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

BULLETIN 1

A PRELIMINARY REPORT

ON THE

GEOLOGY

OF THE

MONARCH MINING DISTRICT

CHAFFEE COUNTY
COLORADO

BY

R. D. CRAWFORD

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GEOLOGICAL BOARD

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LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, May 1, 1910.

Governor John F. Shafroth, Chairman, and Members of the Advisory Board of the State Geological Survey,

GENTLEMEN:—I have the honor to transmit herewith Bulletins 1 and 2 of the Colorado Geological Survey.

Very respectfully,

R. D. GEORGE.
State Geologist.

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INTRODUCTION

FIELD WORK AND ACKNOWLEDGMENTS

The field work on which the present report is based was done in the summer of 1909. Considerable mapping still remains to be done in the Monarch district, but it seems desirable to publish at this time the more important results of examinations already made. During the summer of 1910 the survey will be extended over a wider area, including that part of Gunnison County contiguous to the Monarch district.

The topographic mapping was done by P. G. Worcester, R. C. Coffin, and R. M. Butters, who also assisted in the geologic work. Traverse plane-tables were used in both triangulation and traverse. Elevations were determined by means of aneroid barometers, and hence the contours as shown on the map should not be taken as quantitatively accurate. It is believed, however, that but few of them are in error more than two contour intervals.

The topographic map was prepared for the engraver by Mr. Worcester. Mr. Butters has made many assays and chemical analyses for use in the report. Professor Junius Henderson, of the University of Colorado, has determined the fossils collected, and correlated the formations with those in other parts of Colorado.

The mine owners, managers, superintendents, miners, leasers, and prospectors in the district have done much to facilitate the work of the field party. They have not only shown payable ore bodies, but have pointed out their unprofitable undertakings and have not attempted to conceal unfavorable conditions. Many non-resident mine owners have given valuable assistance. Mr. F. P. Black, who has made many mine and patent surveys in the district, has generously responded to frequent requests for maps and other data. The plans and vertical sections of mines are reductions of drawings furnished by the mining companies.

SITUATION OF THE DISTRICT

The Monarch mining district is in the southwestern part of Chaffee County, Colorado, on the east slope of the Sawatch Range, which forms a part of the Continental Divide. The district may be reached by rail or by tri-weekly stage from Salida, about

twenty miles distant. There are two villages in the region, Garfield and Monarch, about a mile and a half apart.

Beside the productive area shown on the map (Pl. I) ore has been found on Pass Creek several miles southeast of Monarch, and on the North Fork of the South Arkansas River, north of Mount Aetna and Taylor Mountain. The White Pine mining district lies just over the range toward the west.

WATER SUPPLY AND TIMBER

Precipitation during the winter is heavy, and the snow that accumulates on the highest slopes may remain until nearly the end of summer. The melting snow and frequent showers furnish abundant water within the district for every purpose during the summer. In the winter the streams are continually fed by numerous springs. (See p. 28.)

Formerly pine, spruce, and fir covered most of the slopes below timberline, but much of the timber is now removed. Although a few restricted areas are still densely forested, the renewal of a demand, such as existed in the eighties, would soon exhaust the supply in the immediate vicinity of the mines. Even now a large part of the timber used comes from near Leadville.

HISTORY

In 1878 ore was discovered on the Great Monarch claim by the Boone brothers. This was followed in 1878 or 1879 by discoveries of ore, by the four Boones, on the Fairplay, Pay Master, Ben Bolt, and Eclipse. Creede (?) located the Oshkosh in 1878 or 1879. At about the same time Smith and Gray discovered ore in the Madonna and Silent Friend. Early in 1879 Mr. Daily found ore at Cree Camp on the Song Bird claim, which he afterward sold to Alex Cree. The Mountain Chief, Missouri Boy, Eagle Bird, and others in Taylor Gulch, were soon located.

