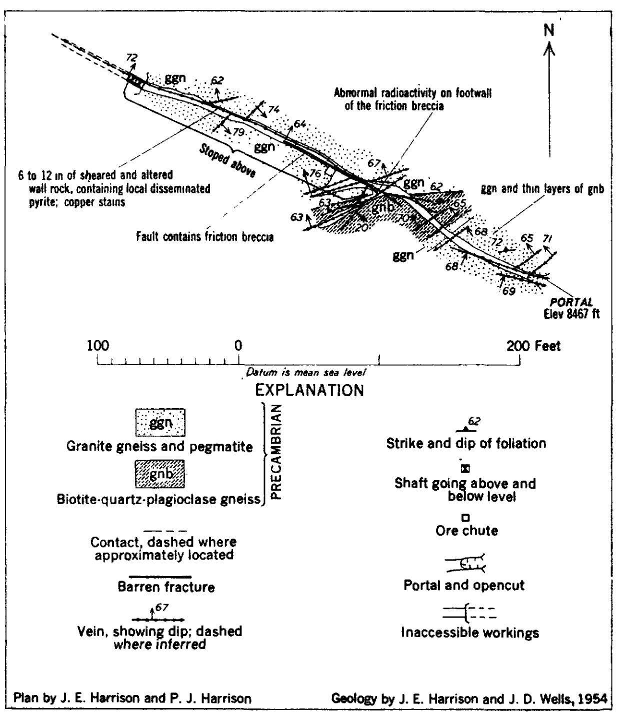


FIGURE 23.—Geologic map of the Chicago tunnel.

Vein minerals reported (Spurr, Garrey, and Ball, 1908, p. 368) from the Black Eagle group of mines include quartz, pyrite, galena, sphalerite, native silver, and black sooty sulfides. The amount of copper recovered from the ore as shown in production records and the abundant copper stains on the walls of the Chicago tunnel show that copper minerals are also present in the ore.

Localization of the ore.—Stoped areas in the mines suggest that vein intersections localized the ore bodies. Most of the ore from the Black Eagle mine has come from the Chicago and Black Eagle veins at and near their intersection (fig. 22). An ore body from the Bismarck mine came from along the Bismarck and Chicago veins near their intersection (fig. 22); and the ore body above the Chicago tunnel is at and near the intersection of the Chicago vein and a series of northeast-trending veins (fig. 23). These data suggest that the probable intersection between the Chicago vein and the Black Eagle vein indicated on figure 22*B* might be the location of an undiscovered ore body.

BLACK LION MINE (68)

The collar of the Black Lion shaft, at an altitude of 9,015 feet, is on the north valley slope of Ute Creek (pl. 2). The size of the dump suggests that the mine contains about 1,200 feet of workings, but the shaft was caved at the collar at the time of the writers' visit.

The only record of production from this mine in the files of the Bureau of Mines is of a shipment of

15 tons of ore in 1902. This ore yielded 10 ounces of gold, 1,500 ounces of silver, and 6,500 pounds of lead.

Wall rock on the dump is mostly granodiorite. A few fragments of trachytic granite porphyry similar to the dike that crops out about 170 feet north of the shaft collar were seen on the dump.

The Black Lion vein strikes about N. 72° E. and dips about 40° NW. It probably connects with the vein at the Big Flat shaft to the southwest (pl. 2).

BLACK SWAN TUNNEL (169)

The portal of the Black Swan tunnel, at an altitude of 7,700 feet, is at road level along Chicago Creek (pl. 2). The tunnel consists of a sinuous drift trending on the average about N. 83° W. for about 670 feet and a crosscut at the end of the drift trending about due north for 150 feet (fig. 24). A small stope occurs near the junction between the drift and the crosscut.

Only a small amount of ore has been produced from the tunnel. A shipment of 5 tons of ore in 1908 yielded 7.88 ounces of gold, and a small stope about 275 feet from the portal yielded some ore (Spurr, Garrey, and Ball, 1908, p. 379). No ore was produced from the mine between 1909 and 1954.

The wall rock in the mine is biotite-quartz-plagioclase gneiss that is locally sillimanitic or garnetiferous; most of the gneiss is migmatitic, especially in the areas of tight folds. At places along the tunnel the gneiss is gently arched and warped; at other places it is dragged and contorted. The gently arched gneiss appears to correlate in position with a syncline that trends N. 30° E. where mapped on the surface. The dragged and contorted areas of gneiss appear to be of two types; some are "compressional-type" folds and some are "fault-type" folds (terrace folds).

The veins in the mine are 1- to 12-inch zones of altered wall rock and gouge containing disseminated

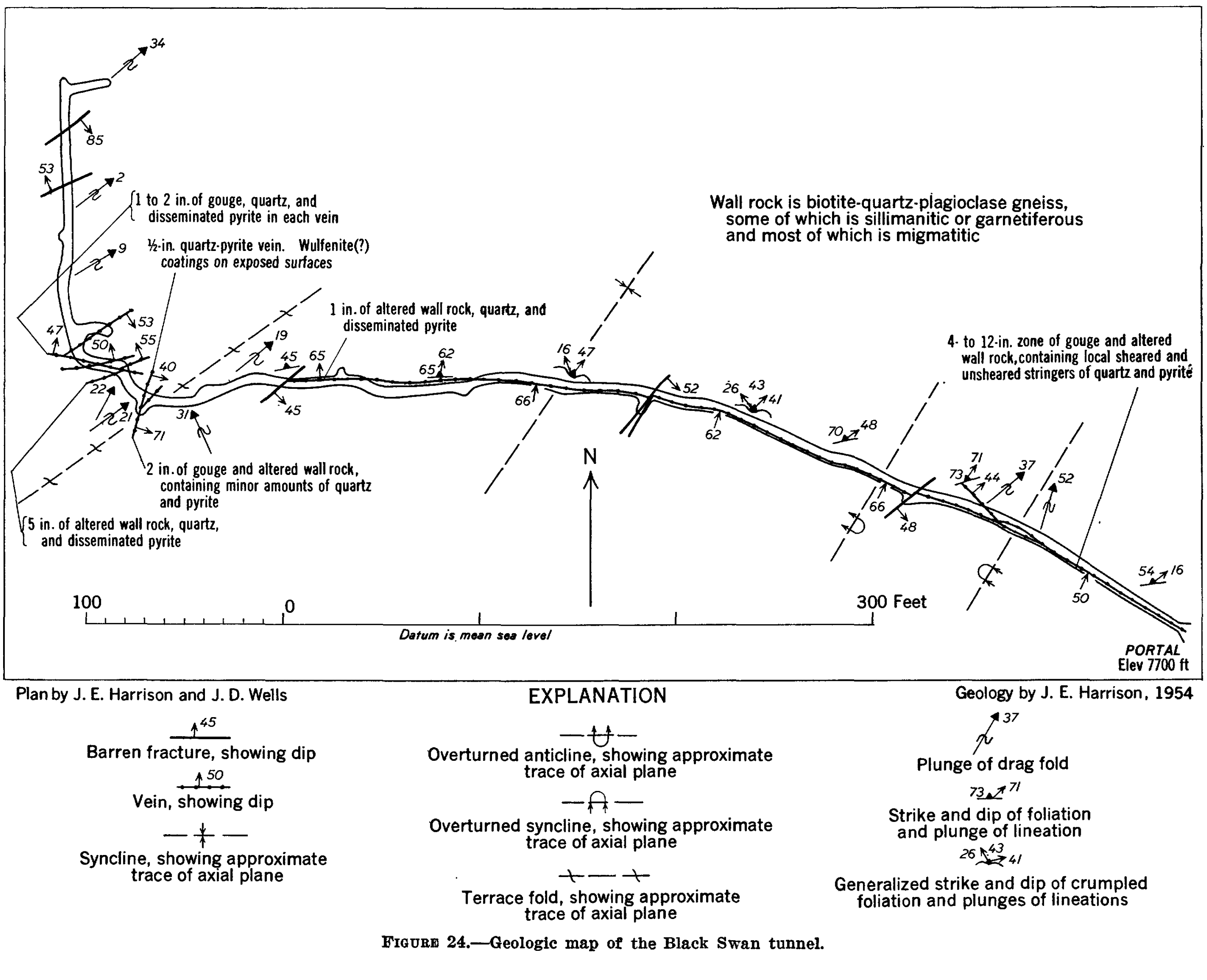


FIGURE 24.—Geologic map of the Black Swan tunnel.

quartz and pyrite or thin stringers of those minerals. Polished surfaces of ore specimens also contain traces of chalcopyrite, bournonite, galena, sphalerite, and hematite. The drift vein is cut by several south-dipping faults, each of which shows an apparent horizontal offset of 18 to 24 inches. Near the junction between the drift and the crosscut, several weakly mineralized fractures are exposed (fig. 24); some of these veins are approximately parallel to the faults seen in the drift. The apparent horizontal offset on the northeast-trending faults is the opposite of that shown by most vein faults seen in the map area. The apparent offset on the south-dipping faults may be due to dip-slip thrust movement rather than strike-slip movement which has occurred on the faults striking northeast and dipping steeply north. The gross fracturing exhibited in the mine at the junction between the crosscut and the drift is due to intersecting veins that dip gently (less than 60°) north or south. This type of fracturing is similar to that mapped in the Beaver mine where thrust movement is demonstrable on some of the faults.

BRUCE MINE (94)

The collar of the Bruce shaft is at an altitude of 9,201 feet on the southeast shoulder of Alps Mountain (pl. 2). At the time of the writers' visit the shaft was caved about 40 feet below the collar. The size of the dump suggests that the mine contains several hundred feet of workings.

According to the records of the Bureau of Mines, 3,550 tons of ore was shipped from the mine during 1935 and 1936. This ore yielded 47.16 ounces of gold, 10,585 ounces of silver, 22,851 pounds of lead, and 14,539 pounds of zinc.

The wall rock on the dump is biotite-quartz-plagioclase gneiss, most of which is sillimanitic.

The Bruce vein strikes about N. 57° E. and dips about 76° NW. It probably extends to the northeast, passes near or through the collar of the Black shaft, and connects with the vein exposed in the Grand View pits (pl. 2). The Bruce vein splits into the 2 veins about 300 feet southwest of the shaft collar (pl. 2). Vein minerals noted on the dump include quartz, carbonate, pyrite, chalcopyrite, galena, and sphalerite.

BRUNSWICK TUNNEL (45)

The Brunswick tunnel portal is on the slope north of Cascade Creek about 750 feet east of the west map boundary at an altitude of 9,386 feet (pl. 2). The workings consist of a 274-foot crosscut tunnel trending about N. 20° W. and 200 feet of accessible drift on 2 veins. The drift on the Brunswick vein is caved 40 feet from the crosscut tunnel (fig. 25). Two shafts have been sunk on the Brunswick vein.

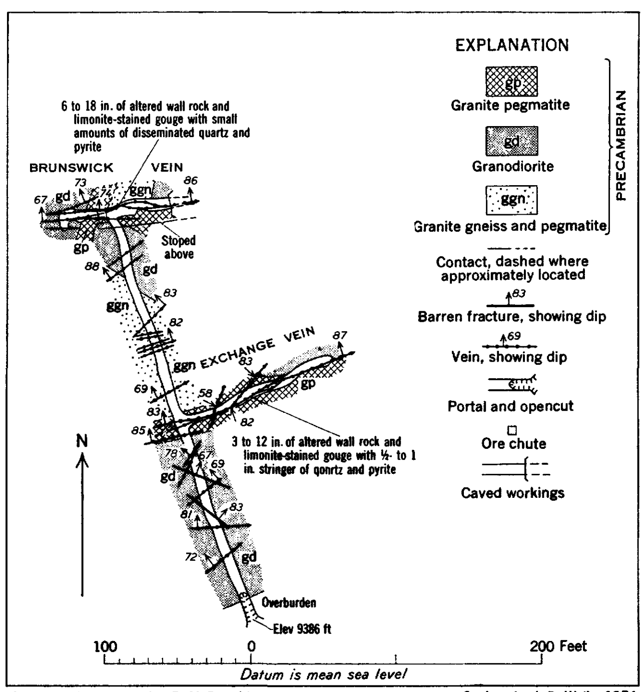
Production records for the mine are incomplete, for the only record is for 1887 (Kimball, 1888), when 4,500 ounces of silver was produced.

The wall rock consists of granodiorite, granite gneiss and pegmatite, and pegmatite.

The veins are lodes with numerous minor fractures. The Brunswick vein strikes about N. 82° E. and dips from 67° to 74° NW., and the vein that was drifted on about 150 feet from the portal strikes about N. 70° E. and dips from 82° to 87° NW. The Exchange vein consists of a series of limonite-stained shears that strike about N. 70° E. and dip 82° NW. The veins consist of limonite gouge zones containing small amounts of quartz and pyrite, disseminated and in stringers. Galena, sphalerite, chalcopyrite, and carbonate are on the dump. The only stope is on the Brunswick vein.

BURNS-MOORE TUNNEL

The portal of the Burns-Moore tunnel is outside the mapped area, but the tunnel extends into the area. The portal is on Chicago Creek about one-third of a mile southwest of the mouth of Ute Creek at an altitude of 8,480 feet. The crosscut tunnel extends N. 63° W. for about 2,800 feet. From near the end of the crosscut tunnel a drift follows a vein striking about N. 63° W. to a caved area about 3,500



Plan by J. D. Wells and J. R. McDonald — Geology by J. D. Wells, 1954

FIGURE 25.—Geologic map of part of the Brunswick tunnel.

feet from the portal (fig. 26). Two minor veins cut by the crosscut tunnel have been drifted on for a short distance.

The wall rock consists almost entirely of granodiorite except for a body of biotite-quartz-plagioclase gneiss in the drift at the end of the crosscut tunnel.

Probably little ore has been produced from the mine, for only one small stope was seen in the drift and no record of production could be found.

CECIL-ARGO GROUP OF MINES (12, 13, 15, 22, 23, 24, 25, 26)

The Cecil-Argo group of mines includes the Cecil, Argo, Argonaut, Wallace, Bald Eagle, and Fog Storm mines. This group of mines is on the north side of Ute Creek in the same valley as Lamartine but about 2,000 feet south of Lamartine (pl. 2). The principal openings along the vein, from southwest to northeast, are the Bald Eagle shaft, the Argo tunnel, the Wallace tunnel, the Argo shaft, the Wallace shaft, and the Cecil shaft. At the time of the writers' visit the only accessible workings were a part of the Wallace tunnel.

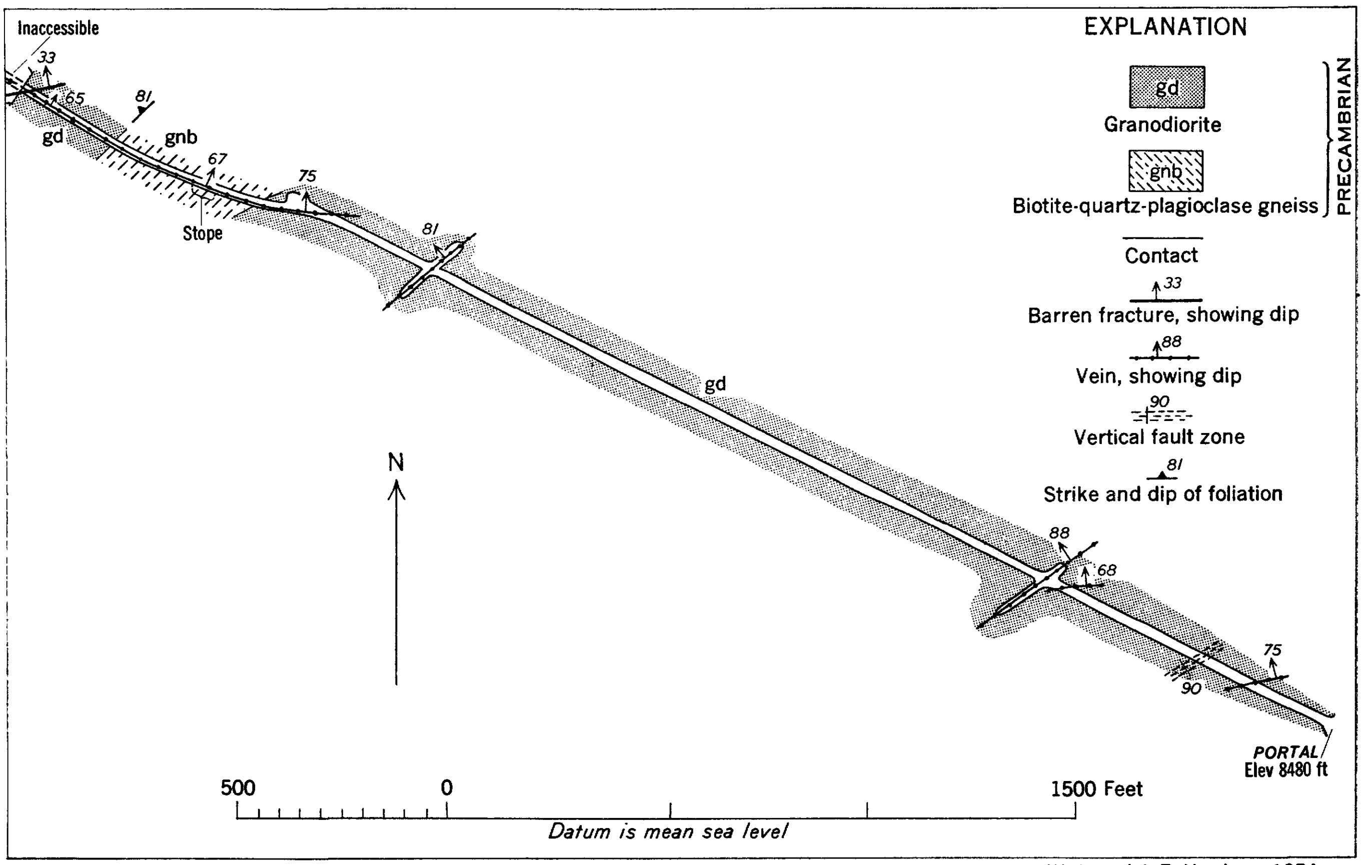
Some of the mines in this group were worked as early as 1887 (Spurr, Garrey, and Ball, 1908, p. 368–370). The records, however, are incomplete for the period before 1906, and the information presented on production prior to 1906 is that given by Spurr, Garrey, and Ball, by Kimball, and by Leech. The information on production after 1906 comes from the records of the Bureau of Mines, whose files are essentially complete.

CECIL MINE

The Cecil mine consists of a shaft about 500 feet deep that connects with drifts on several levels (fig. 27). The extent of the stoping as of 1906 is shown on figure 27.

The attitude of the vein at the shaft is about N. 50° E., vertical. This trend corresponds to a line of prospect pits northeast of the shaft (pl. 2), and the same vein probably is opened up by the Lance shaft. Vein material on the dump consists of stringers of quartz, pyrite, galena, and sphalerite in crushed and altered granite gneiss and pegmatite.

Little is known concerning the production from the Cecil mine. Spurr, Garrey, and Ball (1908, p. 369) report that the yield for 1892 was $740 in gold, $9,578 in silver, and $2,295 in lead. During 1908 and



Geology by J. D. Wells and J. E. Harrison, 1954

FIGURE 26.—Geologic sketch map of part of the Burns-Moore tunnel.

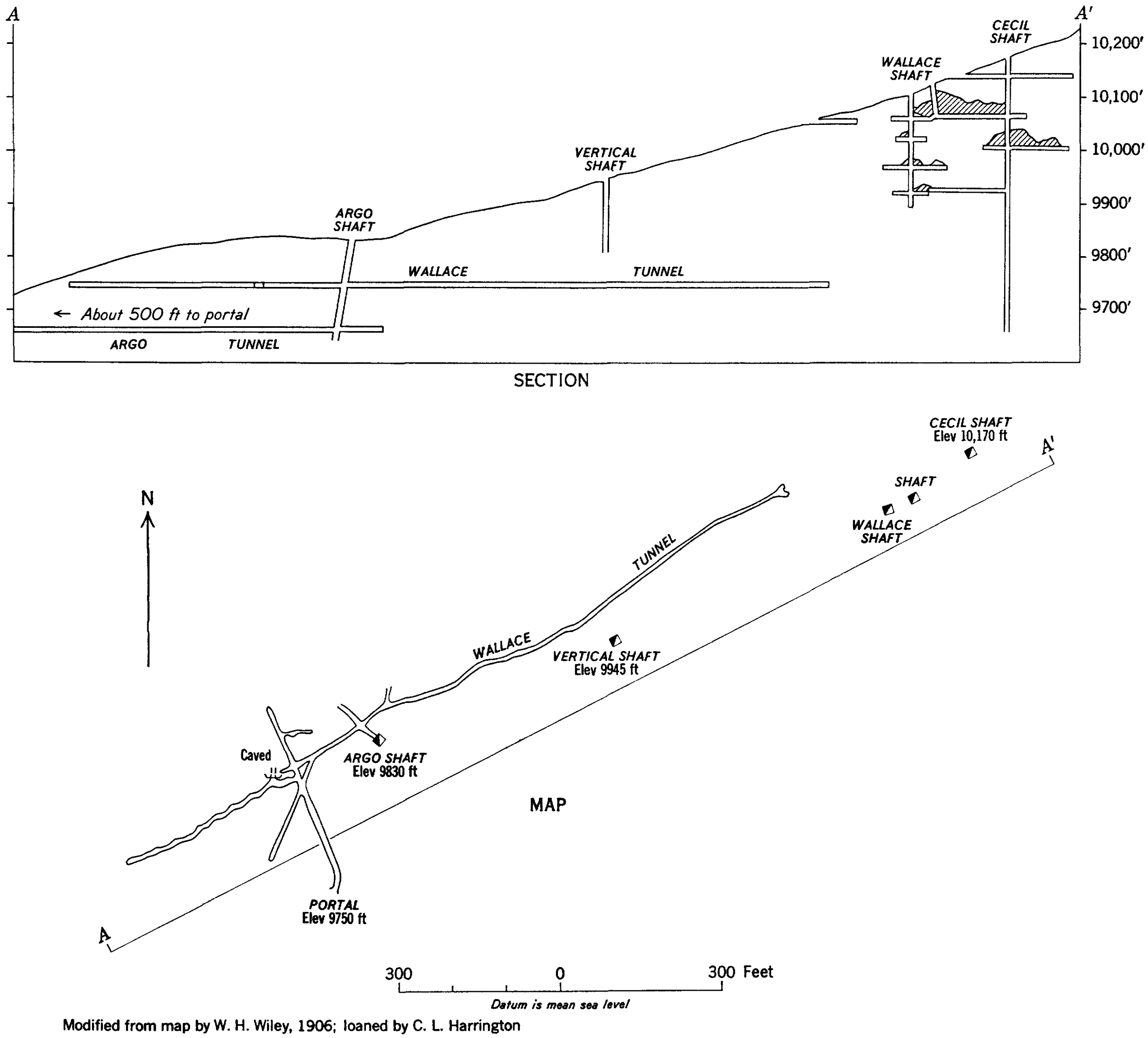


FIGURE 27.—Sketch map and section of part of the workings of the Cecil-Argo mines.