The first ore shipped from the district came from the Great Monarch, and was hauled by wagon to Canon City. It ran about 200 ounces silver per ton. A small amount of ore from other mines was freighted by wagon to Canon City before the railroad was built to Maysville in 1881. The ore from most of the mines was of too low grade to ship after hauling by wagon even to Maysville. The owners of the Madonna, to whom the discoverers sold that claim, built a small smelter at the foot of the hill to treat the Madonna ores, but this was not a success. In 1883 Mr. A. Eilers saw the possibilities of the Madonna, secured the

106°20′ 106°17′30″ 38°35′ 38°32′30″

Mt. Aetna (Keyes) Taylor Mtn. Missouri Hill Cree Camp Hoffman Park Columbus Gulch Kangaroo Gulch Taylor Gulch Clover Mtn. Middle Fork Lake Fork Boss Lake Syncline Hill Lilly Aerial Tram Garfield Rio Grande R. R. South Fork Arkansas River Denver & South Park R. R. Monarch South Fork Monarch Hill Tram

CONTINENTAL DIVIDE

BOUNDARY LINE GUNNISON CO. CHAFFEE CO.

T. 49 N. T. 50 N.

R. 6 E.

LEGEND

Mine or Quarry | Prospect

MINES

1	Silent Friend No. 1
2	Silent Friend No. 2
3	Silent Friend No. 3
4	Silent Friend No. 4
5	Wilson lower tunnel
6	Wilson upper tunnel
7	Madonna No. 0
8	Madonna No. 1
9	Madonna No. 2
10	Madonna No. 3
11	Madonna No. 4
12	Madonna No. 5
13	Madonna No. 6
14	Hawkeye
15	Eclipse No. 4
16	Eclipse No. 3
17	Eclipse No. 2
18	Eclipse No. 1
19	Eclipse discovery shaft
20	Oshkosh
21	Fairplay
22	Little Wonder
23	Great Monarch shaft
24	Great Monarch tunnel
25	Great Monarch tunnel
26	Elkington
27	Little Charm
28	Paymaster
29	April Fool
30	Delaware
31	Evening Star incline
32	Evening Star tunnel
33	Black Tiger
34	Ingersoll
35	Thirty-Six-Thirty
36	Ohio & Colorado S. & R. Co. quarry
37	Garfield quarry
38	Garfield tunnel
39	Garfield mine
40	Alaska
41	Shamrock
42	Major
43	Marble quarry
44	Exchequer
45	Missouri Boy
46	Lilly tunnel
47	Lilly shaft
48	Jewell tunnel
49	Denver
50	Lilly
51	Lilly
52	Rainbow-Eagle Bird
53	Rainbow-Eagle Bird
54	Mountain Chief tunnel
55	Mountain Chief shaft
56	Pinon
57	Clinton
58	Clinton
59	Song Bird
60	Indianapolis
61	Stem Winder
62	Last Chance
63	Bonnie Bell
64	Ben Hill
65	Fraction
66	Desdemona
67	Beta
68	Alpha
69	Maverick tunnel
70	Columbus
71	Columbus
72	Columbus
73	Columbus
74	Golden Age
75	Brighton
76	Bowman tunnel
77	Darling
78	Uncle Sam
79	Gulch
80	Mason
81	Moose

Topography by P. G. Worcester, R. C. Coffin and R. M. Butters. Surveyed in 1909.

TOPOGRAPHIC MAP OF THE MONARCH MINING DISTRICT, COLORADO

INCOMPLETE AND SUBJECT TO CORRECTION

Scale $\frac{1}{25000}$ or approximately 2½ inches to 1 mile

0 ¼ ½ ¾ 1 2 miles

0 ½ 1 2 kilometers

Contour interval 100 feet

Datum is mean sea level

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extension of the railroad from Maysville to Monarch—nine miles—and organized the Colorado Smelting Company, which took over the Madonna mine and erected a smelter at Pueblo. Since an abundance of basic ore was supplied by the Madonna for fluxing siliceous ores purchased from other Colorado districts, this enterprise was a success from the first.

For about ten years, beginning with 1883, the production of the district was large. In 1893 Monarch shared the common experience of Colorado silver-producing camps, and for some time the district was nearly deserted. Within the past few years, however, with a home market for zinc and an increasing demand for basic fluxing ores, there has been a revival of interest in the district. The recent discovery of ore on the lowest level of the Madonna, and in the Mason and Moose mines, the increasing output of the Lilly, the reopening of the Eclipse, and the development work in Taylor Gulch, will probably stimulate the greatest activity that has been known in the district since the early nineties.

That the production of the region has not been greater is due in part to the methods of a number of mine owners, who have been satisfied to acquire modest fortunes with the least possible risk. Very little development work was carried on in some of the good mines while ore was being taken out, and they were closed when the known ore bodies began to fail. To the credit of the district it should be stated that there has been a minimum of expensive litigation among the mine owners. Probably not more than two mines have ever been shut down pending court decisions.

PRODUCTION

Since there have been so many estimates, guesses, and exaggerated statements as to the output of the district a special effort has been made by the Survey to secure data which would be reasonably accurate. Many of the mine owners have cooperated, and the result is fairly satisfactory. The tonnage and value, by years, have been obtained for the Eclipse, Fairplay, Lilly, and Madonna mines, but in most instances only the total production could be learned. Conservative estimates have been accepted for a few mines of which the exact output was not known.

The gross value of the ore shipped appears to be between $7,000,000 and $8,000,000. Of this amount the Madonna has produced $4,535,543.94. (See p. 47.) The production of several others is noted in the description of mines.

LITERATURE

Aside from a three-page article in the Report of the State Geologist for 1883-84[1], treating chiefly of the Columbus mine, I have seen no description of the region in geological or mining publications. Brief reference to the district is made in several volumes of Mineral Resources of the United States by the United States Geological Survey, and in the reports of the State Geologist, and of the Bureau of Mines of Colorado. Ore was not discovered at Monarch until after the work of the Hayden survey was completed in Colorado, and it appears that the geologists of that organization passed over the region somewhat hurriedly. In 1885 the late George H. Eldridge, of the United States Geological Survey, examined the Madonna mine and surroundings, but his report was not published.

[1]Report of E. LeNeve Foster, State Geologist, 1884, pp. 30-33.

OUTLINE OF GEOLOGY

The area mapped is a small part of a large metamorphic area which was intruded by granite probably in pre-Cambrian time. The granite itself underwent a moderate degree of metamorphism.

Probably in Cambrian time marine sediments of unknown thickness were laid down on the granite. Later, elevation exposed these sediments to erosion until they were nearly all removed.

The surface was again submerged in Ordovician time. The presence of Silurian and Lower Devonian strata has not been proved. Upper Devonian and Lower Carboniferous times are represented by sediments more than a mile in thickness.

At an unknown time subsequent to the period of sedimentation the entire region was left high above sea-level and subjected to folding and faulting.

After the folding, a large mass of quartz monzonite was intruded into the sedimentary rocks, and this was followed by the intrusion of many porphyry dikes.

Subsequent to the folding and probably after the intrusion of quartz monzonite, metallic minerals were deposited in the tilted sedimentary rocks. Some mineralization immediately succeeded the intrusion of porphyry.

Erosion has removed a large amount of rock and exposed the porphyry dikes and ore bodies. Whether or not the quartz monzonite originally reached the surface is not known, but erosion has made the outcrop of this rock prominent.

Probably in Pleistocene and Recent times, local glaciers, heading on the divides, moved down the valleys where they deposited moraines.

GENERAL GEOLOGY

TOPOGRAPHY

The area covered by the map is one of high relief, having a vertical range of approximately 4,500 feet. High sharp peaks and valleys with steep sides are characteristic features. Most of the valleys are V-shaped, but U-shaped valleys heading in glacial cirques near the top of the Continental Divide are not uncommon in this area and farther south. The region is drained by the North, Middle, and South forks of the South Arkansas River and numerous smaller tributary streams. North Fork, which does not appear on the map, flows eastward a short distance north of Taylor Mountain.

Glaciation has been an important agent in the development of minor features of the topography. It has been effective in three ways: (1) In planing down and reducing the irregularities of surface, (2) in gouging out rock basins, (3) in forming rough-and-tumble morainal topography.