1909, a total of 20 tons of ore was produced from the mine; this ore yielded 7.40 ounces of gold, 1,514 ounces of silver, and 2,157 pounds of lead. In 1940, a shipment of 23 tons of dump material(?) yielded 1.10 ounces of gold, 63 ounces of silver, 30 pounds of copper, 507 pounds of lead, and 504 pounds of zinc.

WALLACE MINE

The Wallace mine consists of a crosscut tunnel connecting with about 950 feet of drifting northeast along the vein and about 350 feet of drifting southwest along the vein (fig. 27). The Wallace shaft is about 200 feet deep and connects with drifts on 4 levels (fig. 27). The shaft and the drifts on the tunnel level do not connect. The tunnel level is connected with the surface and with a drift on the Argo tunnel level by the Argo shaft. Stoping on the drifts connecting with the shaft was not extensive in 1906 (fig. 27), but miners report extensive stoping along the Wallace tunnel level.

The main vein as seen on the Wallace tunnel level strikes about N. 55° E. and dips 75°–88° NW. The vein consists of about 3 inches of gouge and brecciated quartz, pyrite, galena, and sphalerite where seen, but the stoped areas are not accessible (fig. 28). A vein split from the main vein was intersected in the

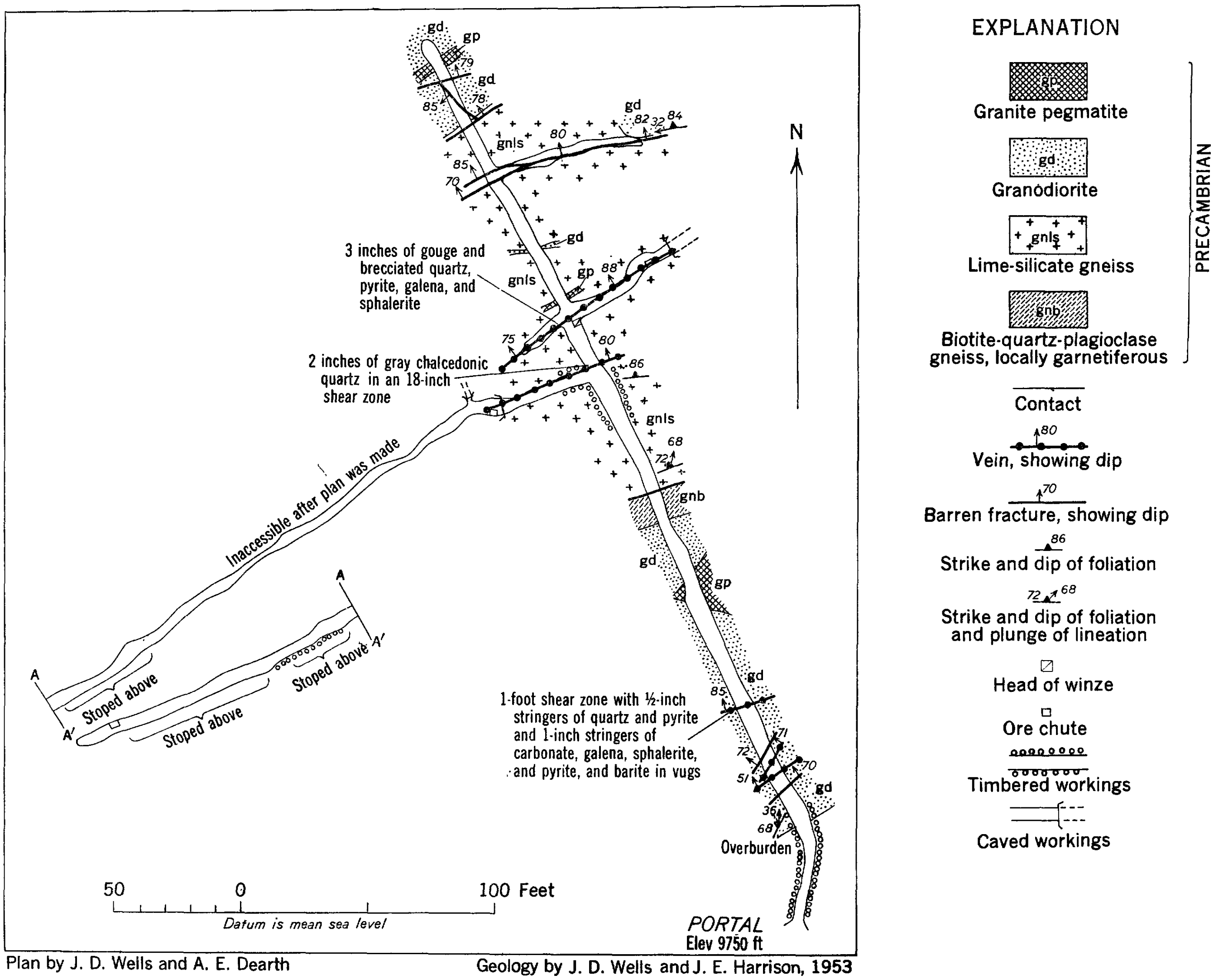


FIGURE 28.—Geologic map of the Wallace tunnel.

crosscut about 40 feet southeast of the main vein. The split strikes about N. 70° E. and dips 80° NW. It consists of a 2-inch-wide stringer of gray chalcedonic quartz and pyrite in an 18-inch-wide sheared zone.

The wall rocks include granodiorite, granite, pegmatite, garnetiferous biotite-quartz-plagioclase gneiss, and lime-silicate gneiss (fig. 28). Where observed, the main vein is confined to the lime-silicate gneiss.

Production records for the Wallace mine are incomplete. Kimball (1888) gives a production of 33 ounces of silver for 1887 and Leech (1893) gives the estimated yield for 1892 to be 30 ounces of gold, 8,500 ounces of silver, and 29,350 pounds of lead. In 1936, 32 tons of ore was produced from the mine; this ore yielded 0.77 ounce of gold, 84 ounces of silver, 145 pounds of lead, and 338 pounds of zinc.

ARGO MINE

The Argo mine consists of a crosscut tunnel and several hundred feet of drifts along the vein. The Argo shaft connects the Argo tunnel with the Wallace tunnel and the surface (fig. 27). None of the underground workings were accessible in 1953, nor were they accessible to Spurr, Garrey, and Ball in 1906, but the large dumps are evidence that extensive development work was done in the mine.

The description of the vein given here is an abstract of that obtained from local miners by Spurr, Garrey, and Ball (1908, p. 369). The vein ranges in width from 3 inches to 2 feet, is composed predominantly of black sphalerite, and commonly contains less than 5 percent galena. At places in the mine a thin streak of black sooty sulfide ore that was found on the hanging wall carried several ounces of gold per ton. This vein appears to branch southwest of the Argo workings; one branch, exposed in the Bald Eagle shaft, strikes N. 39° E. and dips 85° NW.; the other branch, exposed in the Fog Storm shaft, strikes N. 71° E. and dips 57° NW. Neither of the branches has been developed extensively.

Production records for the Argo mine are not complete. The following estimates of production are taken from the reports of the Director of the Mint:

Year	Gold (ounces)	Silver (ounces)	Lead (pounds)
1887	202.0	21,150	-------
1888	20.7	10,480	12,000
1889	225.0	24,950	50,000
1890	1.5	223	-------
1892	32.0	2,360	-------

Records from the Bureau of Mines show that ore was shipped from the mine from 1919 to 1926, in 1939, and in 1941. During this time, 349 tons of ore was produced; this ore yielded 83.64 ounces of gold, 6,099 ounces of silver, 26 pounds of copper, 14,118 pounds of lead, and 16,413 pounds of zinc.

ARGONAUT AND BALD EAGLE

The workings on these claims are not accessible, but records of the Director of the Mint show the following production:

	Year	Gold (ounces)	Silver (ounces)	Lead (pounds)
Argonaut	1890	87.7	12,690	3,600
	1892	70.0	8,100	-------
Bald Eagle	1887	1.4	240	-------
	1888	2.3	2,558	4,000
	1891	25.0	------	-------

COLUMBIA MINE (143)

The collar of the Columbia shaft, at an altitude of 8,572 feet, is on the crest of the ridge east of Cottonwood Gulch (pl. 2).

Production records for the Columbia mine are incomplete. The available records of the Bureau of Mines show that a total of 102 tons of ore was shipped during 1914, 1921, and 1935. This ore yielded 4.66 ounces of gold, 32 ounces of silver, 119 pounds of lead, and 109 pounds of zinc. The 1935 shipment yielded only zinc and probably represents a shipment of dump material.

The mine in 1906 consisted of a shaft and 3 short levels. At the time of the writers' visit the shaft was caved at the collar; the description of the mine has been abstracted from Spurr, Garrey, and Ball (1908, p. 366).

Wall rock in the mine and on the dump is mostly granite gneiss and pegmatite.

The vein strikes from due east to N. 75° E. and dips about 70° NW. It splits west of the shaft into 2 branches that diverge to the west. The vein is generally less than 6 inches wide and consists of silicified wall rock, quartz, opal, pyrite, and leaf gold. Production records suggest that galena and sphalerite occur in some of the ore. The widest part of the ore occurs at the split in the vein, and considerable stoping has been done along the main vein and the branches for a short distance from the junction.

DIXIE MINE (38, 39, 40, 54)

The Dixie mine includes the interconnected workings developed primarily through the Dixie tunnel and the M. and M. tunnel. The mine consists of an upper tunnel about 350 feet long that connects through winzes and raises with about 2,100 feet of drifting on 5 levels on the Dixie vein (pl. 4*A*). The third level drift is connected to the surface by the M. and M. tunnel, a crosscut about 1,020 feet long that also connects with about 660 feet of drifting on 2 other veins (pl. 4*B*). During 1954, work was being done on the fifth level of the mine, and the ore was hauled through the M. and M. tunnel whose portal, at an altitude of 9,080 feet, is near stream level on the northeast side of Ute Creek (pl. 2). At the time of the writers' visit, only the M. and M. tunnel level, part of the fourth level, and the fifth level were accessible.

According to W. W. Janes, part owner of the mine, the Dixie tunnel was begun in December 1936. From 1936 to 1940, development work was carried on through the Dixie tunnel, and the first and second levels of the mine were worked. In 1941, the M. and M. tunnel was driven 310 feet from its intersection with the M. and M. vein to its intersection with the Dixie vein (pl. 4). Since 1941, operations have been carried on through the M. and M. tunnel.

Production data furnished by the Bureau of Mines for the Dixie mine are believed to be complete for the years 1936–54. During these years, 32,275 tons of ore has been shipped from the mine. This ore yielded a total of 17,747 ounces of gold, 57,809 ounces of silver, 3,379 pounds of copper, 84,892 pounds of lead, and 93,505 pounds of zinc.

The wall rock in the accessible part of the mine consists predominantly of granodiorite. The granodiorite is cut by dikes and pods of pegmatite and biotite-muscovite granite; only a few of the dikes and pods are large enough to be shown on the map (pl. 4).

Three veins—the Little Helen, the M. and M., and the Dixie—have been developed in the mine. These veins, where exposed in the mine and on the surface, are subparallel; they strike about N. 68° E. and dip on the average about 80° NW.

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The Little Helen vein on the M. and M. tunnel level is a 12- to 36-inch zone of fractured and altered wall rock containing an inch-wide stringer of quartz, pyrite, galena, tetrahedrite, and sphalerite. One polished surface of an ore specimen also contained tiny blebs of chalcopyrite in the sphalerite.

The M. and M. vein on the M. and M. tunnel level is an 8- to 48-inch altered zone containing discontinuous thin stringers of quartz and sulfides. A polished surface of an ore specimen believed representative of this vein contained quartz, carbonate, pyrite, marcasite, sphalerite, tetrahedrite, chalcopyrite, polybasite, and galena.

The Dixie vein, as seen on the third, fourth, and fifth levels of the mine, consists of a 1- to 5-foot zone of altered wall rock containing some solid and some vuggy stringers of quartz, carbonate, pyrite, marcasite, tetrahedrite-tennantite, chalcopyrite, polybasite, electrum, sphalerite, and galena. The electrum, some of which occurs in vugs, is 75 percent gold and 25 percent silver. Several stages of fracturing and ore deposition can be recognized along the vein because of brecciation and cementation of certain colors of clear to chalcedonic quartz by other colors of chalcedonic quartz. The paragenesis of the vein minerals is the same as that described and illustrated (fig. 36) for the Humboldt vein with the exception that a small(?) part of the electrum in the Dixie vein may be supergene in origin.

Deflection in strike may be a control for some of the ore bodies along the Dixie vein. The apparent horizontal movement along the fault containing the Dixie vein is northwest block to the northeast. Such a movement would tend to form open space along the more easterly trending parts of the vein, and the more northerly trending parts would act as bearing surfaces. The two largest stoped areas, that at the junction of the crosscut tunnel and the Dixie drift and that near the southwest end of the Dixie drift, are along the more easterly striking parts of the vein.

DORIT MINE (110)

The portal of the Dorit crosscut tunnel, at an altitude of 8,020 feet, is near the highway just east of the prominent bend in Chicago Creek (pl. 2).

According to the records of the Bureau of Mines, a total of 227 tons of ore was shipped from the Dorit mine from 1913 to 1916. This ore yielded 27.23 ounces of gold and 505 ounces of silver. Most of this ore came from the Dorit vein.

The Dorit mine consists of a 1,700-foot crosscut tunnel connecting with four drifts, a drift tunnel, and a shallow shaft. At the time of the writers' visit only the crosscut tunnel, 2 of the drifts, and part of the other 2 drifts were accessible (pl. 5). The drift on the Dorit vein is reported to connect with the drift tunnel whose portal is in the first gulch east of the Dorit tunnel portal (pl. 2).

Most of the wall rock in the Dorit tunnel is migmatitic biotite-quartz-plagioclase gneiss (pl. 5) that at places is sillimanitic or garnetiferous. This gneiss contains numerous thin layers of granite pegmatite and of granite gneiss and pegmatite, only a few of which are large enough to be shown on plate 5. Trachytic granite porphyry is exposed in the drift along the Dorit vein, and biotite-quartz latite porphyry is exposed in the drift along the Pacific vein.

The gneisses have been folded into a series of isoclinal folds that can be recognized on the surface but that are difficult to recognize in the tunnel. Two periods of folding of the gneisses can be recognized because of deflection of north-northeast-trending mineral alinements by warps trending north-northwest; this deflection is particularly apparent in the tunnel between the portal and the drift on the Blackstone vein. The near parallelism of foliation and veins has resulted in the tendency for the veins to split and branch into the foliation, which explains in part the braided and branching vein pattern mapped on the surface in the general area of the Dorit mine (pl. 2).

The four principal veins exposed in the mine are the Pacific, the Blackstone, the Dorit, and the Lucky Guess. The Pacific, Blackstone, and Dorit veins converge and join to the northeast (pl. 2). The Lucky Guess vein is traceable only for a short distance on the surface, but it may be one of several branches of the Little Mattie vein.

The Pacific vein strikes about N. 37° E. and dips on the average about 74° NW. In the drift it consists of 1 to 14 inches of altered wall rock and gouge containing minor amounts of disseminated pyrite.

The Blackstone vein strikes about N. 51° E. and dips on the average about 65° NW. Where exposed in the drift it consists of ½ to 4 inches of altered wall rock and gouge containing minor amounts of pyrite.

The Dorit vein strikes about N. 75° E. and dips on the average about 72° NW. Where exposed in the mine it consists of 8 to 24 inches of gouge and altered wall rock containing minor amounts of pyrite.

The Lucky Guess vein strikes about N. 56° E. and dips on the average about 75° NW. The thicker parts of the vein exposed in the mine consist of 6 to 12 inches of gouge and altered wall rock containing

¼-inch-wide stringers of quartz, pyrite, marcasite, sphalerite, tennantite, chalcopyrite, polybasite, and galena. Study of polished surfaces of ore specimens from the Lucky Guess vein indicates that the vein minerals were deposited in the following sequence: quartz; pyrite; sphalerite and marcasite; tennantite, polybasite, and chalcopyrite; and finally galena.

"E" TUNNEL (184)

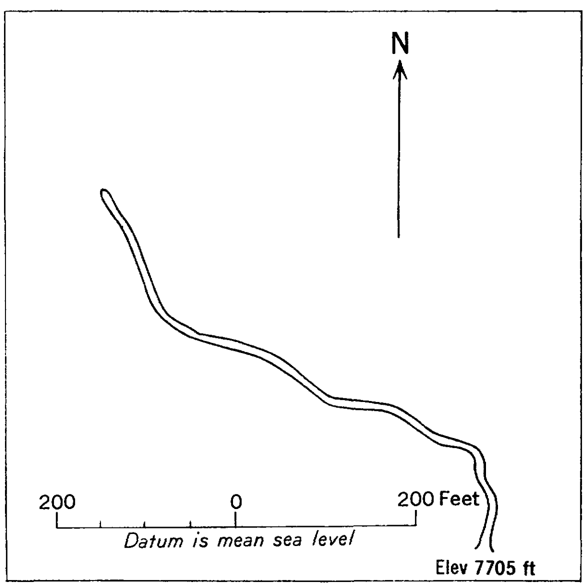
The portal of the "E" tunnel, at an altitude of 7,705 feet, is near road level on the northwest side of Chicago Creek (pl. 2). At the time of the writers' visit the tunnel was caved a few feet from the portal.

The tunnel is somewhat tortuous and probably is in part a crosscut heading toward the P. T. shaft. The tunnel is about 630 feet long and trends on the average N. 50° W. (fig. 29).

A vein is exposed at the portal and is obviously followed by the first few feet of the tunnel. This vein strikes N. 18° E., dips 29° SE., and consists of a 10-inch zone of sheared and altered wall rock containing thin stringers of quartz and pyrite. This vein could not be traced on the surface.

ECLIPSE MINE (77)

The portal of the Eclipse lower tunnel, at an altitude of 9,060 feet, is on the southwest side and near the head of Eclipse Gulch (pl. 2). A lower and upper tunnel were used to work the mine, but the portals of both were caved at the time of the writers' visit. The mine was also inaccessible in 1906 (Spurr, Garrey, and Ball, 1908, p. 376), and no maps of the workings could be located although the development appears to be extensive.



After map loaned by C. L. Harrington, dated July 1908

FIGURE 29.—Plan of the "E" tunnel.

Spurr (Spurr, Garrey, and Ball, 1908, p. 376) states that the local miners reported the production from the Eclipse mine to have been considerable. The reports of the Director of the Mint list the following production:

Year	Gold (ounces)	Silver (ounces)	Lead (pounds)
1887	48.0	12,030	11,850
1888	6.1	1,349	1,978
1889	38.5	5,500	16,500

The vein strikes about N. 70° E. and dips about 70° NW.; it is probably a split off the Big Chief vein (pl. 2). Specimens of vein material found on the dumps consist of brecciated fragments of quartz, pyrite, tetrahedrite, galena, and sphalerite cemented by tan chalcedonic quartz. A little carbonate is present in some of the ore specimens. Spurr (Spurr, Garrey, and Ball, 1908, p. 376) also found argentite associated with some of the ore.

ELLA McKINNEY TUNNEL (57)

The portal of the Ella McKinney tunnel, at an altitude of 8,960 feet, is near stream level on the southwest side of Ute Creek (pl. 2). The first 500 feet of the tunnel is a tortuous crosscut that ultimately intersects a vein at a point about 415 feet S. 84° W. of the tunnel portal (fig. 30). About 200 feet of drifting has been done along this vein from the place where the crosscut intersects the vein. No stoping has been done in the mine, and no record of production for the mine could be found.

The wall rock in the mine is predominantly granodiorite that is cut by dikes of granite pegmatite. The wall rock is cut by many fractures along the crosscut part of the tunnel (fig. 30).

The vein strikes about N. 64° E. and dips 79°–82° NW. It consists of a 5- to 30-inch zone of sheared wall rock that at places contains some sheared and some unsheared ½- to 1½-inch-wide stringers of quartz and pyrite on the footwall side of the sheared zone.

FREE GOLD MINE (171)

The portal of the Free Gold mine, at an altitude of 7,690 feet, is at road level along Chicago Creek (pl. 2). The workings consist of about 465 feet of drifts and crosscuts on the tunnel level, a shallow winze, and a shaft that connects the tunnel level with the surface (fig. 31). Several small areas near and along the shaft have been stoped.

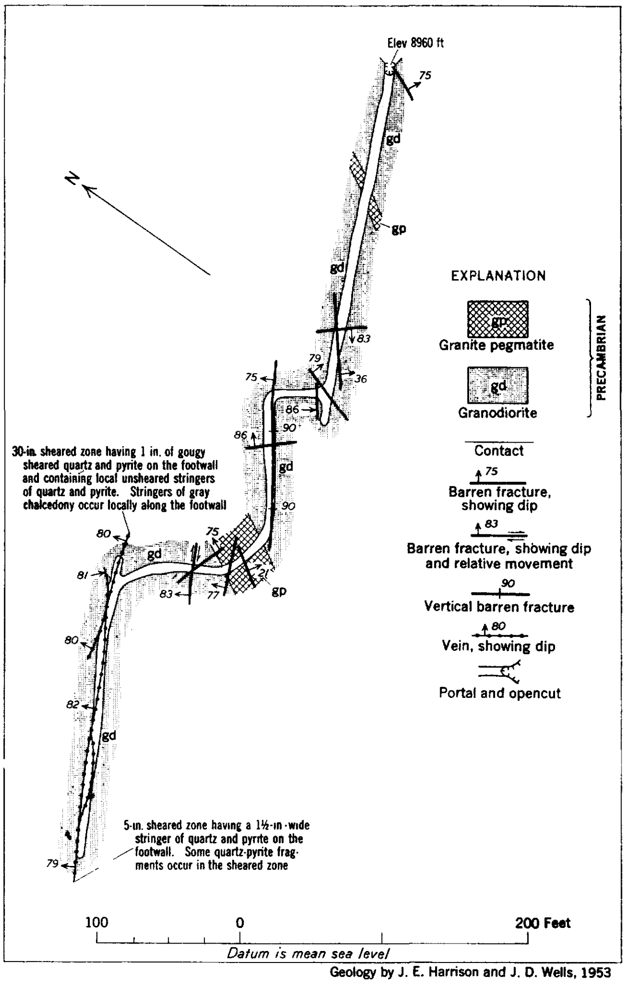


FIGURE 30.—Geologic map of the Ella McKinney tunnel.

Records of the Idaho Springs Sampling Works show that shipments were made from the mine in 1924 (13.28 tons) and in 1925 (4.09 tons). This ore contained 8.9 ounces of gold, 67 ounces of silver, and 225 pounds of zinc. Bureau of Mines records show that further shipments of ore from the mine were made in 1929 (16 tons) and 1934 (4 tons). This ore yielded 20.01 ounces of gold, 75 ounces of silver, and 223 pounds of zinc.

The wall rock in the mine is migmatitic biotite-quartz-plagioclase gneiss that is drag-folded and contorted throughout most of the workings.

The main vein strikes about N. 82° W. and dips on the average about 52° NE. This vein can be traced only a few hundred feet on the surface (pl. 2). On the tunnel level near the shaft the vein consists of 6 to 12 inches of sheared quartz and pyrite that contains crosscutting stringers of unsheared quartz, pyrite, chalcopyrite, and tennantite. Polished surfaces of this ore also contain minor amounts of free gold, polybasite, and covellite. The paragenetic sequence of the vein minerals is shown diagrammatically (fig. 32).

Localization of the wider parts of the vein appears related to dip of the vein. The main vein ranges in dip from 75° N. at the collar of the shaft to 41° at the shaft on the tunnel level. The dip is steeper than 41° along the tunnel level both east and west of the shaft. The thicker part of the vein and the stoped area are confined to the part of the main vein that dips less than 50° N.

GOLDEN GLEN TUNNEL (105)

The portal of the Golden Glen tunnel is at an altitude of 8,388 feet in Golden Glen Gulch (pl. 2).

Although no record of production could be found for the Golden Glen tunnel, the remains of a large mill near the tunnel portal suggest that an appreciable amount of ore was produced from the mine. As the Bruce Consolidated Mining Co. at one time owned the Bruce mine and the Golden Glen and Orinoco tunnels, the production records given for the Bruce

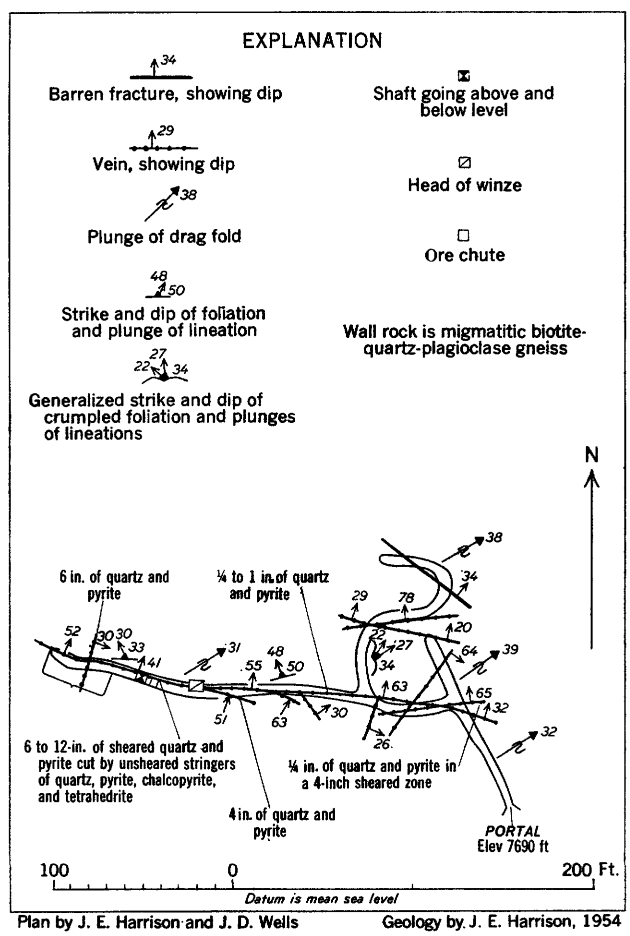


FIGURE 31.—Geologic map of the Free Gold tunnel.

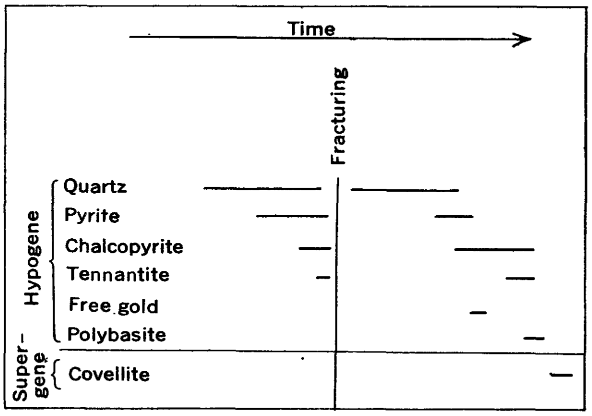


FIGURE 32.—Paragenetic diagram for the vein minerals of the Free Gold vein.

mine may include ore taken from the Golden Glen mine.

The Golden Glen tunnel is a 2,375-foot crosscut trending N. 16° W. (fig. 33). Several drifts connect with the tunnel, but most of these as well as almost half of the crosscut were inaccessible at the time of the writers' visit. A geologic map of the accessible part of the tunnel is shown in plate 6.

The wall rock in the accessible part of the tunnel is mostly biotite-quartz-plagioclase gneiss, locally sillimanitic, that contains layers of amphibolite and granite gneiss and pegmatite and dikes of biotite-muscovite granite, pegmatite, trachytic granite porphyry, and bostonite. The gneisses along the tunnel appear to be highly folded at many places. The walls were so thickly coated by dirt and slime, however, that the details of the structure were obscured.

Most of the veins in the accessible part of the mine are 1- to 8-inch gougy zones containing trace amounts of quartz and pyrite. Two of the veins, the Sweden and the vein in the drift nearest the portal (pl. 6), contain thin stringers of quartz, pyrite, carbonate, and base metal sulfides.

GOMER (HEDDENSBURG) MINE (129)

The collar of the Gomer shaft, at an altitude of 8,890 feet, is about 60 feet above stream level on the north side of Spring Gulch (pl. 2). At the time of the writers' visit the shaft was beginning to cave.

The total production from the Gomer mine is not known. The records of the Bureau of Mines show

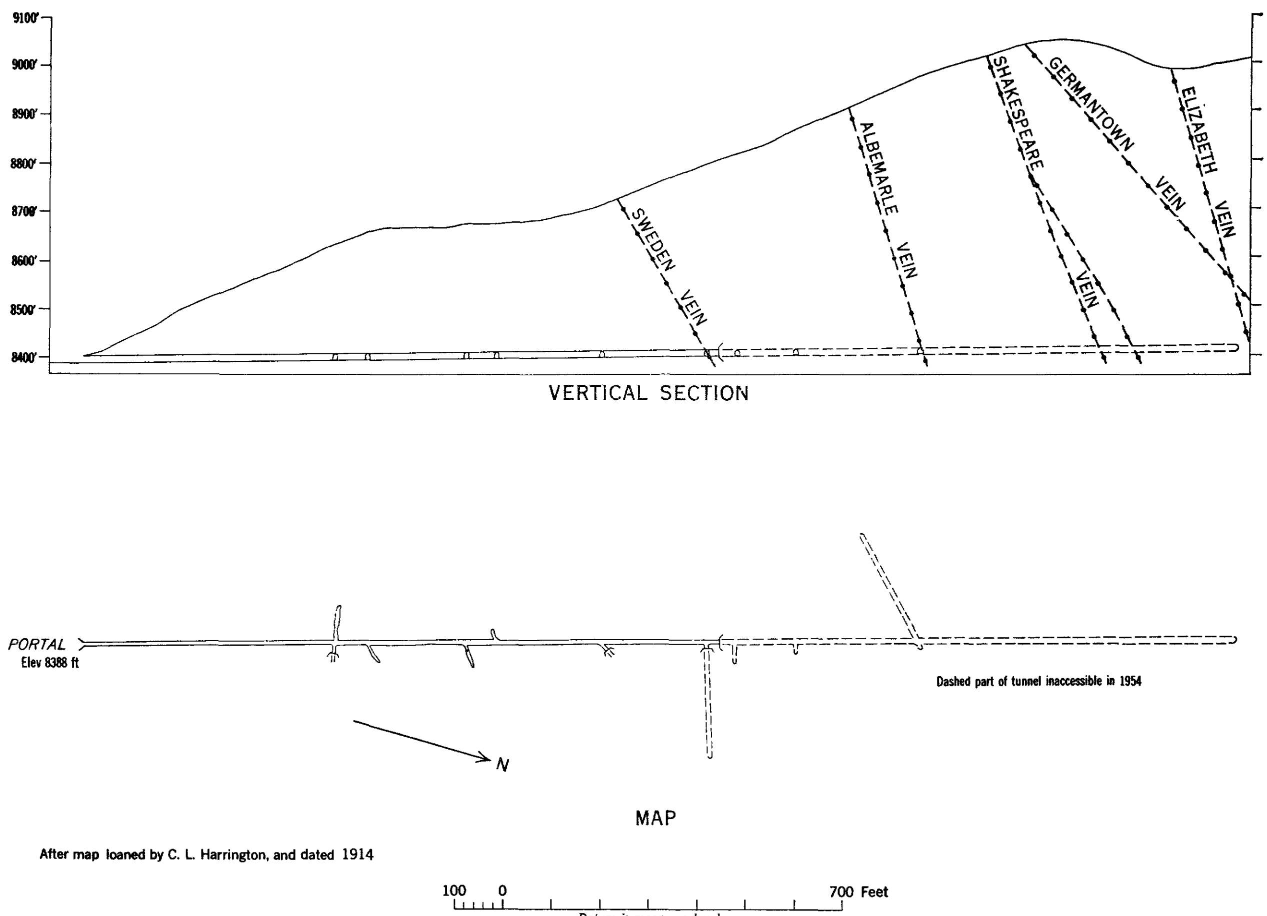


FIGURE 33.—Map and section of the Golden Glen tunnel.

that a total of 31 tons of ore was shipped during 1903, 1906, and 1910. This ore yielded 21.67 ounces of gold, 242 ounces of silver, and 464 pounds of lead.

The wall rock is predominantly biotite-quartz-plagioclase gneiss although part of the workings are in a dike of bostonite porphyry (Spurr, Garrey, and Ball, 1908, fig. 133).

The vein has an irregular strike, owing to its deflection where it crosses the dike; in general, it strikes about N. 80° E. and dips about 45° NW. (Spurr, Garrey, and Ball, 1908, p. 351). The ore consists of rhodochrosite, barite, quartz, pyrite, galena, and sphalerite; it is thicker (p. 352) along the margins and outside of the dike than in it. Some dump specimens of ore contain radioactive material, but the radioactive mineral or minerals could not be separated for identification.

HARRISON-ACCIDENTAL GROUP OF MINES (156, 157)

The Harrison-Accidental group of mines includes the mines worked principally through the Harrison shaft and the Accidental shaft. The collars of these shafts are in the second gulch northeast of Cottonwood Gulch (pl. 2).

Only two shipments of ore are recorded from these mines. One shipment in 1890 (Leech, 1891) yielded 24 ounces of gold, and another shipment of 17 tons in 1920 (Bureau of Mines records) yielded 5.0 ounces of gold, 69 ounces of silver, 297 pounds of lead, and 136 pounds of zinc. Most, if not all, of this ore probably came from the Harrison mine.

The mine workings are on two separate veins and do not connect, though the veins probably intersect near the collar of the Accidental shaft (pl. 2). None of the workings were accessible at the time of the writers' visit. The size of the mines, judged by the size of the dumps, is about 500 feet of workings connected with the Harrison shaft and about 250 feet of workings connected with the Accidental shaft.

Wall rock on the mine dumps is predominantly migmatite and migmatitic light-colored biotite-quartz-plagioclase gneiss. A few fragments of highly altered biotite-quartz latite were seen on the Accidental dump.

The Harrison vein strikes about due east and dips on the average about 65° NW. It possibly extends to the east and joins the vein opened by the Quito tunnel (pl. 2). The vein, as exposed in the Harrison shaft and in a prospect shaft 350 feet west of the Harrison shaft (pl. 2), is a 6- to 12-inch zone of gouge and altered wall rock containing thin stringers of quartz, carbonate, pyrite, sphalerite, and galena.

The Accidental vein, as exposed at the collar of the Accidental shaft, strikes N. 50° E., dips 41° NW., and consists of a 10-inch sheared and altered zone containing disseminated quartz, pyrite, and galena. The vein, as exposed in a pit about 170 feet northeast from the shaft collar, is a 10-inch sheared and altered zone containing 2 inches of gossan on its hanging wall.

HUMBOLDT MINE (42, 43, 44)

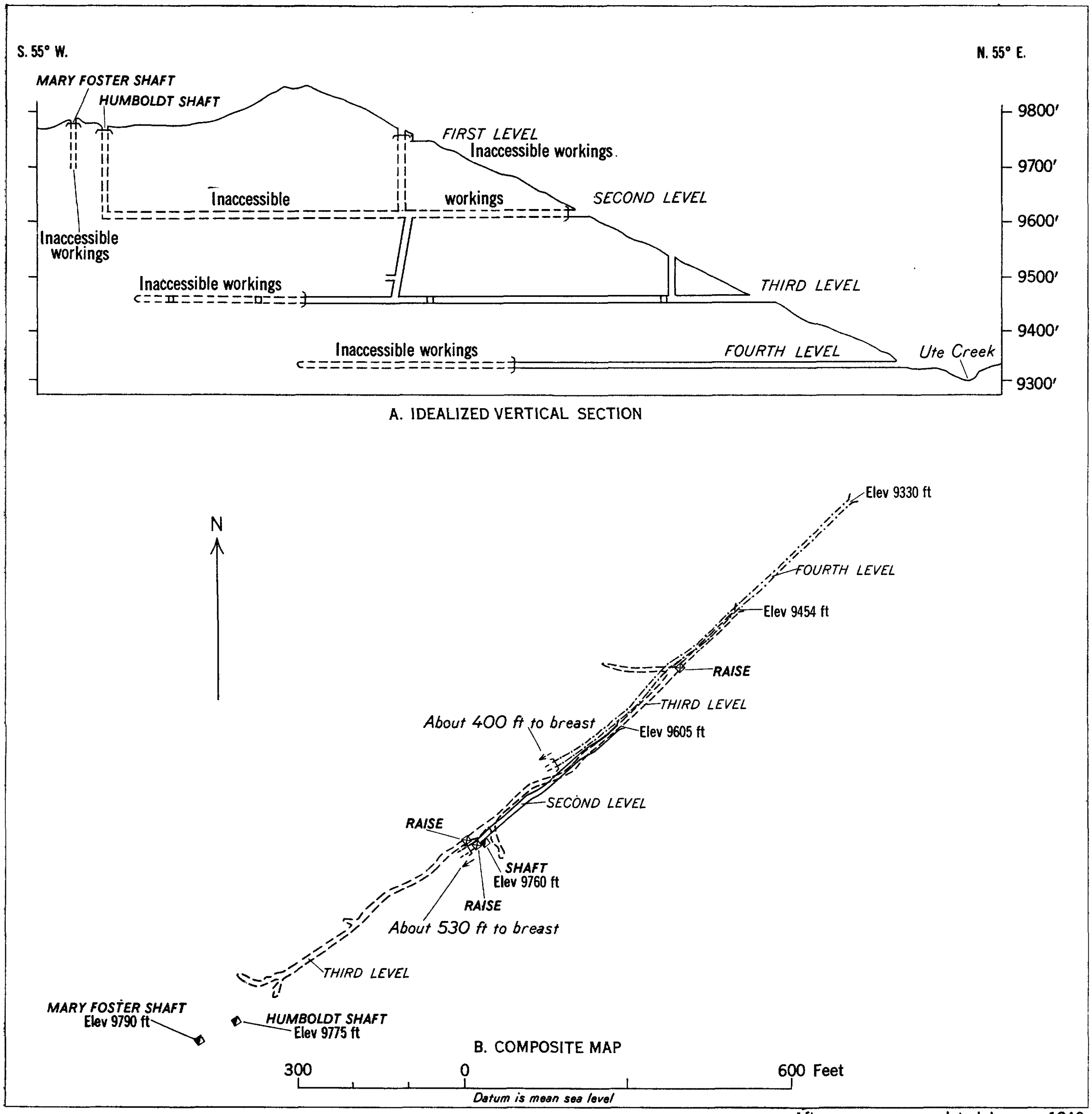
The Humboldt mine includes workings on the Humboldt claim and those at the Mary Foster shaft (fig. 34). The portal of the fourth-level tunnel, at an altitude of 9,330 feet, is near stream level on the southwest side of Ute Creek (pl. 2). The collar of the Humboldt shaft, at an altitude of 9,775 feet, is about 1,500 feet S. 55° W. of the fourth-level tunnel portal.

The Humboldt mine consists of drifts on three main levels (second, third, and fourth), a short first-level tunnel, and a shaft that connects with the second level (fig. 34). At the time of the writers' visit, the only accessible parts of the mine were 843 feet of the third level and 733 feet of the fourth level (fig. 35). Extensive stoping has been done in the mine, but the information available does not allow delimiting of the stoped areas.

The mine was worked as early as 1887, for it was reported by Kimball in 1888, but adequate mine records have been kept only since 1902. Reports of the Director of the Mint list the production of the Mary Foster mine as confidential, but the following figures are given for the Humboldt mine.

Year	Gold (ounces)	Silver (ounces)
1888	150	5,000
1889	180	11,250
1890	642	36,100
1891	52	3,000

Bureau of Mines records indicate that the mine has been worked almost continually from 1902 to 1916, for a short time in 1924, and then intermittently from 1934 to 1951. From 1935 to 1939, production from the Humboldt mine was reported with production from the Lord Byron mine, and any ore produced from the Humboldt mine during this period is not recorded in the following report on production. Total ore produced from the mine since 1902 (with the exception of the 5-year period previously noted) has been 2,951 tons. This ore yielded 825.49 ounces of gold, 2,453 ounces of silver, 419 pounds of copper, 5,210 pounds of lead, and 9,510 pounds of zinc.



After company map dated January 1940, loaned by J. E. Tinsley

FIGURE 34.—Composite map and section of the Humboldt mine.

Wall rock in the accessible part of the mine is predominantly granodiorite that is cut by dikes and pods of pegmatite and biotite-muscovite granite (fig. 35). The dumps at the shafts and at the portals of the inaccessible levels are composed predominantly of the same rocks.