Good examples of the first may be seen in the roches moutonees east of Garfield, west of Boss Lake, and in the valley of North Fork. Striæ are present only where the abraded surface has been protected by a covering of soil. Boss Lake presents the best example of gouging. Glaciation was unusually effective here perhaps because of mineralization of the faulted sedimentary rocks at the contact with the eruptive quartz monzonite. This is indicated by the large amount of magnetite and iron sulphide just east and north of the lake. Rough-and-tumble topography occurs in several places, but is perhaps best seen in the valley a short distance southeast of Cree Camp.

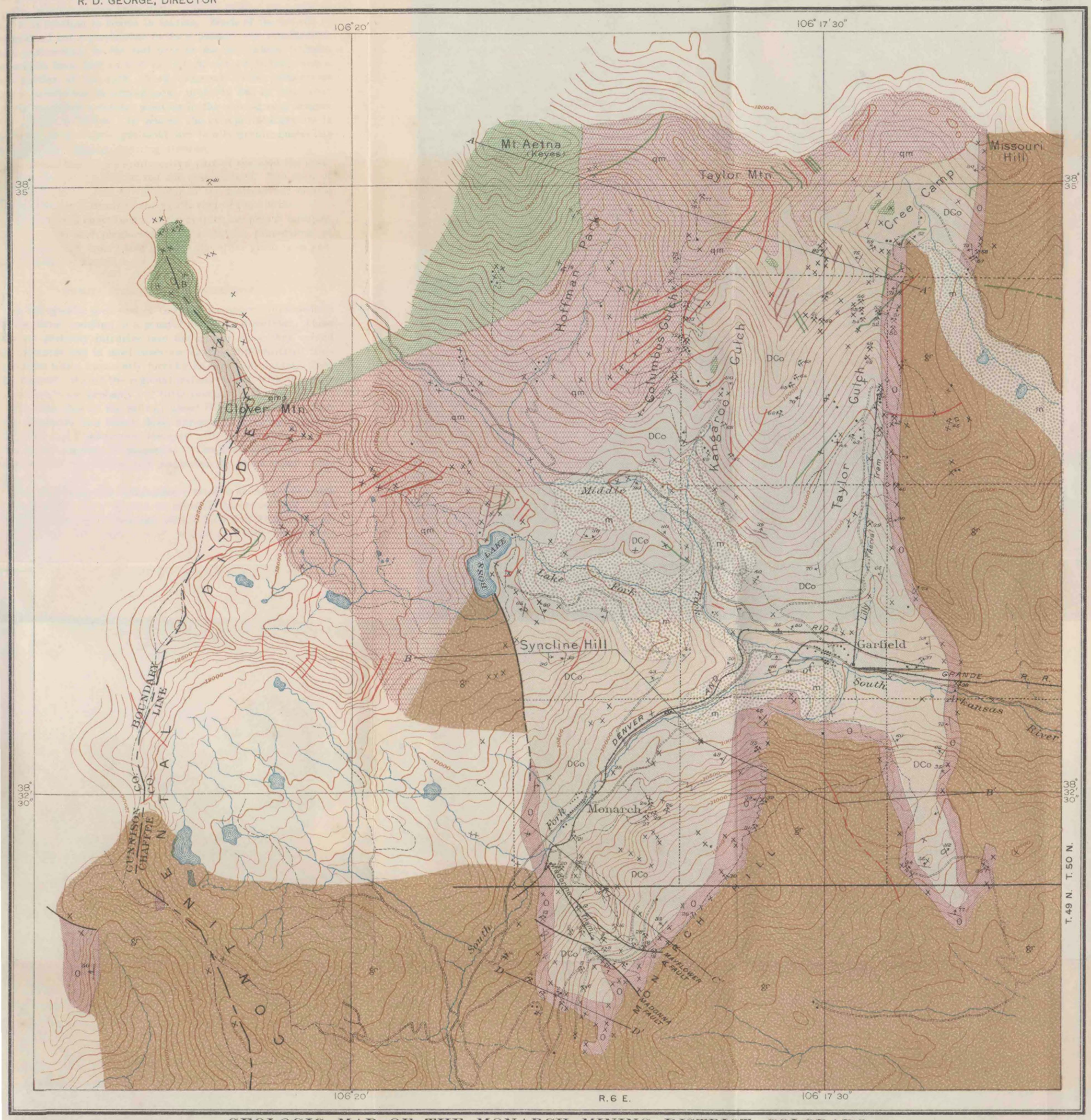
PRE-CAMBRIAN ROCKS

GRANITIC GNEISS

Although no highly metamorphosed pre-Cambrian rocks are present in the area covered by the map, granitic gneiss occurs over wide areas not far east and southeast.

GRANITE

One of the most important rocks of the district in areal extent is biotite granite which was intruded into the gneiss prob-



LEGEND

QUATERNARY
- Moraines

DEVONIAN-CARBONIFEROUS
- DCo — Ouray Limestone

PRE-DEVONIAN *with a determined Ordovician horizon*
- O — Limestone and Quartzite

IGNEOUS

POST DEVONIAN
- B — Breccia
- Latite and Latite Porphyry
- qmp — Quartz Monzonite Porphyry
- qm — Quartz Monzonite (*Adamellite*) and Granite Apophyses

PROBABLY PRE-CAMBRIAN
- gr — Granite

- Fault
- Dip and Strike
- Overturn
- Mine or Quarry
- Prospect

Topography by P. G. Worcester, R. C. Coffin and R. M. Butters. Surveyed in 1909.

GEOLOGIC MAP OF THE MONARCH MINING DISTRICT, COLORADO

INCOMPLETE AND SUBJECT TO CORRECTION

Scale $\frac{1}{25000}$ or approximately 2½ inches to 1 mile

0 — ¼ — ½ — ¾ — 1 — 2 miles

0 — ½ — 1 — 2 kilometers

Contour interval 100 feet

Datum is mean sea level

Geology by R. D. Crawford, assisted by R. M. Butters, R. C. Coffin and P. G. Worcester. Surveyed in 1909.

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ably in pre-Cambrian time. The reasons for considering it pre-Cambrian are its structural similarity to granite in other parts of Colorado, whose age has been fairly well established, and the stratigraphic evidence of overlying rocks noted below.