The Humboldt vein strikes N. 45°–65° E. and dips from 85° SE. to 72° NW. Where observed, the vein ranges in width from 2 inches to 14 inches and consists of brecciated wall rock, quartz, pyrite, and gray to brown chalcedonic quartz that is locally cross-cut by thin stringers of resinous sphalerite and car-

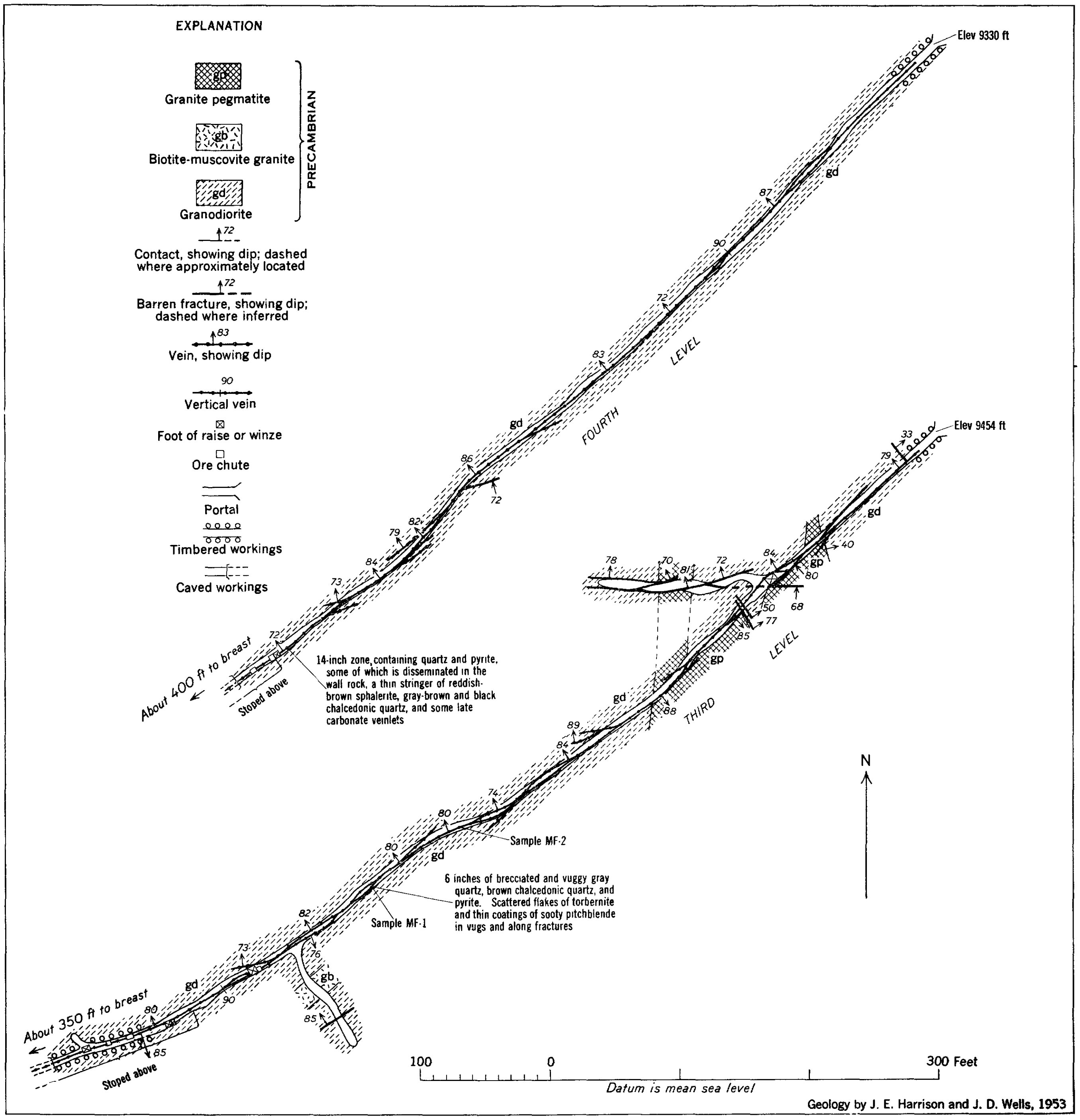


FIGURE 35.—Geologic maps of separate levels of the Humboldt mine.

bonate or stringers of red-brown sphalerite, pyrite, and black chalcedonic quartz. Scattered flakes of torbernite and coatings of sooty pitchblende were noted in the vein material on the third level about 565 feet from the tunnel portal. Study of polished surfaces of a suite of ore specimens collected from the Humboldt vein disclosed the presence of several minerals not seen during mapping of the mine. Most of the pyrite is intergrown with blades and bladed aggregates of marcasite. The sphalerite commonly contains blebs and veinlets of chalcopyrite, tennantite, and polybasite. Galena commonly is in irregular veinlets cutting through the other sulfides, but at places it is intergrown with red-brown sphalerite in the center of a veinlet having coxcomb quartz and marcasite along its walls. A few blebs of free gold were noted in marcasite grains. The paragenetic sequence of the vein minerals is shown diagrammatically in figure 36.

The character of the ore in the Humboldt mine is similar to that in the Dixie mine. Projection of the Dixie vein suggests that it is a split from the Humboldt vein, and the area along the Humboldt vein where the Dixie vein would join is broken into a series of splits and branches (the area between 250 feet and 350 feet from the portal on the third level, and the area between 500 and 600 feet from the portal on the fourth level). It is possible that the Humboldt vein splits into several branches going northeast, and that the distinctive ore containing free gold in association with red-brown sphalerite is peculiar to this vein and its branches.

Localization of the ore body in the Humboldt mine may be related to a deflection in strike of the vein. Most of the stopes in the mine are around the Humboldt shaft and in the back parts of the various tunnel levels. The vein gradually swings more easterly along the tunnel away from the portal on the two partly accessible levels. The more easterly the trend of the vein the wider is the ore; and the first stope on either accessible level begins where the vein, which trends about N. 45° E. at the tunnel portals, swings to about N. 60° E. (fig. 35).

KATIE EMMETT MINE (48)

The upper level portal of the Katie Emmett mine is north of Cascade Creek at an altitude of 9,245 feet (pl. 2); the lower level portal is out of the mapped area about 210 feet S. 51° W. of the upper level portal at an altitude of 9,158 feet. The lower level workings consist of a 529-foot main drift, a 26-foot crosscut, and a 190-foot drift extending west from a point 276 feet from the portal (fig. 37). The upper level consists of a tortuous crosscut tunnel near the portal and drift for the remainder of the tunnel. A small raise is 100 feet from the portal. The tunnel is caved at the beginning of a stoped area 293 feet from the portal.

Bureau of Mines records show intermittent production from the Katie Emmett mine between 1908 and 1948, during which time a total of 1,848 tons of ore was shipped. This ore yielded 168.59 ounces of gold, 465 ounces of silver, 133 pounds of copper, and 2,001 pounds of lead. The copper and lead were from the 1947–48 production, when 185 tons of ore was shipped. As no stopes are on the lower level, most of the production must have come from the upper level and possibly some from a surface cut along the vein northeast of the upper portal.

The wall rock is mostly granodiorite, which is cut by biotite-muscovite granite and pegmatite dikes. Granite gneiss and pegmatite is present as inclusions in the granodiorite.

The Katie Emmett vein is exposed in the upper tunnel (fig. 37); it strikes N. 60° E. and dips about 80° NW. near the portal. Beyond the vein split it strikes N. 40° E.; the footwall vein dips 70° NW. and the hanging-wall vein dips 85° NW. The N. 40° E. part of the vein contains the stope. Several cross fractures are present on the upper level. On the lower level the main drift vein is probably not the Katie Emmett vein, but a nearly parallel subsidiary fracture. This vein strikes about N. 60° E. and dips about 80° SE. southwest of a cross vein and strikes about N. 40° E. and dips from 79° to 85° NW. northeast of the cross vein. The cross vein strikes from N. 45° to 85° W. and dips 59°–80° NE.; this vein was not recognized on the upper level.

The vein minerals are not abundant in the exposed part of the vein; only thin veinlets of quartz and pyrite are present. Lead and copper sulfides must have been present in the stoped areas, for these metals have been produced.

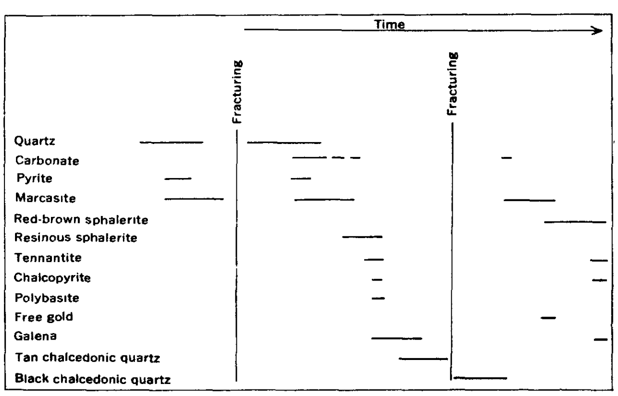


FIGURE 36.—Paragenetic diagram for the vein minerals of the Humboldt vein.

KING SOLOMON MINE (116)

The portal of the King Solomon tunnel, at an altitude of 8,005 feet, is about 100 feet above road level on the northwest side of Chicago Creek (pl. 2).

Production records of the Bureau of Mines indicate that the King Solomon mine was operated during 1914, 1950, and 1951. During this time, 2,895 tons of ore was shipped from the mine. This ore yielded 357.2 ounces of gold, 12,156 ounces of silver, 1,262 pounds of copper, 23,793 pounds of lead, and 11,176

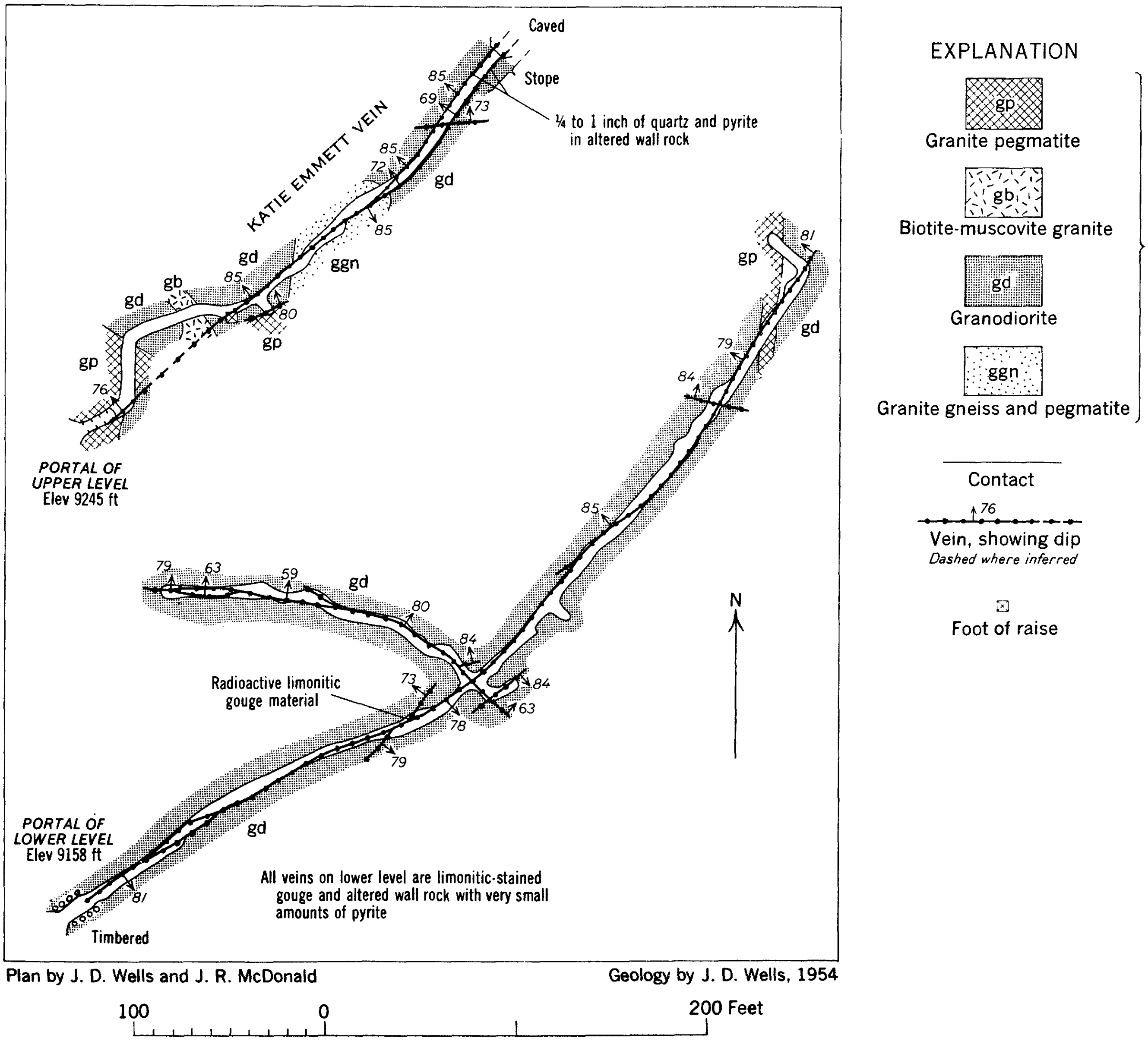


FIGURE 37.—Geologic map of the lower level and part of the upper level of the Katie Emmett mine.

pounds of zinc. Most of this ore came from the Arthur vein.

The mine consists of a crosscut tunnel 1,100 feet in length and about 1,865 feet of drifts and crosscuts along 2 main veins (pl. 7). A small amount of stoping has been done on the King Solomon vein, and extensive stoping has been done on the Arthur vein southwest of its intersection with the main crosscut tunnel (pl. 7). The owner, Mr. John Deerkson, supplied the information on distances to the face in the inaccessible parts of the mine.

The wall rock in the accessible part of the mine consists predominantly of biotite-quartz-plagioclase gneiss that is at places sillimanitic (pl. 7). The gneiss contains layers of granite gneiss and pegmatite and is cut by dikes of biotite-muscovite granite, pegmatite, biotite-quartz latite porphyry, granite porphyry, bostonite porphyry, and trachytic granite porphyry. The gneisses have been folded into a series of tight isoclinal folds that have been refolded.

Two principal veins—the Arthur and the King Solomon—have been developed by the mine. The Arthur vein strikes about N. 54° E. and dips on the average about 78° NW. This vein in the drift northeast of the main crosscut (pl. 7) has a pronounced tendency to branch into the foliation of the host rocks.

The parts of the vein exposed in the mine are 3- to 12-inch zones of gougy wall rock containing disseminated pyrite. The production data, however, suggest that the ore bodies were composed predominantly of galena and sphalerite with lesser amounts of copper minerals. The King Solomon vein strikes about N. 40° E. and dips on the average about 80° NW. It probably joins the Arthur vein on the surface about 1,450 feet northeast of the Arthur shaft and continues northeast through the Silver Glance shaft (pl. 2). The King Solomon vein as seen in the King Solomon tunnel consists of sheared and altered zones a few inches wide that at places contain minor amounts of quartz, pyrite, galena, and sphalerite.

KITTY CLYDE MINE (128)

The collar of the Kitty Clyde shaft, at an altitude of 8,914 feet, is on the north side of Spring Gulch near the north boundary of the mapped area (pl. 2).

Production records for the Kitty Clyde mine are not complete. Reports of the Director of the Mint give the following production for the years 1887–92:

Year	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1887	80.0	1,855	------	-------
1888	22.5	524	------	6,000
1889	190.0	2,575	533	39,820
1890	138.0	1,545	------	20,000
1891	60.0	------	------	-------
1892	167.8	1,530	------	35,420

Spurr, Garrey, and Ball (1908, p. 350) state that little work was done in the mine for about 15 years (1892–1907). Records of the Bureau of Mines show that the Kitty Clyde was operated intermittently from 1907 to 1952. The owners of the Fraction mine, which is on the Kitty Clyde vein and is a few hundred feet outside the mapped area (Spurr, Garrey, and Ball, 1908, pl. 75), refer to the workings developed since 1933 through the Collie tunnel as the Kitty Clyde mine, even though these workings are connected to the old Fraction mine and not to the old Kitty Clyde mine. The writers believe, therefore, that the production listed for the Kitty Clyde mine in the Bureau of Mines files is a mixture of production that came from the old Kitty Clyde mine prior to 1932 and from workings connected with the Fraction mine after 1932. Only the production believed to have come from the old Kitty Clyde workings is given in this report. From 1907 to 1932 a total of 412 tons of ore was shipped from the mine. This ore yielded 474.65 ounces of gold, 4,922 ounces of silver, 27,272 pounds of copper, 134,925 pounds of lead, and 16,074 pounds of zinc.

The extent of the mine workings could not be determined because the shaft was caved at the collar at the time of the writers' visit. An old section of the mine (fig. 38) shows the extent of the workings in 1902.

Wall rock on the dump includes biotite-quartz-plagioclase gneiss, some of which is garnetiferous, quartz monzonite gneiss, and granite gneiss and pegmatite. A few fragments of trachytic granite porphyry were seen on the dump and, according to Spurr, Garrey, and Ball (1908, p. 350), this rock was found in the mine.

The Kitty Clyde vein, at the collar of the Kitty Clyde shaft, strikes N. 50° E. and dips 50° NW. The main vein extends to the northeast as the Fraction vein (Spurr, Garrey, and Ball, 1908, p. 350), and a split diverges to the north through the Little Jacket shaft (pl. 2). Ore found on the dump at the Kitty Clyde shaft contained quartz, pyrite, chalcopyrite, tetrahedrite, galena, and sphalerite. Spurr, Garrey, and Ball (1908, p. 350) also report rhodochrosite and barite in dump specimens. According to R. H. Moench (oral communication, 1955), who has mapped the accessible parts of the Fraction mine, this vein is typical of the type called pyritic galena-sphalerite with copper sulfides and copper and silver sulfosalts.

LITTLE MATTIE GROUP OF MINES (135, 136, 140, 141, 142)

The Little Mattie group of mines with its connected underground workings is the largest in the Chicago Creek area. The mines consist of more than 2,200 feet of shafts and 5 miles of drifts. The main openings are the Little Mattie tunnel and shaft, the Silver Glance shaft, and the Newton shaft. The Little Mattie shaft and tunnel are in the east branch of Cottonwood Gulch at an altitude of 8,250 feet (pl. 2). The Silver Glance shaft is in the west branch of Cottonwood Gulch at an altitude of 8,300 feet. The Newton shaft is in the first gulch east of the Little Mattie shaft at an altitude of 8,520 feet.

History.—The first record of development on the Little Mattie vein is in the Director of the Mint Report for 1882 (Burchard, 1883). In 1882 the Little Mattie shaft was 200 feet deep and connected with several drifts. In 1883 the Silver Glance mine consisted of a 200-foot shaft and 500 feet of drifts and adits (Burchard, 1884). The vein in the Little Mattie shaft was said to contain high-grade ore consisting of tetrahedrite, sphalerite, galena, ruby silver, native silver, and argentite (Burchard, 1884).

Development progressed rapidly in the Little Mattie shaft in the following years, the first record of production being in 1887 when $57,842 worth of ore was shipped. In 1889 $52,217 worth of ore was shipped from the Little Mattie shaft workings, and in 1892

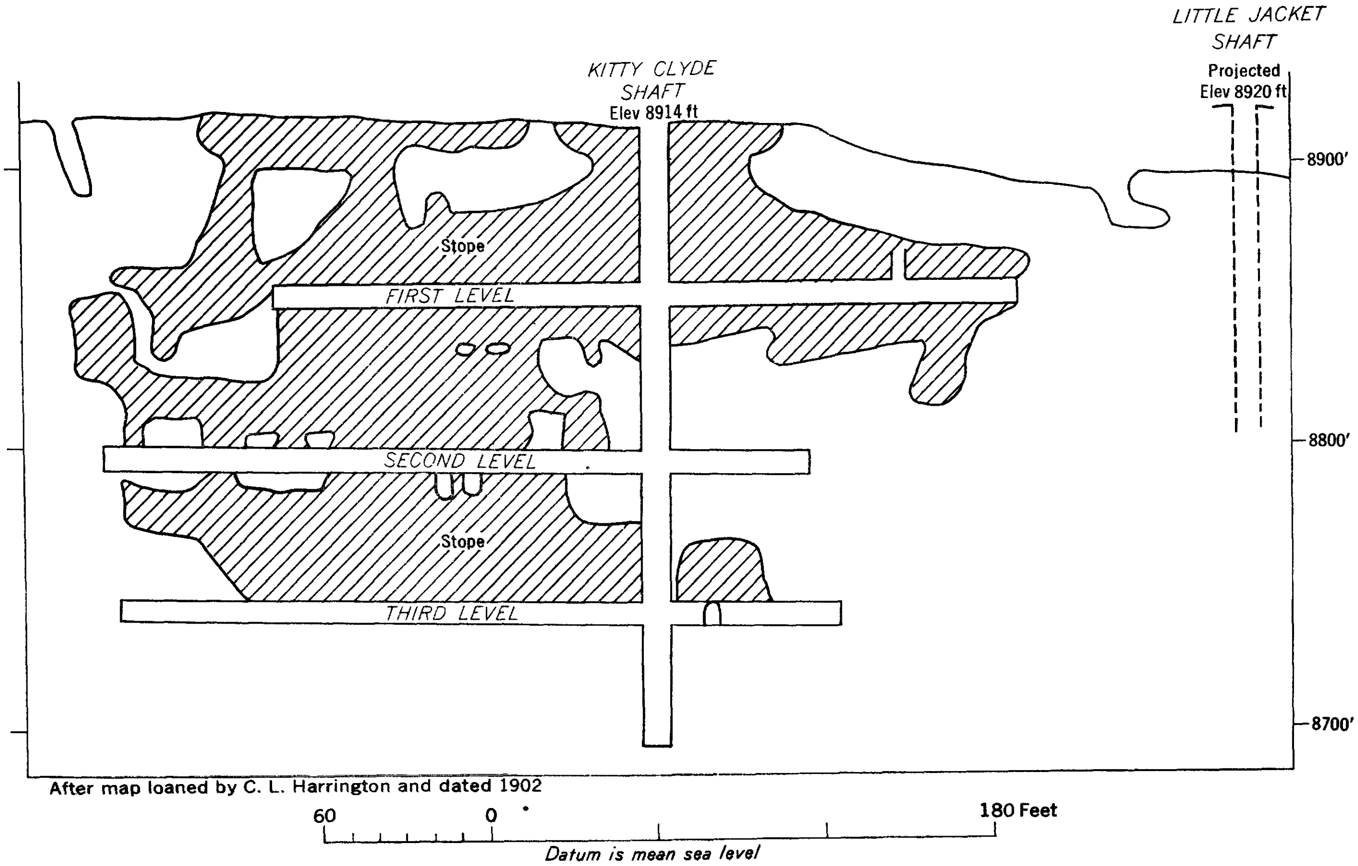


FIGURE 38.—Section of the Kitty Clyde mine.