The granite ranges from light gray to darker gray and to red. It is medium to coarse in texture. Much of the granite is even-grained but a porphyritic facies is present over considerable areas, particularly in the east part of the field where feldspar phenocrysts from half an inch to an inch and a half long form a large portion of the rock. Very commonly these phenocrysts show a parallelism in arrangement, probably due in large part to their assuming a similar position in the moving rock magma before it had solidified. In general the even-grained granite is massive or only slightly gneissoid, but locally granite-gneiss has been developed through shearing stresses.

In the southern and southwestern part of the field the granite is predominantly pink or red and even-grained. The color of the rock is due in part to the color of the feldspar but is also in large measure a result of the weathering of the biotite.

The essential constituents of the granite are potash feldspar, quartz, biotite, and plagioclase. Although the proportions of the minerals vary from place to place the order given is in general the order of importance.

DIORITE, SYENITE, AND HORNBLENDITE

In the granite area east of Garfield are several intermediate to basic dikes, trending in a general northerly direction. These dikes are probably intrusive into the granite since they extend long distances and in most cases are sharply differentiated from the granite walls, apparently forming an eruptive contact. They have, however, shared the regional metamorphism with the granite, and are hence probably but little younger.

The dike seen at the railway about 800 feet east of the base of the limestone is a heavy, dark, fine-grained rock composed of hornblende and subordinate feldspar with considerable titanite and a small quantity of magnetite. The microscope shows the feldspar to be microcline and plagioclase in about equal quantities.

The Bay State and Independence tunnels about a mile north of the railroad, cut a similar or probably the same dike. The rock in the specimens examined differs from that at the railroad chiefly in that the feldspar is all orthoclase. This dike, or one

parallel to it, can be traced northward nearly half a mile to a point where it passes under the glacial drift.

A few feet east of the first dike mentioned is one of hornblendite composed chiefly of hornblende but carrying some pyrite.

A strong dike of diorite, about a mile and a half east of Garfield, runs nearly parallel to those described. It is porphyritic in appearance and shows evidence of having been squeezed and folded through shearing stresses. While the dike appears to be intrusive into the granite it does not show walls as well defined as do some of the others, and is itself cut by veins of pegmatite from a fraction of an inch to several inches wide.

PALEOZOIC SEDIMENTS

A series of sedimentary rocks more than a mile in thickness is present between the east side of Taylor Gulch and the west side of Columbus Gulch. North of Clover Mountain eruptive rocks enclose large masses of sediments which differ lithologically from any toward the east and are probably younger. The entire section is nowhere exposed, but the general character can be determined and the lower part of the series can be examined in detail. Within the lower 4,000 feet Ordovician, Devonian, and Carboniferous fossils have been found, but the upper part of the series has thus far yielded no fossils.

PRE-DEVONIAN LIMESTONE AND QUARTZITES

Throughout the district wherever the contact of the sediments with the underlying granite is exposed at the surface the limestone described below lies immediately on the granite. But in several mines quartzite varying in thickness from a few inches to several feet lies between the granite and overlying limestone. This quartzite may be seen in the Clinton and Lilly mines north of Garfield and in the Evening Star tunnel on Monarch Hill.

Since no fossils have been found in this quartzite it cannot be referred with certainty to any age. The fact that it is a remnant left at the close of a period of erosion before the Ordovician sediments were deposited, indicates that it may be of Cambrian age.

Bluish-gray limestone, having a thickness of 235 to 250 feet, overlies the quartzite where the latter is present, and rests on the granite where the quartzite is absent. The limestone is magnesian throughout, is for the most part thick-bedded and con-

tains several cherty strata. Most of the chert is in nodules but there are more or less continuous beds up to three inches thick.

Above the limestone described is a persistent bed of quartzite, locally called the "parting quartzite". No attempt is here made to correlate this formation with the Parting Quartzite of Leadville and Aspen, although it is not impossible that the two may occupy the same stratigraphic position. The quartzite varies in thickness from 37 feet, east of Garfield, to less than 20 feet, southwest of Monarch. It is bluish to white and for the most part rather fine in texture. Locally it carries a thin bed of carbonaceous shale near the upper part. The quartzite is conformably overlain by magnesian limestone in which chert is less common than in the limestone below the quartzite. Fossils from this limestone, 40 feet above the quartzite, were identified as *Receptaculites oweni* by Professor Henderson and by Dr. E. O. Ulrich who consider them to represent an Ordovician horizon.

The late George H. Eldridge collected a number of specimens from Monarch Hill in 1885. Doctor Girty, who has very kindly looked up Mr. Eldridge's notes and collection, states that several years ago he provisionally identified Ordovician fossils from this collection. He has also found lists, which he thinks were made by Doctor Walcott, giving the following species obtained by Mr. Eldridge:

Halysites catenulatus
Halysites agglomeratus
Diphyphyllum sp.
Zaphrentis sp.
Heliolites sp.
Stromatopora sp.
Orthoceras of the type of *Multitubulatum*

The present writer does not have at hand Mr. Eldridge's notes but the description of stations as given by Doctor Girty indicates that at least part of the fossils were found below the quartzite. Hence it appears that neither the upper nor the lower limits of the Ordovician have been specifically determined.

OURAY LIMESTONE

About 900 feet of limestone conformably overlies the "parting quartzite" and is overlain by a thick series of quartzites, shales, and limestone. The limestone is for the most part blue or gray but a stratum of black limestone occurs in the upper part. Beginning at about 100 feet above the quartzite is a stratum

about 80 feet thick which ranges from siliceous limestone to a structureless hard mottled shale which breaks with a conchoidal fracture and weathers to reddish or chocolate brown.

Most of the limestone is magnesian or dolomitic, fine-grained, and breaks with sub-conchoidal fracture. However, about 600 feet above the quartzite is a bed approximately 100 feet thick composed of almost pure calcium carbonate; it is blue in color and crystalline. This is the rock that is quarried at Garfield for flux.