$23,000 worth was shipped from the Newton shaft workings. No information is available regarding the operation of the mines between 1892 and 1902. Bureau of Mines records show that 8,500 tons of ore was shipped in 1902, and from this date until 1941 the mine operated almost continuously, commonly shipping as much as 10,000 tons per year. During World War II no ore was produced, but shipments were again made in 1950 and 1951. The present owners of the mine, Front Range Mines, Inc., did not operate the mine between 1952 and 1955.

Production.—Production records include ore shipped from the Little Mattie, Silver Glance, Great Republican, Decator, General Thomas, Newton, and Wild Rose claims. Records before 1900 are incomplete. Director of the Mint records show production as follows:

Year	Gold (ounces)	Silver (ounces)
1887	720	33, 600
1889	795	28, 080
1890	795	28, 200
1892	1, 150	-------

Bureau of Mines records show that 188,652 tons of ore has been shipped from the Little Mattie group of mines since 1902. This ore yielded 47,141.43 ounces of gold, 361,996 ounces of silver, 13,924 pounds of copper, 264,725 pounds of lead, and 288,906 pounds of zinc. John Deerkson, president of Front Range Mines, Inc., states (oral communication, 1955) that $700,000 worth of ore was taken from the Newton shaft between 1931 and 1951.

Mine workings.—The surface openings of the Little Mattie group of mines consist of three main shafts, a tunnel level, and several smaller shafts and tunnels (fig. 39). The depth of the Little Mattie shaft is 1,150 feet; the Newton shaft, 720 feet; and the Silver Glance shaft, 400 feet. Other shafts located between the Little Mattie and Newton shafts are the Decator, Air, General Thomas, and Republican. Between the Silver Glance shaft and the Little Mattie shaft are the Apex and "B" shafts. The Hilltop and Wild Rose shafts are over the ridge east of the Newton shaft and out of the area covered by this report. The main tunnel level extends from near the Little Mattie shaft northeast along the vein through the Newton shaft and 1,800 feet beyond. The Silver Glance tunnel extends westward from near the Silver Glance shaft for about 400 feet. Several other smaller adits

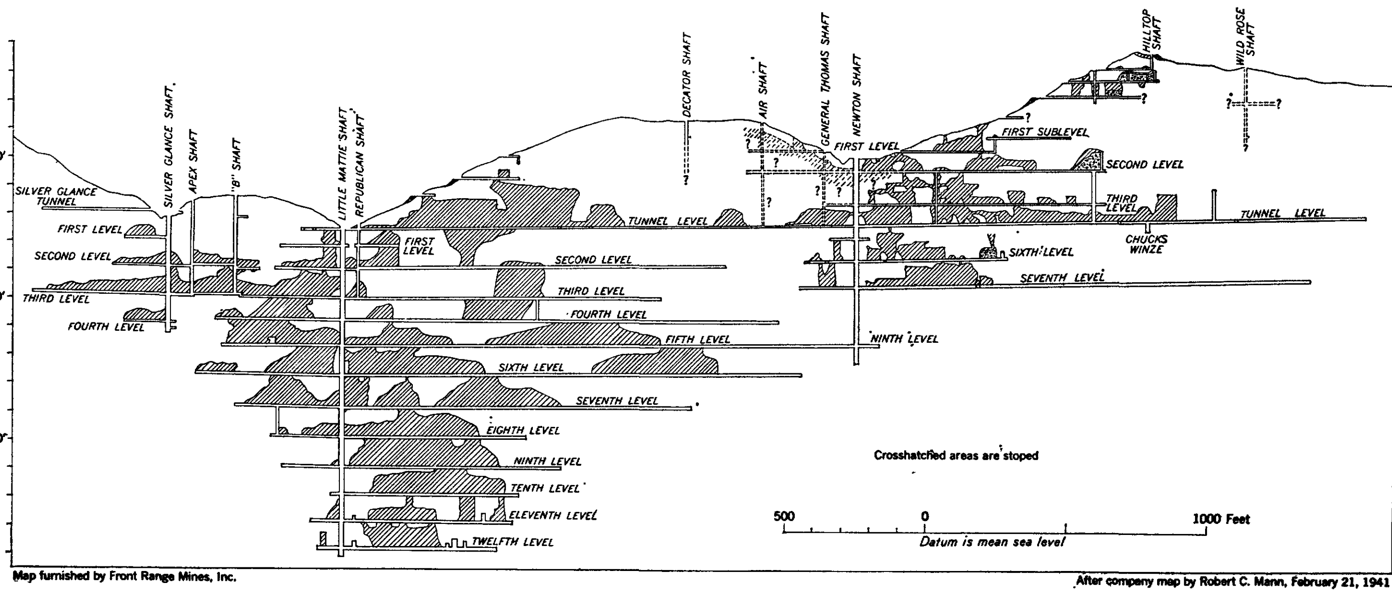


FIGURE 39.—Vertical projection of workings along the Little Mattie vein.

expose the vein along its length. Drifts have been made on 17 levels. Much stoping has been done near the shafts, especially the Little Mattie shaft. Only 2,429 feet of the tunnel level was accessible at the time of the writers' visit.

Wall rocks.—The wall rocks in the accessible part of the Little Mattie tunnel are Precambrian rocks—interlayered biotite-quartz-plagioclase gneiss, granite gneiss and pegmatite, and pegmatite—and Tertiary dikes—bostonite and quartz bostonite (pl. 8). Along most of the length of the drift, Precambrian rocks are on one wall and Tertiary dikes on the other.

The Precambrian gneisses on the surface have been folded into a series of tight isoclinal folds; these folds cannot be distinguished in the accessible mine workings because of poor exposures. Contacts between the gneisses are gradational and parallel to the foliation which generally is about N. 60° E., 70° NW. on the Little Mattie tunnel level. The pegmatites generally have sharp contacts parallel to the foliation.

A bleached quartz bostonite porphyry extends from the portal of the tunnel to the Newton shaft. A lilac-colored bostonite porphyry occurs from about 200 feet southwest to about 450 feet northeast of the Newton shaft. About 250 feet northeast of the Newton shaft a reddish-brown bostonite comes in on the footwall and extends to the end of the accessible tunnel.

Veins.—The Little Mattie vein is a lode that strikes about N. 42° E. and dips on the average about 70° NW. This vein is unusual in that it cuts the foliation at an angle of about 30 degrees. To the southwest, the Little Mattie branches into veins that are subparallel to the foliation and Tertiary dikes (pl. 1). One of the branch veins is exposed in the Silver Glance shaft; the other, an unexplored vein, is about 100 feet north of the Silver Glance shaft (pl. 2). To the northeast, the Little Mattie vein extends into the Spring Gulch area.

In the accessible part of the Little Mattie mine the veins follow both sides of the Tertiary dikes, which cut the foliation of the Precambrian rocks at a low angle. The main vein is on the footwall of the dike near the portal, on the hanging wall in the Newton shaft area, and between dikes farther east. Vein splits that follow the foliation are common, but they are weakly mineralized except for the vein about 700 feet from the portal.

Fractures that offset the Little Mattie vein in the accessible part of the workings are essentially unmineralized. At the Decator shaft the Edna-Black Eagle vein offsets the main vein about 20 feet, the northeast wall having moved southeast. Similar movement occurred on the breccia fault near the portal. The breccia fault is an extension of the Star vein.

The vein exposed between the extensive stopes in the Little Mattie tunnel has distinct hanging-wall and footwall veins along most of its length. The ground between has been affected to a varying degree by alteration, and ore minerals occur in it, disseminated and in stringers. The mineralized zone ranges in width from a few inches to 6 feet; the hanging-wall and footwall veins range from a few inches to 18 inches. The vein has been stoped where both the hanging-wall and footwall veins could be mined together.

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The Little Mattie vein has been opened by repeated fracturing and filled by repeated deposition of vein minerals. Several periods of fracturing can be recognized in the vein and in polished section. The mineralogy and paragenetic sequence of the veins are similar to that of other galena-sphalerite-rich veins in the area. Quartz, carbonate, pyrite, chalcopyrite, sphalerite, galena, tennantite, and gold have been identified in specimens taken from this vein. Under the microscope the gold was seen as blebs and stringers in sphalerite and with galena as a fracture filling in sphalerite.

Although the Little Mattie vein contains the abovementioned minerals in the usual sequence, individual stringers or parts of the vein vary in quantitative mineral content. The footwall vein commonly contains different minerals and (or) different proportions of these minerals from the hanging-wall vein, as can be seen 400 feet northeast of the Newton shaft. The same suite of minerals is in the hanging wall at places and in the footwall at other places. Different parts of the vein were probably opened at different times—allowing different mineral suites to be deposited.

MAMMOTH-LE ROI GROUP OF MINES (120, 121a, 121b, 122)

The Mammoth-Le Roi group of mines includes the Mammoth, Black, Billie, Brunswick, and Le Roi mines. This group of mines is on the east shoulder of Alps Mountain near the prominent saddle in the ridge separating Spring Gulch from Chicago Creek (pl. 2).

No production records for any of these mines could be found; most of the mine development appears to have been done before 1900.

At the time of the writers' visit, all the mines were inaccessible. The extent of the workings in 1900 is shown on plate 9.

The wall rock on the dumps of these mines is mostly biotite-quartz-plagioclase gneiss, some of which is sillimanitic. The Mammoth tunnel dump contains some migmatite and some granite gneiss and pegmatite; the Black shaft dump contains a few fragments of hornblendite.

The Mammoth-Le Roi group of mines develops a group of intersecting veins (pl. 2). The principal veins are the Billie, Mammoth, Big Soft, and Little Topsy. The Billie vein at the collar of the Billie shaft strikes N. 70° E., dips 58° NW., and probably joins the Mammoth vein near the Le Roi shaft. The Mammoth vein strikes about N. 55° E. and dips 40°–70° NW. Ore on the dumps of workings along the Mammoth vein consists of quartz, carbonate, pyrite, chalcopyrite, sphalerite, and galena. The Big Soft vein strikes about N. 45° E. and dips about 35° NW. It intersects the Bruce-Black vein near the collar of the Black shaft (pl. 2) and may cut off the Bruce-Black vein, for this vein was not recognized along the Mammoth tunnel. The Little Topsy vein strikes about N. 60° E. and dips about 75° NW. Where this vein is exposed in the Little Topsy shaft, about 900 feet west of the Mammoth tunnel portal (pl. 2), it consists of a 6-foot sheared and altered zone containing thin stringers of quartz, pyrite, sphalerite, and galena. Judged by the development on the veins, any production from the mine probably has come from the Big Soft and Mammoth veins.

MARTHA E MINE (125)

The portal of the Martha E mine, at an altitude of 9,298 feet, is on the south side of Spring Gulch about 3,750 feet N. 63° E. of the eastern peak of Alps Mountain (pl. 2).

This mine originally was a prospect on the Daisy Freese claim opened by the Stanley Mines. In 1948, the claim was relocated by James Manning, of Louisville, Colo. Mr. Manning and Harvey Zook extended the prospect adit to 152 feet and put down a 15-foot winze on the most promising part of the sheared zone disclosed by the drifting. Uranium-bearing minerals were noted in the sheared zone, and a detailed map of the surface and underground geology was made by the U. S. Geological Survey in 1951. A contract with the Defense Minerals Exploration Administration was let for extension of the winze to 100 feet and for a small amount of drifting on the 100-foot level. This work was completed in May 1953, but no minable material of ore grade was discovered. Since May 1953 the owners have extended the tunnel level for 70 feet, and during 1954 a shipment of 2,920 pounds of ore was handpicked from high-grade spots in the winze. The settlement sheet for this ore gave an assay value of 0.14 percent uranium.

The mine consists of a 222-foot adit trending about N. 75° W. and a winze that connects this level with about 75 feet of drifting and crosscutting on the 100-foot level (pl. 10). No stoping has been done in the mine.

Wall rock in the mine is predominantly migmatite that is locally garnetiferous or sillimanitic. A granite pegmatite is exposed in the winze near the 100-foot level and crosscuts the foliation in the migmatite. A layer of granite gneiss and pegmatite is exposed in the northerly-trending crosscut on the 100-foot level. The migmatite gradually becomes more granitic toward the breast of the southerly-trending crosscut on the 100-foot level, and the vein zone may be confined to a migmatite layer between 2 layers of granite gneiss and pegmatite.

The adit has been driven into the southeast flank of a major open syncline, and the portal of the adit is about 400 feet southeast of the crest of this fold (pl. 1). Foliation and layering in the rock units trends from about N. 80° E. to N. 80° W. in the area of the mine, and this trend has probably influenced the direction of shear in the rocks.

In the Martha E, the vein zone is less well defined and contains many more minor slips and fractures than the typical lode zones seen in mines of the surrounding area. The sheared zone is wider than the greatest width exposed by the mine workings, but the fractures that are mineralized or that have alteration along them appear to be confined to a width of about 20 feet and to the less granitic parts of the migmatite.

The shear zone as a whole trends about N. 75° W., dips about 45° N., and is subparallel to the foliation. The most persistent single shear in the mine (*a* on pl. 10) was carried in the back of the winze and is exposed on the adit level and 100-foot level. This shear splits or bends near the winze; the eastern part trends about N. 80° W., but the western part on both levels trends about N. 68° W.

The shears contain gouge and altered wall rock, and, where primary ore minerals are present, pyrite, chalcopyrite, galena, and sphalerite in a quartz gangue. Pyrite is commonly the only sulfide visible, and where the other sulfides are present they are in trace amounts. Some black chalcedonic quartz is present at places in the mine. The sulfides are in 1-inch-thick stringers that are sheared or in fragments scattered through the gouge and altered wall rock of the shears.

Of particular interest is the occurrence and distribution of ore minerals classed as secondary for this report. These minerals include limonite, autunite, torbernite, and sooty pitchblende. The presence of limonite throughout the mine workings attests to the fact that the workings are all within the zone of oxidation.

The uranium minerals occur in pods or bunches along the shears and seem to alternate with areas containing only gouge and altered wall rock. In the winze section (pl. 10*B*) these alternations occur about every 10 feet. The sooty pitchblende occurs within or along an individual shear; autunite and torbernite occur as flakes or in pods in the footwall of the shear along the foliation of the wall rock and along joint surfaces. The occurrence of these minerals suggests to the writers that the torbernite and autunite have been deposited by ground water percolating through the shear zone. The sooty pitchblende probably served as a source of uranium for this process. The origin of the sooty pitchblende is less evident. Although the sooty pitchblende appears confined to the major shears, it sometimes occurs as thin coatings on fractures confined to, but crosscutting, a shear. An X-ray powder diffraction examination[7] of the sooty pitchblende shows that it is fine-grained uraninite of moderately good crystallinity. The sooty pitchblende may represent hard pitchblende deposited with the hydrothermal minerals and subsequently oxidized, or it may represent material deposited entirely by supergene processes.

Channel samples were cut across the radioactive shears in the winze; the west wall was sampled at 4-foot intervals and the east wall at 8-foot intervals. (See pl. 10.) The average grade of 21 samples from the west wall is 0.031 percent uranium, and the average of 12 samples from the east wall is 0.022 percent uranium. If the one "erratic" sample from the west wall (WWW–12) is disregarded, then the average of the remaining 20 samples from that wall is also 0.022 percent uranium. The average width of the samples from both walls of the winze is 1.25 feet.

Samples of similar average grade and width were collected along the tunnel level and the 100-foot level although no attempt was made to sample systematically.

MOHAWK TUNNEL (47)

The portal of the Mohawk tunnel is at stream level along Cascade Creek at an altitude of 9,190 feet (pl. 2).

The tunnel consists of a 228-foot crosscut that connects with a 257-foot drift; about 200 feet along the drift from the crosscut is a raise (fig. 40).

Production from the mine must have been small, for only one small stope was observed. Any production from the Mohawk probably would be included with the Katie Emmett records.

Wall rock in the mine consists of granodiorite and granite gneiss and pegmatite cut by biotite-muscovite granite dikes.

The Mohawk vein strikes N. 65° E. and dips from 86° SE. to 73° NW. A horse in the vein contains the best ore, which consists of brecciated chalcedonic quartz cemented by quartz, pyrite, marcasite, galena, and sphalerite.

ORINOCO TUNNEL (102)

The portal of the Orinoco tunnel is at an altitude of 8,536 feet in Golden Glen Gulch (pl. 2). This mine

[7] Determination by W. F. Outerbridge, U. S. Geological Survey.

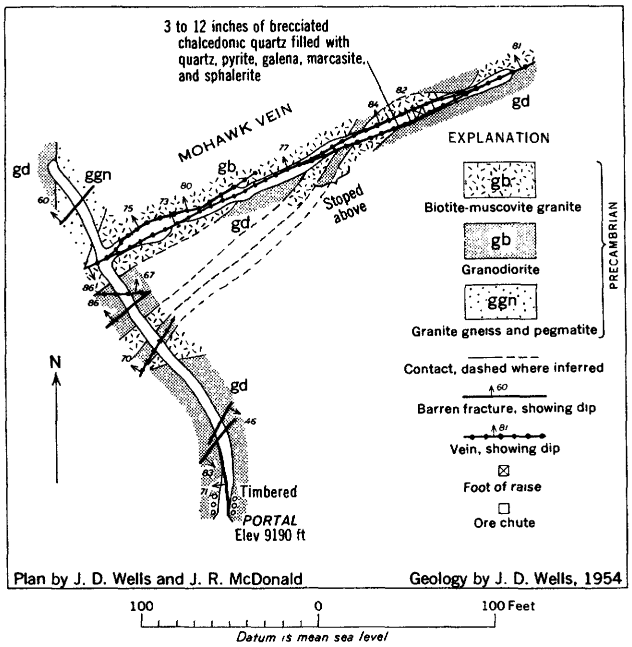

FIGURE 40.—Geologic map of the Mohawk tunnel.

was called the Golden Glen by Spurr, Garrey, and Ball (1908, p. 377 and pl. 17).

The only production recorded for the mine is 10 tons of ore, averaging $95 to the ton (Spurr, Garrey, and Ball, 1908, p. 377).

The extent of the workings could not be determined because of bad air in the mine. The tunnel is a crosscut that trends N. 33° W. and is probably more than 1,000 feet long.

Wall rock in the first few feet of the tunnel is mostly interlayered biotite-quartz-plagioclase gneiss and granite gneiss and pegmatite that occurs in tight folds that are overturned to the southeast. These rocks are cut by dikes of highly radioactive pegmatite and, at the portal, by a 25-foot-thick dike of coarse-grained trachytic granite porphyry.

Several northeast-trending veins probably were intersected by the crosscut. At least one of these contained ore consisting of quartz, pyrite, galena, and tetrahedrite (Spurr, Garrey, and Ball, 1908, p. 377).

PERKINS TUNNEL (117)

The portal of the Perkins tunnel, at an altitude of 8,740 feet, is in King Solomon Gulch (pl. 2). The tunnel is a crosscut adit trending N. 11° W. for 1,917 feet (pl. 11). At a point 480 feet from the portal a drift extends 113 feet westerly and 218 feet easterly; at a point 1,420 feet from the portal, a drift extends westerly but is caved at a point about 80 feet from the crosscut; at a point 1,566 feet from the portal, a drift extends 50 feet easterly. The only stope in the accessible part of the mine is above the drift farthest from the portal. No record of production from the mine could be found.

Wall rock in the mine consists predominantly of granitic gneiss and biotite-quartz-plagioclase gneiss interlayered with sillimanitic biotite-quartz gneiss (pl. 11). Biotite-muscovite granite or biotite-muscovite granite and associated graphic pegmatite form dikes and sills as much as 65 feet thick in the two principal rock units. Three dikes of Tertiary age are exposed along the crosscut near the drift closest to the portal.

The crosscut has been driven into the southeast flank of an open syncline, and the two predominant wall rocks represent layers on this flank. The biotite-muscovite granite sills and dikes are sheetlike bodies, principally along the foliation, that probably connect with the stock of this granite at Alps Mountain.

Veins exposed in the mine range in width from ½ to 24 inches and commonly contain stringers of quartz, pyrite, tetrahedrite, sphalerite, and galena in a brecciated zone consisting of gouge, fragments of altered wall rock, and fragments of quartz-pyrite. The veins, in general, tend to follow the foliation in the host rocks or contacts between different kinds of host rocks. The vein exposed in the drift nearest the portal is about 24 inches wide at the crosscut, but near the west end of the drift it breaks up into a series of weakly mineralized fractures that branch out into the foliation.

P. T. MINE (175, 179)

The portal of the P. T. mine, at an altitude of 7,674 feet, is on the northwest side of Chicago Creek near the northeast corner of the mapped area (pl. 2). The collar of the P. T. shaft is about 1,670 feet due west of the portal and is at an altitude of 8,110 feet.