Girty[1] has recorded the following Devonian fossils collected by Eldridge from the Ouray limestone of Monarch Hill:

Athyris colorodoensis Girty

Camarotœchia contracta (Hall) Hall and Clarke

Camarotœchia endlichi (Meek) Schuchert

Monotrypella sp.

Orthoceras sp.

Orthothetes chemungensis (Conrad) Hall and Clarke= *Schuchertella chemungensis* (Conrad) Kindle[2]

Orthothetes chemungensis var.

Productella semiglobosa Nettleroth? = *P. coloradoensis* Kindle[3]

Productella sublata Hall?

Productella sublata var.

Schizophoria striatula (Schlotheim) Schuchert=*S. striatula* var. *australis* Kindle[4]

Spirifer disjunctus animasensis Girty

Straparollus clymenioides Hall?

Specimens of all the fossils named above, excepting *Productella* and *Straparollus,* were found by our party. The lowest horizon in which we found Devonian fossils is about 240 feet above the bed which carries an Ordovician fauna. Since there is no apparent structural unconformity it is possible that during the Silurian period and perhaps part of the Devonian, sedimentation was very slow and that the time mentioned is represented by scarcely 200 feet of limestone. Further search may extend the vertical range of Ordovician and Devonian forms.

[1]Girty, G. H., Devonian Fossils from Southwestern Colorado: the Fauna of the Ouray Limestone, U. S. Geol. Surv., 20th Ann. Rept. Pt. 2, pp. 34-80.

[2]Kindle, E. M., The Devonian Fauna of the Ouray Limestone, U. S. Geol. Surv., Bull. 391, p. 16.

[3]Idem, p. 17.

[4]Idem, p. 21.

The Carboniferous fossils collected by Eldridge on Monarch Hill and described by Girty[1] are:

Spirifer centronatus Winchell
Syringopora aculeata Girty
Syringopora surcularia Girty

In course of the present survey the following were collected:

Fenestella sp.
Productus sp.
Spiriferina solidirostris White
Syringopora aculeata Girty
Syringopora surcularia Girty

These fossils were found in two horizons: (1) in the black limestone mentioned above; (2) in a shale stratum on the south slope of Syncline Hill and about 3,000 feet higher stratigraphically than the black limestone. It should be added that no Devonian fossils were found in the black limestone or above, and it is possible that this limestone may be at the base of the Carboniferous. A more detailed study will be made later.

POST-DEVONIAN IGNEOUS ROCKS

QUARTZ MONZONITE (ADAMELLITE)

This rock, which is provisionally called quartz monzonite, occurs in a stock, or body of irregular form, in the northwestern part of the district. It extends northeastward beyond the North Fork of the South Arkansas; its southwestern extent has not been determined, but the stock probably forms an irregular contact with the pre-Cambrian granite southwest of Boss Lake and distant one to three miles. Its greatest width within the area mapped is about one mile.

Petrography.—In the field this rock would be readily taken for a quartz-poor granite. In fact, west of Boss Lake where it is much weathered and quartz is prominent, it is impossible to distinguish between the older granite and the later eruptive. The absence of microcline and the presence of much plagioclase and abundant accessory titanite seen in thin sections are characteristic features of the younger rock. It is medium to coarse in texture and composed of pink and white feldspars, quartz, biotite, hornblende, and accessory titanite, apatite, zircon, and magnetite. On Taylor Mountain, where it can best be studied, the rock is generally even-grained, but occasionally a pink feldspar pheno-

[1]Girty, G. H., Carboniferous Formations and Faunas of Colorado, U. S. Geol. Surv., Professional Paper 16, pp. 273, 286, 531.

cryst with a maximum diameter of one inch (25 mm.) may be seen. Ordinarily the feldspars are less than 5 or 6 mm. in diameter. The biotite and hornblende crystals are 1 to 3 mm. in diameter. Although quartz is nearly always present it is frequently subordinate in quantity and in some cases almost disappears. Titanite is a constant and conspicuous accessory in yellow crystals 1 to 3 mm. long. Nearly everywhere the dark minerals are subordinate in amount. The fresh rock is pinkish-gray but in some weathered exposures is nearly white.