The mine consists of a shaft that connects with five levels and a winze from the fifth level that connects with the sixth level and the tunnel level. The tunnel level has more than 2,500 feet of drifts and crosscuts (pl. 12). At the time of the writers' visit, most of the workings on the tunnel level were accessible and were mapped. The winze was climbed, but the workings on the upper level were deemed unsafe and only sketched hastily. Extensive stoping has been done in the mine in the area between the fifth level and the surface. Some stoping has been done on the tunnel level in the western part of the mine (pl. 12).

Complete production records for the P. T. mine are not available. About $70,000 worth of ore had been shipped from the mine by 1906 (Spurr, Garrey, and

Ball, 1908, p. 380). Bureau of Mines records show production in most of the years between 1908 and 1941, but none from 1942 to 1954. During the period from 1908 to 1941, 8,813 tons of ore was shipped from the mine. This ore yielded 1,614.18 ounces of gold, 6,655 ounces of silver, 5,666 pounds of copper, 5,924 pounds of lead, and 1,321 pounds of zinc.

Wall rock in the mine consists predominantly of interlayered biotite-quartz-plagioclase gneiss and granite gneiss and pegmatite (pl. 12). A 15-foot-wide dike of biotite-muscovite granite is exposed near the portal, and dikes of bostonite porphyry containing an unusual number of mafic phenocrysts are exposed at three places in the mine. A porphyry dike forms the footwall of the vein on the first and third levels (Spurr, Garrey, and Ball, 1908, p. 379). This dike was seen in the west end of the fifth level and on the tunnel level 100 feet southeast of the principal vein junction.

The gneisses exposed in the eastern part of the mine have been bent into a series of broad gentle warps whose axes trend about N. 30° E.; axes of smaller and tighter open folds seen in the north-trending crosscut have the same trend. The broad warps probably correspond to the two principal fold axes of the same trend traced for several hundred feet on the surface.

The gentle warping is at places deflected by small terrace-type or chevron-type drag folds that trend about N. 60° E. These deflections are local in extent and rarely exceed 40 feet in width.

Three principal veins are exposed on the tunnel level of the P. T. mine. The main vein, called the P. T. vein, strikes about N. 75° W. and dips, on the average, about 50° NE. from the collar of the shaft to the sublevel below the 150-foot level and about 65° NE. from the sublevel to the tunnel level. In general, the flatter parts of this vein have been stoped and the steeper have not. A second vein was followed for about 380 feet from the portal on the tunnel level. This vein probably is the same as the one followed by the east-trending drift seen in the western part of the tunnel level (pl. 12). This vein strikes about N. 85° W. and dips, on the average, about 75° NE. The third principal vein is exposed on the tunnel level in the fractured area about 1,350 feet from the portal. This vein strikes N. 36° E. and dips 50°–55° SE. It appears to cut through and offset both of the other principal veins. This vein is probably the "cross lead" described by Spurr, Garrey, and Ball (1908, p. 379). The Quito vein, which appears to join the P. T. vein near the portal of the Quito tunnel on the surface (pl. 2), could not be definitely identified on the tunnel level, although it is probably represented by one of the veins seen in the crosscut extending southwest from the eastern end of the drift on the P. T. vein.

The ore from the upper levels consisted of quartz and cupriferous pyrite associated with an appreciable amount of tetrahedrite and siderite (Spurr, Garrey, and Ball, 1908, p. 379). These minerals plus other carbonates, chalcopyrite, and sphalerite were seen in the veins on the tunnel level. At a few places in the mine, an early phase of quartz and pyrite was seen to be sheared or brecciated and contained unsheared stringers of quartz and cupriferous pyrite and less commonly sphalerite and (or) carbonate. A few minerals were seen in polished surfaces of ore specimens that were not noted during mapping. Small amounts of bournonite, pearceite, pyrargyrite, and galena commonly form blebs in, or fill fractures in, pyrite. The paragenetic sequence of the vein minerals is shown diagrammatically in figure 41.

Localization of the ore bodies along the P. T. vein appears related to dip of the vein and possibly to deflection through the porphyry dike. Most of the stopes in the mine are on the flatter parts of the vein. The vein in the shaft has the porphyry dike as a footwall on some levels, but the vein must cross the dike at a low angle in both strike and dip if the surface is mapped correctly (pl. 2). As such intersections are, in general, favorable sites for deposition of ore in the Chicago Creek area, the vein-dike intersection might have aided in localization of the ore body mined at the shaft.

QUITO MINE (178)

The portal of the Quito tunnel, at an altitude of 7,660 feet, is at road level on the northwest side of Chicago Creek (pl. 2).

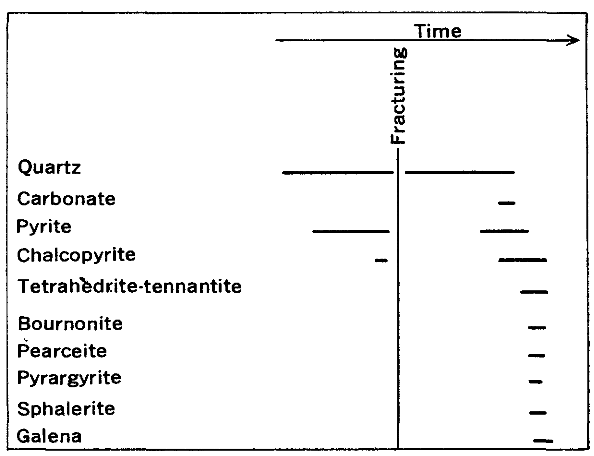

FIGURE 41.—Paragenetic diagram for the vein minerals of the P. T. vein.

First record of production for the Quito mine is that given by Kimball (1889) for the year 1888, when ore yielding 111.95 ounces of gold and 16 ounces of silver was produced from the mine. The next recorded production is given by the Bureau of Mines files and is for the year 1902. According to these files, the mine operated intermittently from 1902 to 1934. During this time a total of 3,163 tons of ore was produced from the mine. This ore yielded 2,919.23 ounces of gold, 2,887 ounces of silver, and 5,918 pounds of copper.

The Quito mine consists of a tunnel about 1,180 feet long and an underground shaft that connects with short drifts on three levels (fig. 42). Extensive stoping has been done between the tunnel level and the surface and between the tunnel level and the first level below it.

Wall rock in the mine seen on the dump includes biotite-quartz-plagioclase gneiss and granite gneiss and pegmatite.

The Quito vein strikes about east and dips on the average about 62° N. Ore on dumps of workings along this vein contains mostly quartz, pyrite, tetrahedrite, and chalcopyrite. The Quito vein joins the P. T. vein near the portal of the Quito tunnel (pl. 2).

The ore body outlined by the stoped area in the Quito mine (fig. 42) is at or near the junction of the Quito and P. T. veins. The lack of stoping on either the Quito (fig. 42) or P. T. (pl. 12) veins away from this junction suggests to the writers that the ore body is controlled by the vein intersection. Older production records show a considerably higher gold-to-silver ratio and probably represent supergene-enriched ore taken from the near-surface parts of the ore body (fig. 42).

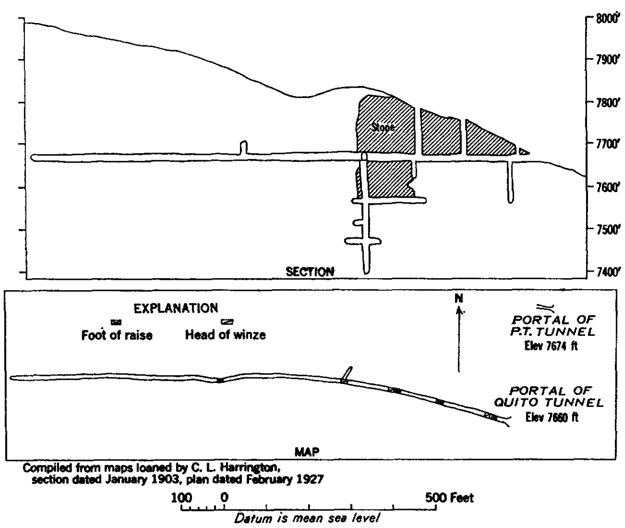

FIGURE 42.—Sketch map and section of the Quito mine.

SAPPHO-OUIDA GROUP OF MINES (27, 28, 29, 30)

The Sappho-Ouida group of mines includes the Sappho, Ouida, Gold and Silver Coin, and the French Girl mines. These mines are on both sides of Ute Creek in the general area where Ute Creek changes direction from east flowing to south flowing (pl. 2).

At the time of the writers' visit none of the mines were accessible. Judged from the size of the dumps, none of the mines have been extensively developed, and the French Girl property is more of a prospect than a mine. The Sappho, Ouida, and Gold and Silver Coin mines have each had a little ore produced from them (Spurr, Garrey, and Ball, 1908, p. 370). The only record of production found, listed by Kimball (1888) for the Gold and Silver Coin for the year 1887, was 100.9 ounces of gold, 1,793 ounces of silver, and 4,140 pounds of lead.

Surface mapping indicates that the wall rock probably is granodiorite and biotite-muscovite granite. The mapping also suggests that the Ouida vein connects with the vein prospected by an adit on the French Girl claim and possibly extends to the east as the vein seen in pits on the Veteran claim; the Sappho vein probably intersects the Ouida vein near the portal of the French Girl mine; and the Gold and Silver Coin vein is probably a split off the Ouida or Sappho veins.

The Ouida vein strikes about N. 55° E. and dips about 65° NW.; the Sappho vein strikes about N. 32° E. (Spurr, Garrey, and Ball, 1908, p. 370) and probably dips steeply northwest; the Gold and Silver Coin vein strikes about N. 72° E. and dips about 66° NW. Brief descriptions of the ores by Spurr, Garrey, and Ball (1908, p. 370) and examinations of vein material on the dumps suggest that all these veins are predominantly composed of clear quartz, chalcedonic quartz, pyrite, galena, and sphalerite. Spurr (p. 370) also noted the presence of minor amounts of barite and tetrahedrite(?) in ore from the Sappho mine.

SILVER BELL MINE (85)

The portal of the Silver Bell tunnel, at an altitude of 9,100 feet, is on the northeast side of Eclipse Gulch (pl. 2). The portal of a second tunnel, which was mostly inaccessible in 1953, is about 200 feet N. 60° W. of the portal of the Silver Bell tunnel.

The only record of production was found in the ledger of the Idaho Springs Sampling Works and was for 1.15 tons of ore in 1934 and for 3.98 tons of ore in 1935. This ore contained a total of 0.14 ounce of gold, 7.4 ounces of silver, and 32 pounds of zinc.

This mine consists of the Silver Bell tunnel, which trends about N. 40° E. for 309 feet, and a second adit which trends N. 67° E. for about 340 feet (fig. 43). These 2 adits join about 50 feet from the breast of the working. A winze has been put in below the Silver Bell tunnel near the junction of the adits, and some stoping has been done above the other adit.

Wall rock in the mine is biotite-quartz-plagioclase gneiss that is locally sillimanitic and (or) migmatitic.

The vein in the inaccessible adit is probably the Big Chief vein. It consists of a 3-foot sheared zone containing local stringers and pods of quartz and disseminated pyrite. The vein in the Silver Bell tunnel is a branch from the Big Chief vein (called the Gold Eclipse vein) and consists of ½ to 8 inches of crushed wall rock containing discontinuous thin stringers of quartz, pyrite, galena, and sphalerite.

SILVER HORN MINE (56)

The Silver Horn tunnel portal is at stream level along Ute Creek at an altitude of 9,000 feet (pl. 2). As this mine was inaccessible at the time of the writers' visit, the description and map of the mine are after Spurr, Garrey, and Ball (1908, p. 371–373).

Bureau of Mines records show that small amounts of ore were produced from the Silver Horn mine every year from 1908 to 1914 and in 1934. The total ore shipped since 1908 is 182 tons. This ore yielded 39.03 ounces of gold, 2,554 ounces of silver, 13 pounds of copper, 991 pounds of lead, and 619 pounds of zinc.

The workings consist of a short crosscut tunnel and about 700 feet of drift on 2 veins (fig. 44). A shaft extends through the tunnel level to 2 short levels

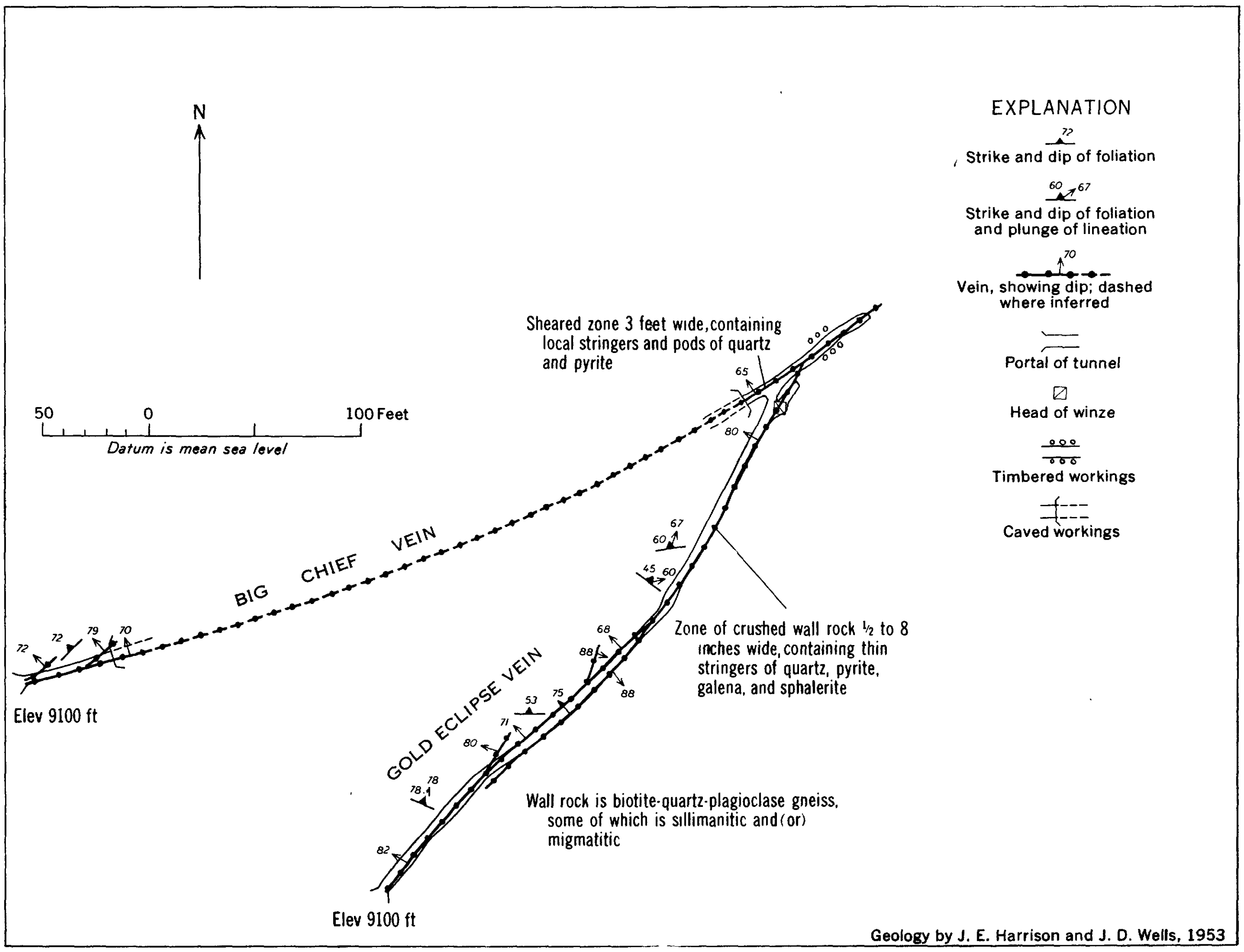

FIGURE 43.—Geologic map of the Silver Bell mine.

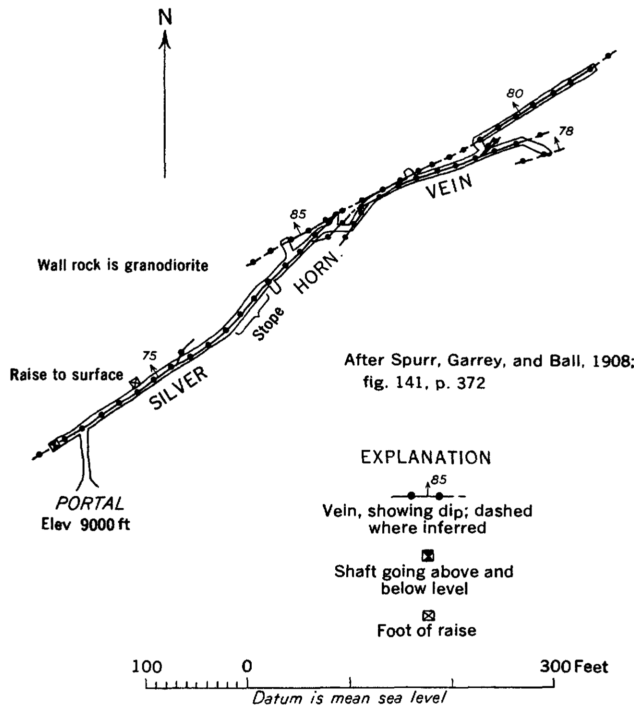

FIGURE 44.—Geologic sketch map of part of the Silver Horn mine.

below. Some development work has been done in the mine since Spurr's description was made in 1908.

Wall rock in the mine consists of granodiorite and small pegmatite dikes.

The Silver Horn vein strikes from N. 45° E. to N. 68° E. and dips about 75° NW. A weakly mineralized gouge zone that strikes N. 60° E. and dips from 80° to 85° NW. cuts through the northeast part of the mine workings on the Silver Horn vein. The vein minerals consist of galena, sphalerite, pyrite, tetrahedrite, and quartz. The sphalerite is both dark brown and red brown in color. Parts of the vein contain appreciable amounts of gold, as much as 6 or 7 ounces per ton. The direction of horizontal movement along the vein is northwest wall to the northeast, as shown in the mine by offsets of small pegmatite dikes.

These vein features described by Ball (Spurr, Garrey, and Ball, 1908) indicate that the vein is similar to the Dixie vein in mineralogy and direction of movement.

SILVER RING-MUSCOVITE MINES (75, 87)

The Silver Ring and Muscovite mines are near the head of Eclipse Gulch; the openings to the Silver Ring mine are on the slopes northeast of the gulch and the openings to the Muscovite mine are on the slopes to the southwest (pl. 2). The Muscovite mine has 3 adit levels, and the Silver Ring mine has a shaft and 2 adit levels. At the time of the writers' visit, however, all the adits were caved at the portal, and the shaft was filled with water to the collar.

Although some ore has been produced from each of these mines, most was produced prior to the time when adequate records were kept. According to Spurr, Garrey, and Ball (1908, p. 376), "something like $120,000 worth of ore" that had chief values in gold was produced from the lower level on the Silver Ring (called Silverine in their report). They also mention that some ore from the upper tunnel of the Muscovite mine was worth from $100 to $120 per ton and had its chief values in silver and lead. The report of the Director of the Mint gives the following production data for the Silver Ring mine:

Year	Gold (ounces)	Silver (ounces)	Lead (pounds)
1887	------	3,000	-------
1888	15.0	1,400	6,020
1889 [1]	------	------	-------
1890	87.6	10,200	40,000
1891	------	5,100	-------
1892	------	1,020	-------

[1] Production records confidential.

Records of the Bureau of Mines show that a total of 14 tons of ore was shipped from the Silver Ring mine during 1913 and 1914. This ore yielded a total of 3.29 ounces of gold and 331 ounces of silver. These records also show that 12 tons of ore was shipped from the Muscovite mine during 1907 to 1909, 1916, and 1920. This ore yielded 8.14 ounces of gold, 534 ounces of silver, and 27 pounds of lead.

Wall rock on the footwall side of the vein is an alaskite porphyry in both mines (Spurr, Garrey, and Ball, 1908, p. 375). The rock mapped on the surface on the hanging-wall side of the vein is predominantly quartz diorite, granite gneiss and pegmatite, and biotite-muscovite granite near the Muscovite mine and biotite-quartz-plagioclase gneiss near the Silver Ring mine (pl. 1).

The vein strikes about N. 60° E. and dips from 76° to 85° NW. Surface mapping suggests that the Silver Ring-Muscovite vein joins the vein seen at the Bruce shaft to the northeast (pl. 2). The vein consists of a 1- to 2½-foot zone of crushed wall rock, quartz, and clay that "is for the most part but slightly mineralized" (Spurr, Garrey, and Ball, 1908, p. 375). Specimens of ore picked up on the dumps contain brecciated fragments of quartz, pyrite, galena, sphalerite, and tetrahedrite cemented by chalcedonic quartz. Some carbonate was noted with the ore on the lower dump of the Muscovite mine, and flakes of torbernite were seen in fragments of sheared and altered biotite-muscovite granite on the dump of the upper Muscovite tunnel.

SOLID MULDOON MINE (151)

The collar of the Solid Muldoon shaft, at an altitude of 7,870 feet, is near the mouth of the second gulch northeast of Cottonwood Gulch (pl. 2).

Records on the production from the Solid Muldoon mine are incomplete. The first recorded production is that given by Kimball (1888) for the year 1887, when ore from the mine yielded 35.3 ounces of gold and 1,693 ounces of silver. Bureau of Mines files list production from the Solid Muldoon for the years 1906, 1910, 1922, and 1923. During these years a total of 33 tons of ore was shipped from the mine. This ore yielded 11.55 ounces of gold, 1,420 ounces of silver, 12,048 pounds of lead, and 212 pounds of zinc.

The mine has not been worked since 1926, and the shaft was caved at the collar at the time of the writers' visit. The dump has been scattered during maintenance of the road up the gulch so that examination of the dump is difficult. As seen at the collar of the shaft, the vein is a 6-inch zone of sheared and altered wall rock that strikes N. 55° E. and dips 73° NW. The vein could not be traced on the surface.

SOUTH AMERICAN MINE (55)

The portal of the South American tunnel is near stream level along Ute Creek at an altitude of 9,005 feet (pl. 2). Extent of the workings could not be determined because the portal was caved at the time of the writers' visit. Judged from the size of the dump, the mine probably consists of about 500 feet of workings. The Director of the Mint report (Kimball, 1888) shows that 3 ounces of gold, 314 ounces of silver, and 467 pounds of lead was produced in 1887. This is the only record of production from this mine.

Wall rock in the mine consists of granodiorite, biotite-muscovite granite, and pegmatite.

The vein is a southwest extension of the Silver Horn vein. Minerals observed on the dump are galena, sphalerite, pyrite, and quartz.

STAR TUNNEL (148)

The portal of the Star tunnel, at an altitude of 7,805 feet, is near road level on the northwest side of Chicago Creek (pl. 2). At the time of the writers' visit the first 1,000 feet of the tunnel was being used for tourist tours, and consequently the mine was not mapped.

No record of production could be found for this mine, and until the time when work was suspended on the tunnel in 1905 the mine had "yielded but little pay ore" (Spurr, Garrey, and Ball, 1908, p. 366).

The Star tunnel trends about N. 45° W. for a distance of about 2,500 feet. The operators stated that only a few short drifts had been driven from the tunnel.

According to Spurr, Garrey, and Ball (1908, p. 366), the tunnel for most of its length follows a large soft sparsely mineralized vein believed to be the "cross lode" that offsets the Little Mattie vein near the portal of the Little Mattie tunnel (pl. 8). The trend of this vein on the surface is about N. 60° W. and its dip ranges from 68° to 79° NE.

SUNNY SOUTH TUNNEL (155)

The portal of the Sunny South tunnel, at an altitude of 7,900 feet, is in a small gulch tributary to Chicago Creek about halfway between the mouth of Cottonwood Gulch and the northeast corner of the mapped area (pl. 2).

No record of production for the Sunny South tunnel could be found.

A map loaned by C. L. Harrington shows that the tunnel is a drift about 370 feet long and trends on the average S. 75° W. At the time of the writers' visit the tunnel was caved at the portal.

Wall rock found on the dump is biotite-quartz-plagioclase gneiss, some of which is migmatitic.

At the portal of the tunnel, the vein strikes N. 75° E. and dips 27° NW. Fragments of ore on the dump consist of quartz, carbonate, red-brown sphalerite, and galena with minor amounts of pyrite. The general trend and character of the vein suggest that it is an extension of the Beaver vein. If it is, the intersection of the vein and the dike of biotite-muscovite granite mapped on the surface about 150 feet north of the tunnel portal is the possible location of an undiscovered ore body. (See description of Beaver mine.)

TYONE (50) AND CHARTER OAK (51) MINES

The portal of the lower level of the Tyone mine is in a small gulch north of Cascade Creek at an altitude of 9,388 feet (pl. 2). The portal of the upper level is 310 feet N. 62° E. of the lower portal, and the Charter Oak shaft is 830 feet N. 69° E. of the lower portal.

Workings of the lower level of the Tyone mine consist of a crosscut tunnel 235 feet long and 658 feet of drift and short crosscuts (fig. 45). The upper level consists of an 80-foot crosscut from the portal to the vein, 370 feet of drifting, and a 63-foot crosscut north from the drift. A shaft near the face of the upper level connects to the surface. Near the face of the lower level is a raise that extends to a 75-foot sublevel; the sublevel is connected to the upper level by a winze.

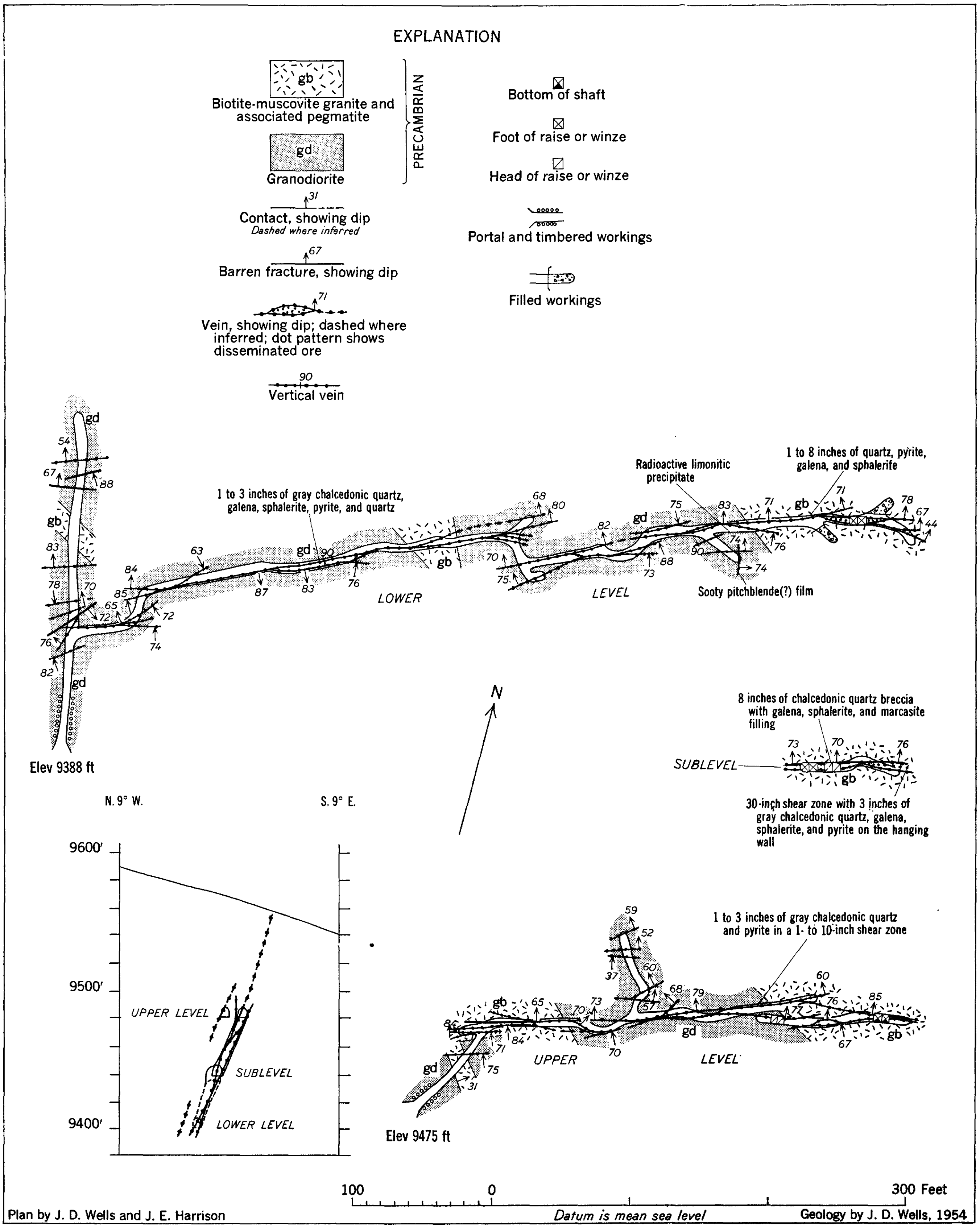

FIGURE 45.—Geologic maps of separate levels and section of the Tyone mine.

The Charter Oak shaft was inaccessible at the time of the writers' visit, but the size of the dump indicates the mine may have as much as 1,000 feet of workings.

Production data for these mines are incomplete, but some information is available. In the Director of the Mint report for 1881 (Burchard, 1882) the Charter Oak was classed as a steady producer although no figures were given. Bureau of Mines records show that the Charter Oak was operated in 1923, 1938, and 1940. During this time 60 tons of ore was shipped. This ore yielded 44.5 ounces of gold, 490 ounces of silver, 726 pounds of lead, and 870 pounds of zinc. These records show that the Tyone mine shipped 199 tons of ore in 1945, 1948, 1949, and 1951. This ore yielded 23 ounces of gold, 1,184 ounces of silver, 997 pounds of copper, and 7,469 pounds of lead.

Wall rock in the mine consists mostly of granodiorite that was intruded by dikes of biotite-muscovite granite, and pegmatite. As the pegmatite is irregularly shaped and gradational into the biotite-muscovite granite, the two units were mapped together as biotite-muscovite granite.

The Tyone-Charter Oak vein is a lode that has two vein splits on the north (pl. 2). As exposed in the Tyone workings, the vein is a complex series of more or less mineralized fractures. The vein has an average strike of about N. 65° E. and a dip of about 73° NW. Vein minerals consist of galena, sphalerite, pyrite, marcasite, quartz, gray chalcedonic quartz, and sooty pitchblende(?). (See section on radioactivity.) On the sublevel, brecciated chalcedonic quartz has been cemented partly by galena, sphalerite, and marcasite.

In polished section, broken pyrite crystals are shown to have been veined and cemented by galena, sphalerite, tetrahedrite, polybasite, and quartz. Some pyrite crystals have cores of quartz and broken blades of marcasite. Gold occurs as blebs in gray chalcedonic quartz and along contacts between sphalerite and tetrahedrite. Some covellite occurs as a coating on galena. The paragenetic sequence is shown diagrammatically in figure 46.

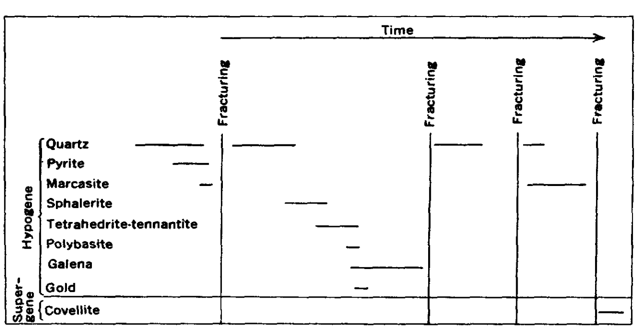

FIGURE 46.—Paragenetic diagram for the vein minerals of the Tyone vein.

U. S. TUNNEL (152)

The portal of the U. S. tunnel, at an altitude of 7,740 feet, is at road level along Chicago Creek (pl. 2). The mine consists of a tunnel 1,602 feet in length and drifts of 537 feet and 62 feet that connect with the tunnel (pl. 13). No extensive stoping has been done along the workings, and no production has been recorded from the U. S. tunnel.

Wall rock in the mine consists predominantly of biotite-quartz-plagioclase gneiss that is at places garnetiferous or sillimanitic and that commonly contains thin layers of granite gneiss and pegmatite. Some quartz diorite, biotite-muscovite granite, and pegmatite also are exposed in the mine workings. A 3-foot-wide dike of biotite-quartz-latite porphyry is exposed at the tunnel face; a 12-inch dike that is too fine grained to classify as to dike type is exposed in the drift along the Harrison vein.

The biotitic gneisses have been crumpled into a series of northeast-trending north-plunging upright folds that at places have been rewarped by nearly horizontal terrace drag folds. Where the terrace drag folds occur, foliation that trended about northeast has been deflected to an east or northwest trend and flattened in dip. The terrace drag fold appears to affect the foliation only within about 25 feet on either side of its axial plane.

The three principal veins exposed in the mine workings are the Tunnel vein, the Bertha(?) vein, and the Harrison vein (pl. 13).

The Tunnel vein strikes about N. 55° W. and dips 57°–76° NE. The widest part of the vein is composed of 6–18 inches of altered wall rock and gouge containing sheared stringers of quartz, pyrite, galena, and sphalerite; polished surfaces of specimens from this vein also contain traces of chalcopyrite, tennantite, and free gold. About 400 feet from the portal, the Tunnel vein breaks up into a series of branches and unmineralized faults and is no longer followed by the tunnel.

Bertha(?) vein, in the first drift from the portal, strikes N. 45° E. and dips 34°–39° NW. This vein is composed of 6–10 inches of altered wall rock and gouge containing at places stringers of quartz and disseminated pyrite as much as 1 inch wide. This vein is probably exposed on the surface to the southwest at the portal of the Bertha tunnel and to the northeast at the portal of the Democrat tunnel (pl. 2).

Harrison vein, in the drift nearer the tunnel face, strikes about east and dips 36°–77° N. The vein has numerous splits and branches that roll out into foliation planes of the enclosing gneiss. What little quartz, pyrite, and galena that were seen in the vein occur at places where the vein cuts across folds and thus cuts through rather than parallels foliation planes. The Harrison vein is exposed in shafts and pits over a strike length of about 400 feet on the surface (pl. 2). In addition to the minerals seen in the vein underground, a patch of free gold was seen in one polished surface of an underground ore specimen, and sphalerite and carbonate are present in ore specimens on the dumps of the shafts. The Harrison vein possibly is a western extension of the vein developed in the Quito tunnel.

WASHINGTON MINE (153)

The Washington mine includes the workings developed through the Parker, Baehr, and "A" shafts (fig. 47). The collar of the Baehr shaft is at an altitude of 8,029 feet in the second gulch northeast of Cottonwood Gulch (pl. 2).

Reports of the Director of the Mint give the following production for the Washington mine:

Year	Gold (ounces)	Silver (ounces)	Lead (pounds)
1887	9	4,040	12,850
1888	15	1,202	3,915
1889 [1]	------	------	-------
1890	3.6	4,420	18,000
1891	300	11,815	18,200

[1] Production records confidential.

No record of production for this mine is listed in the files of the Bureau of Mines, but a shipment of 1 ton of ore was purchased by the Idaho Springs Sampling Works in 1923. This ore contained 0.36 ounce of gold and 35 ounces of silver.

The size of the dumps suggests that the mine contains several hundred feet of workings, but the mine was not examined because the shafts were caved at the time of the writers' visit. The extent of the workings in 1889 is shown in figure 47.

Wall rock on the dumps of the mine is biotite-quartz-plagioclase gneiss, some of which is migmatitic, and biotite-muscovite granite.

The two principal veins in the mine are the Washington and the Cross Cut. The Washington vein strikes about N. 72° E. and dips on the average about 36° NW. It extends to the northeast and is seen in the Beaver mine, where it offsets the Beaver vein. The Cross Cut vein strikes about N. 50° E. and dips on the average about 75° SE. It has been traced northeast on the surface for about half a mile (pl. 2).

Ore specimens on the dumps are similar to ore specimens collected in the Beaver mine on the Washington vein. The ore consists of quartz, carbonate, red-brown sphalerite, and galena with minor amounts of pyrite.

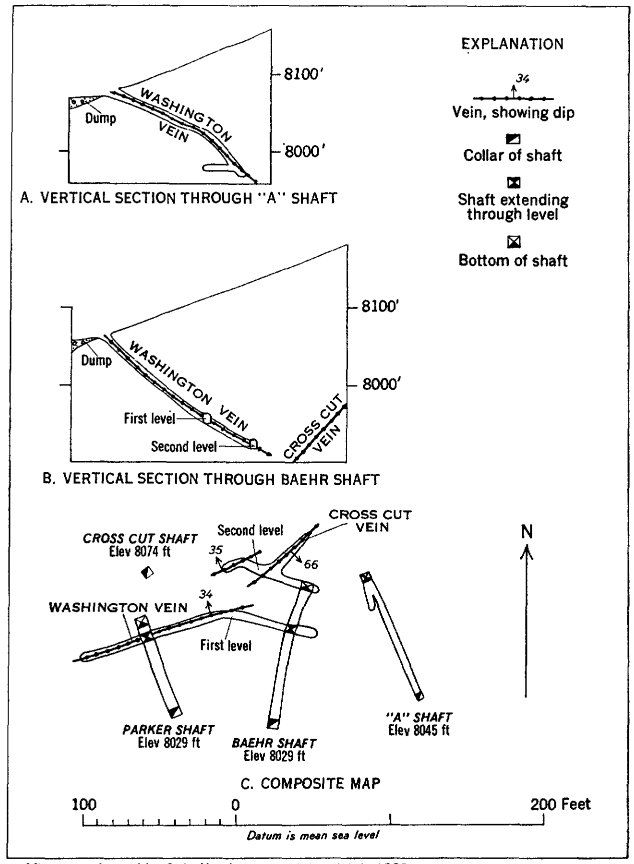

FIGURE 47.—Map and sections of the Washington mine.

Localization of the ore is believed to be the result of deflection of the vein through a biotite-muscovite granite dike, as in the Beaver mine. In the Washington mine, however, intersection of the Washington and Cross Cut veins might have been a favorable location for the deposition of ore.

WEST GOLD (JEWELRY SHOP) MINE (181, 182)

The portal of the lower adit of the West Gold mine, at an altitude of 7,629 feet, is on the northwest side of Chicago Creek near stream level in the northeast part of the mapped area (pl. 2). The portal of the upper adit, at an altitude of 7,680 feet, is about 360 feet N. 30° E. from the portal of the lower adit.

The mine consists of two levels connected by a shaft, raises, stopes, and an open pit. At the time of the writers' visit, only the upper level (fig. 48) was accessible for study.

According to Lovering and Goddard (1950, p. 187), the mine was opened in February 1926. Bureau of Mines records show that a shipment of ore was made in 1925, possibly from the surface workings. The mine was operated almost continuously until 1942,

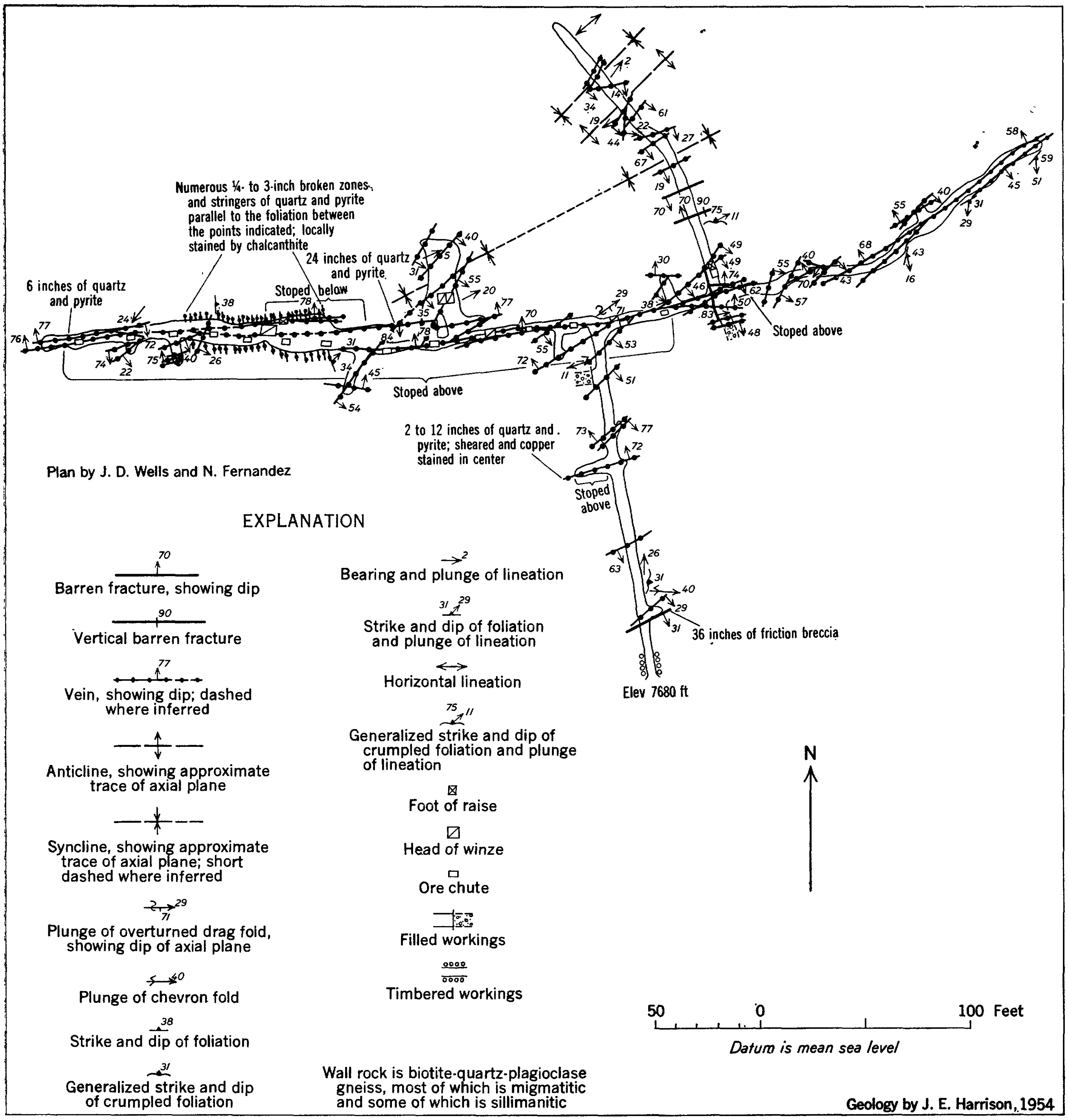

FIGURE 48.—Geologic map of the upper level of the West Gold mine.

when war-prompted government regulations and shortages of men and equipment forced the mine to shut down. No ore was shipped from the mine between 1943 and 1954.

During the period of operation, 24,225 tons of ore was shipped from the mine. This ore yielded 6,232.99 ounces of gold, 2,112 ounces of silver, 399 pounds of copper, 3,552 pounds of lead, and 346 pounds of zinc.

Wall rock in the mine is biotite-quartz-plagioclase gneiss, some of which is sillimanitic and most of which is migmatitic. The gneiss has been folded into a series of tight folds that trend N. 45°–65° E.; at places the gneiss is contorted or highly warped.

The "main vein" is actually a series of subparallel veins that strike about east and dip from 70° N. through vertical to 72° S. This vein group is intersected by two other vein groups: one strikes northeast and dips southeast, and the other strikes north and dips east. The second group of veins intersecting the "main vein" was found principally in the area along the "main vein" west of the shaft room (fig. 48). The northeast-trending veins at places offset the main vein, but at other places appear to join it. Age relations between the north-trending fractures and the other fractures were not observed.

Vein minerals seen in the mine include quartz and pyrite that are at places stained by chalcanthite. Polished surfaces of telluride ore examined by M. N. Short (Lovering and Goddard, 1950, p. 187) contained quartz, pyrite, siderite, barite, opal, native gold, galena, sphalerite, and the telluride minerals, altaite, coloradoite, petzite, krennerite, and sylvanite. According to Short,

> The order of deposition of the gangue minerals is pyrite and sericite, siderite, kaolin, quartz, barite, and opal. The tellurides are found in the vuggy parts of the veinlets associated with barite and quartz. The tellurides are more or less intergrown and occur in small bunches or blades rarely more than a quarter of an inch in diameter, which are scattered in the gangue.

The telluride minerals are abundant "along the many vertical cross fractures that cut the main break at rather small angles" and although "these seams end within a short distance, * * * where they are closely spaced rich ore may be mined to a width of 40 feet from the main vein." (Lovering and Goddard, 1950, p. 187).

Localization of the ore body may be related to vein deflection as well as to intersection of veins. The stoped part of the "main vein" is limited to the east-trending part of the lode; obviously the northeast-trending parts at the east end of the mine and the possibly southwest-trending parts at the west end of the mine were not rich enough to be stoped.

SMALL INACCESSIBLE MINES AND PROSPECTS

The area contains many small inaccessible mines and prospects. No production information could be found for any of these workings. The information that could be gathered on the workings whose names are known, or on the more important workings whose names could not be discovered, is presented in table 15.

TABLE 15.—*Data on small inaccessible mines and prospects*

Mine or prospect	Locality no. (pl. 2)	Type of surface opening	Probable vein name	Probable attitude of vein		Kind of vein observed or vein materials seen on dump	Kind of wall rock observed along vein or seen on dump
				Strike	Dip		
A. D.	139	Pits		N. 87° W.	86° NE.	Gossan	Biotite-quartz-plagioclase gneiss.
Albany	2	Shaft	Financier	N. 44° E.			Granite gneiss and pegmatite, migmatite.
Albemarle	98	Pits	Albemarle	N. 20°–40° E.	61°–80° NW.	Gossan	Biotite-quartz-plagioclase gneiss, biotite-muscovite granite, trachytic granite porphyry, granite gneiss and pegmatite.
Alma	165	Pits		N. 55° E.	86°–88° NW.	1- to 2-in.- sheared and altered zone.	Migmatite.
Alps	76	Pits	Split off Big Chief.	N. 65° E.	57° NW.	Gossan	Granite gneiss and pegmatite, biotite-muscovite granite.
American Boy	52	Shaft	Ella McKinney	N. 52° E.	79° NW.	Quartz, pyrite	Granodiorite, biotite-muscovite granite.
American Eagle	5	Shaft	American Eagle	N. 52° E.			Granite gneiss and pegmatite.
Anglo American	19	Pits		N. 68° E.		Chalcedonic quartz, carbonate, pyrite, chalcopyrite, galena, sphalerite.	Granodiorite, pegmatite, granite gneiss and pegmatite.
Argentite	20	Shaft	Argentite	N. 57° E.	70° NW.	Chalcedonic quartz, galena, sphalerite, pyrite.	Biotite-muscovite granite.
Baker	149	Pit		N. 62° E.	76° NW.	6-in. sheared and altered zone.	Migmatite.
Ben Dare	144	Tunnel, shaft.	Ben Dare	N. 68° E.	69° NW.	6- to 18-in. sheared and altered zone.	Migmatite, trachytic granite porphyry. Granite porphyry, biotite-quartz latite porphyry.

TABLE 15.—*Data on small inaccessible mines and prospects*—Continued

Mine or prospect	Locality no. (pl. 2)	Type of surface opening	Probable vein name	Probable attitude of vein		Kind of vein observed or vein materials seen on dump	Kind of wall rock observed along vein or seen on dump
				Strike	Dip		
Bertha	150	Tunnel, shaft.	Bertha	N. 30° E. N. 55° E.	30° NW. 48° NW.	¼-in. galena and sphalerite; 1-in. sheared and altered zone.	Migmatite.
Big Chief	93	Shaft	Split off Bruce	N. 55° E.	83° NW.	Quartz, pyrite, galena, sphalerite.	Biotite-quartz-plagioclase gneiss.
Big Flat	61	Shaft	Black Lion	N. 82° E.	39° NW.	Milky quartz, chalcedonic quartz, pyrite, galena, sphalerite.	Biotite-quartz-plagioclase gneiss, granodiorite.
Blackstone	108	Pits	Split off Pacific	N. 59° E.	76° NW.	4-in. limonite-stained gouge.	Migmatite.
Blackwood	11	Shaft		N. 80° E.		Gossan	Lime-silicate gneiss.
Brown Quartz	170	Tunnels	Brown Quartz	Due N.	20° E.	3-in. sheared and altered zone.	Migmatite.
Buckeye	89	Tunnel					Biotite-quartz-plagioclase gneiss, granite gneiss and pegmatite, biotite-muscovite granite.
Calumett	36	Shaft	Split off Humboldt.	N. 63° E.		Gossan	Granodiorite.
Cape Breton	9	Pits		N. 60° E.		Milky quartz, chalcedonic quartz, pyrite, galena, sphalerite.	Biotite-quartz-plagioclase gneiss, biotite-muscovite granite.
Chemung County	71	Shaft	Eclipse(?)	N. 60° E., N. 78° E.	Vertical; 85° NW.	Quartz, pyrite, sphalerite, galena.	Granodiorite.
Chicago	34	Shaft	Humboldt	N. 64° E.	71° NW.	Quartz, chalcedonic quartz, pyrite, galena, sphalerite.	Granodiorite, biotite-muscovite granite.
Cross Cut	164	Pits		N. 50° E.	80° SE.	2-in. sheared and altered zone.	Migmatite, granite gneiss and pegmatite, quartz bostonite porphyry.
C. Tyrol	53	Tunnel	C. Tyrol	N. 65° E.	82° NW.	Quartz, pyrite, galena, sphalerite.	Granodiorite, biotite-muscovite granite.
Daisy	166	Pits		N. 75° E., N. 85° E.	72° NW; 52° NW.	1-in. sheared and altered zones.	Migmatite.
Democrat	168	Tunnel	Bertha	N. 80° E.	43° NW.	2-ft sheared and altered zone.	Migmatite.
Dunbarton (Dumbordin of Spurr, Garrey, and Ball, 1908, p. 375).	66	Pits	Dunbarton	N. 82° E.	31° NW.	Gossan	Biotite-quartz-plagioclase gneiss.
Edna	137	Shaft	Split off Little Mattie.	N. 60° E.	81° NW.		Biotite-quartz-plagioclase gneiss, granite gneiss and pegmatite.
Elizabeth	95	Pits	Little Topsy			Gossan	Biotite-quartz-plagioclase gneiss, granite gneiss and pegmatite.
Emily	90	Pit		Due E.	78° N.	Quartz, gossan	Biotite-muscovite granite.
Emma Jane	32	Tunnel, shaft.	Emma Jane	N. 66° E.	66° NW.	2-ft. sheared and altered zone.	Granodiorite, biotite-muscovite granite.
Evergreen	41	Tunnel		N. 46° E.		Quartz, pyrite, sphalerite, galena.	Granodiorite.
Exchange	46	Pits		N. 80° E.	71° NW.	Quartz, galena, sphalerite.	Granodiorite, biotite-muscovite granite.
Franklin	158	Pit		N. 60° E.	76° NW.	Gossan	Migmatite.
Germantown	96	Pits	Germantown	N. 62° E.	57° NW.	Gossan	Granite gneiss and pegmatite.
Gold Dust	176	Tunnel		N. 60°–70° E.	71°–78° SE.	3- to 12-in. sheared and altered zone.	Migmatite.
Gold Eclipse	84	Tunnel	Split off Big Chief.	N. 45° E.	75° NW.	Quartz, pyrite, galena, sphalerite.	Biotite-quartz-plagioclase gneiss, biotite-muscovite granite.

TABLE 15.—*Data on small inaccessible mines and prospects*—Continued

Mine or prospect	Locality no. (pl. 2)	Type of surface opening	Probable vein name	Probable attitude of vein		Kind of vein observed or vein materials seen on dump	Kind of wall rock observed along vein or seen on dump
				Strike	Dip		
Gold Flint	78	Pit		N. 50° E.	78° NW.	Gossan	Granite gneiss and pegmatite, biotite-muscovite granite.
Golden Light	83	Tunnel		N. 65° E.	75° NW.	Quartz, pyrite, sphalerite, galena.	Granite gneiss and pegmatite.
Grand View	131	Pits	Bruce	N. 58° E.	65°–72° NW.	Gossan	Migmatite, granite gneiss and pegmatite, bostonite porphyry.
Guy Irving	138	Tunnel, shaft.		N. 63° E.	70° NW.		Migmatite, granite gneiss, and pegmatite.
Hawkeye	3	Shaft	Split off Lamartine.	N. 43° E.	75° NW.		Granite gneiss and pegmatite, granodiorite.
Henry Wilson	21	Shaft	Henry Wilson	N. 70° E.		Quartz, chalcedonic quartz, pyrite, marcasite, chalcopyrite, galena, sphalerite, carbonate.	Granodiorite, biotite-muscovite granite.
Herbert	60	Pits	Eclipse(?)	N. 66° E.	79° NW.	Gossan	Granodiorite.
Indigo B	70	Shaft	Rocky and Stoney.	N. 55° E.	60° NW.	Gossan	Granodiorite.
Inman	106	Pits		N. 55° E.	81° NW.	18-in. sheared and altered zone.	Biotite-quartz-plagioclase gneiss, trachytic granite porphyry.
Iron Hat	16	Shaft		Due E.	71° N.	Gossan	Granodiorite, biotite muscovite granite.
Kearsage	31	Tunnel, shaft.	Kearsage	N. 60° E.	80° NW.	Quartz, pyrite	Granodiorite, pegmatite.
King William	82	Tunnels	Split off Pacific	N. 80° E.	72° NW.	Quartz, pyrite, galena, sphalerite.	Migmatite, granite gneiss and pegmatite.
			Pacific	N. 66° E.	77° NW.	1–8 in. of limonite-stained gouge.	Migmatite, granite gneiss and pegmatite, biotite latite.
K. P	112	Pits	K. P	N. 65° E.	73° NW.	12 in. of limonite-stained gouge.	Migmatite, bostonite porphyry.
Lance	6	Shaft	Cecil-Argo	N. 57° E.		Quartz, pyrite, barite, galena, sphalerite.	Granite gneiss and pegmatite.
Little Florence	58	Shaft		N. 74° E.	Vertical	Quartz, pyrite, sphalerite, galena.	Granodiorite.
Little Topsy	119	Shaft	Little Topsy	N. 60° E.	75° NW.	Quartz, chalcedonic quartz, pyrite, galena, sphalerite.	Biotite-quartz-plagioclase gneiss.
Lizzie S	79	Tunnel		N. 50° E.	88° NW.	1 in. of limonite-stained gouge.	Biotite-muscovite granite, migmatite.
		Shaft		N. 35° E.	52° NW.	Gossan	
Louise	103	Pits	New York	N. 45° E.	65° NW.	3 in. of limonite-stained gouge.	Granite gneiss and pegmatite.
Lucky Guess	101	Pits	Arthur(?)	N. 50° E.	87° NW.	4 in. of limonite-stained gouge.	Biotite-quartz-plagioclase gneiss, migmatite, granite gneiss and pegmatite.
Mable	59	Shaft		N. 70° E.	75° NW.	Quartz, carbonate, pyrite, galena, sphalerite.	Biotite-muscovite granite.
Magna	92	Pits	Split off Bruce	N. 63° E.	83° NW.	Gossan	Biotite-quartz-plagioclase gneiss.
Maximillian	65	Tunnel, shaft.	Maximillian	N. 50° E.	82° NW.	Gossan	Biotite-quartz-plagioclase gneiss, granodiorite.
Mirage	134	Shaft	Sampson	N. 57° E.	65° NW.	2 in. of limonite-stained gouge.	Migmatite, granite gneiss and pegmatite.
Mollie Fisher	132	Shafts	Little Topsy	N. 73° E.	70°–78° NW.	Quartz, pyrite, sphalerite, galena.	Migmatite, granite gneiss and pegmatite.

TABLE 15.—*Data on small inaccessible mines and prospects*—Continued

Mine or prospect	Locality no. (pl. 2)	Type of surface opening	Probable vein name	Probable attitude of vein		Kind of vein observed or vein materials seen on dump	Kind of wall rock observed along vein or seen on dump
				Strike	Dip		
New York	99	Pits	New York	N. 55° E.	66° NW.	3 in. of limonite-stained gouge.	Granite gneiss and pegmatite, biotite-muscovite granite, bostonite porphyry.
Orinoco No. 3	104	Pits	Sweden	N. 65° E.	84° NW.	2-in. sheared and altered zone.	Migmatite, granite gneiss and pegmatite.
				N. 43° E.	71° NW.	3-in. sheared and altered zone.	
Oriole	180	Shaft, tunnel.		N. 10° W.	Horizontal to 32° NE.	2- to 10-in. sheared and altered zone.	Migmatite.
Pacific	107	Pits	Pacific	N. 38°–44° E.	68°–85° NW.	4 to 20 in. of limonite-stained gouge.	Migmatite, granite gneiss and pegmatite.
Peter	177	Tunnel	Peter	Due E.	38° N.	6-in. sheared and altered zone.	Migmatite.
Rachel	80	Tunnel		N. 55° E.	75° NW.	3 to 8 in. of limonite-stained gouge.	Migmatite, biotite-muscovite granite.
Rhoda	37	Shaft	Dixie	N. 70° E.	77° NW.	Quartz, sphalerite	Granodiorite.
Roca	8	Shaft, tunnel.	Alpine	N. 80° E.	52° NW.	Quartz, pyrite, sphalerite, galena.	Granite gneiss and pegmatite, biotite-muscovite granite.
Rocky and Stoney.	74	Shaft	Rocky and Stoney.	N. 50° E.	52° NW.	Quartz, chalcedonic quartz, pyrite, chalcopyrite, galena, sphalerite.	Granodiorite.
Rocky Cliff	88	Tunnels	Rocky Cliff	N. 45° E.	75° NW.	Gossan	Biotite-quartz-plagioclase gneiss, biotite-muscovite granite.
Sampson	133	Shaft	Sampson	N. 61° E.	80° NW.	Quartz, disseminated pyrite.	Granite gneiss and pegmatite.
Seventy-Six	18	Shaft		N. 80° E.	Vertical	Chalcedonic quartz, galena, sphalerite, pyrite.	Granodiorite.
Shakespeare	97	Pits	Shakespeare	N. 52° E.	75° NW.	Gossan	Granite gneiss and pegmatite, bostonite porphyry.
Silver Cliff	62	Tunnel, shaft.	Silver Link	N. 51° E.		Gossan	Granodiorite.
Silver Leaf	17	Shaft	Silver Leaf	N. 60° E.	66° NW.	Quartz, chalcedonic quartz, pyrite, galena, sphalerite.	Granodiorite.
Silver Link	63	Tunnel	Silver Link	N. 58° E.		Chalcedonic quartz, pyrite, galena, sphalerite.	Granodiorite.
Silver Thread	146	Pit		N. 53° E.	80° NW.	6-in. sheared and altered zone.	Migmatite.
Stover	72	Pits		N. 80° E.	75° NW.	Quartz, pyrite, galena, sphalerite.	Biotite-muscovite granite.
Sulitelma	35	Tunnel, shaft.	Humboldt	N. 63° E.	75° NW.	Quartz, pyrite, sphalerite, galena.	Granodiorite.
Swan	147	Pits	Swan	N. 55° E.	75° NW.	3-ft sheared and altered zone.	Biotite-quartz-plagioclase gneiss.
Sweden	100	Pits	Sweden	N. 60° E.	74°–83° NW.	3 in. of limonite-stained gouge.	Biotite-quartz-plagioclase gneiss, granite gneiss and pegmatitie, bostonite porphyry.
Swiss	145	Pit	Ben Dare	N. 67° E.	68° NW.	12-in. sheared and altered zone.	Migmatite, trachytic granite porphyry, granite porphyry, biotite-quartz latite porphyry.
Thirty Second	73	Tunnel		N. 70° E.	70° NW.		Biotite muscovite granite, alaskite porphyry.
Union	1	Shaft		N. 72° E.		Chalcedonic quartz, carbonate, pyrite, sphalerite, galena.	Granite gneiss and pegmatite.

TABLE 15.—*Data on small inaccessible mines and prospects*—Continued

Mine or prospect	Locality no. (pl. 2)	Type of surface opening	Probable vein name	Probable attitude of vein		Kind of vein observed or vein materials seen on dump	Kind of wall rock observed along vein or seen on dump
				Strike	Dip		
Veteran	14	Tunnel	Ouida	N. 80° E.		Gossan, sphalerite	Migmatite, granite gneiss and pegmatite.
Viking	69	Shaft		N. 45° E.	70° NW.	Quartz, pyrite	Granodiorite.
Wire Gold	67	Pit		N. 43° E. N. 63° E.	70° NW. 50° NW.	Gossan	Biotite-quartz-plagioclase gneiss, pegmatite.
Unknown A	183	Tunnel		N. 85° W.	83° SW.–81° NE.	Quartz, pyrite	Migmatite.
Unknown B	172	Tunnel	Beaver	N. 75° W.	48° NE.	Quartz, pyrite	Migmatite, granite gneiss and pegmatite.
Unknown C	173	Shaft	Quito	N. 82° E.	60° NW.	Quartz, pyrite, tennantite.	Migmatite.
Unknown D	174	Shaft		N. 25° W.	30° NE.	Quartz, pyrite	Migmatite.
Unknown E	184	Tunnel	Beaver	N. 75° E.	27° NW.	Quartz, pyrite	Biotite-quartz-plagioclase gneiss.
Unknown F	167	Tunnel		Due E.	49° N.	Quartz, pyrite	Migmatite.
Unknown G	163	Shaft		N. 56° E.	74° NW.	Quartz, pyrite, galena, sphalerite.	Granite gneiss and pegmatite.
Unknown H	162	Shaft	Black Eagle	N. 54° E.	63° NW.	Quartz, pyrite, galena, sphalerite.	Granite gneiss and pegmatite.
Unknown I	115	Shaft	Pacific	N. 37° E.	80° NW.	Quartz, pyrite, galena, sphalerite.	Migmatite.
Unknown J	130	Pits		N. 70° E.	58°–63° NW.	Quartz, pyrite, galena, sphalerite.	Migmatite.
Unknown K	127	Shaft		N. 72° E.	61° NW.	Quartz, siderite, pyrite, tennantite, galena, sphalerite.	Granite gneiss and pegmatite, containing layers of migmatite.
Unknown L	126	Pit	Kitty Clyde	N. 65° W.	68° NE.	Quartz, pyrite, galena, sphalerite.	Biotite-quartz-plagioclase gneiss.
Unknown M	124	Pit		N. 77° E.	55° NW.	Quartz, pyrite, chalcopyrite, sphalerite, galena.	Biotite-quartz-plagioclase gneiss, sillimanitic biotite-quartz gneiss.
Unknown N	118	Tunnel		N. 75° E.	77° NW.	Quartz, pyrite, sphalerite, galena.	Granite gneiss and pegmatite, biotite-muscovite granite, alaskite porphyry, bostonite porphyry.
Unknown O	91	Shaft	Split off Bruce	N. 45° E.	66° NW.	Quartz, pyrite, chalcopyrite, tennantite, sphalerite.	Biotite-quartz-plagioclase gneiss, biotite-muscovite granite.
Unknown P	86	Tunnel, shaft.	Eclipse	N. 83° E.	54° NW.	Quartz, carbonate, galena, sphalerite.	Biotite-quartz-plagioclase gneiss, migmatite.
Unknown Q	64	Shaft		N. 60° E.	76° NW.	Quartz, chalcedonic quartz, pyrite, galena, sphalerite.	Granodiorite.
Unknown R	10	Tunnel		N. 29° E.		Gossan, galena	Biotite-quartz-plagioclase gneiss, sillimanitic biotite-quartz gneiss.
Unknown S	49	Shaft	C. Tyrol	N. 73° E.	72° NW.	Quartz, pyrite, galena, sphalerite, tetrahedrite.	Granodiorite, biotite-muscovite granite.
Unknown T	4	Shaft	Split off Lamartine.	N. 62° E.	65° NW.	Gossan	Granite gneiss and pegmatite.

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