The miscroscope shows plagioclase in excess of orthoclase in many specimens, but the proportion is not constant. In some cases orthoclase is almost wanting; in others it equals or exceeds the plagioclase in amount. Although labradorite is present extinction angles indicate that the plagioclase is principally andesine with perhaps some oligoclase. Carlsbad twinning in a few instances accompanies the universal albite twinning, and twinning after the pericline law is common. The plagioclase shows a strong tendency toward automorphism, and zonal structure is not infrequently seen. Occasional crystals enclose many flakes of biotite. Excepting quartz, orthoclase was the last mineral to crystallize. Its crystallization was in part synchronous with that of quartz. This feldspar presents no crystal outline and poikilitically encloses all the earlier formed minerals. It is occasionally perthitically intergrown with the plagioclase. Carlsbad twins are only occasionally seen.

Hornblende and biotite are present in nearly equal amounts, and are intergrown in many cases. On the whole they appear to have crystallized a little later than the plagioclase, but are automorphic toward the orthoclase. The hornblende is the common green pleochroic variety and not infrequently twinned.

Small magnetite crystals are commonly associated with, or enclosed by, both hornblende and biotite. While small apatite crystals are included in all the essential constituents they seem to have a special affinity for the biotite. Titanite, the most abundant accessory, is present in irregular grains and wedge-shaped crystals. Minute zircons are enclosed by quartz and the feldspars.

Texture and structure.—In general the quartz monzonite is medium to coarse in texture as above stated. However, along the west border of the mass on the slope of Mount Aetna the rock is extremely coarse with the dark minerals segregated in large patches, and feldspar crystals up to an inch in diameter. Here also the rock is distinctly gneissoid in structure, which may possibly be a fluxional arrangement. Except near the border at this and other points the quartz monzonite is massive and presents no evidence of metamorphism. The rock is irregularly jointed in blocks which may reach 15 feet or more in diameter.

The name.—On the strength of mineral determination alone it is very difficult to place this rock, and as stated above the term quartz monzonite is used provisionally. Some specimens might be unhesitatingly called granodiorite. In places, by increase in quartz and orthoclase the rock approaches the diorites or quartz diorites. In addition to the granite dikes mentioned below there are within the main body granitic facies with a large proportion of quartz and orthoclase and subordinate plagioclase. In the main, however, the mineral composition seems to be essentially that of quartz monzonite, that is, a rock between syenite and diorite with the addition of considerable quartz.

Apophyses.—Along the east border of the stock, apophyses extend into the sedimentary rocks usually in the form of dikes. In most cases these dikes are roughly parallel to the border of the stock, and in several instances there is no observed connection with the main body at the surface. The rock of most of these dikes is finer in texture and more acidic than the main mass. It ranges from a biotite granite to alaskite, which is a granite composed essentially of quartz and alkali feldspar. Inclusions of the sedimentary rocks are common. Some of these dikes, even though but a few feet wide carry parallel dikes or veins of pegmatite. Pegmatite veins extend also into the contact-metamorphosed sedimentary rocks, where they may be from a fraction of an inch to a foot or more in width. Examples of this may be seen on the south wall of the spillway of Boss Lake where the largest vein varies from three to ten inches wide. This vein shows feldspar with a little quartz at the sides, and at the center quartz with a little feldspar together with black tourmaline, biotite and muscovite.

QUARTZ MONZONITE (BANATITE)

There is an outcrop of monzonite carrying a small amount of quartz about three-fourths of a mile westward from Monarch, and the same rock may be in contact with the limestone a short distance northwest of the village. This is indicated by the large number of boulders on this slope and the coarse marble formed by the metamorphism of the limestone. The boulders, however, may have been brought to their present position by glaciers.

This monzonite does not resemble the more acid monzonite of Taylor Mountain. It carries much less quartz, is finer in texture, contains a larger proportion of the dark minerals, and

closely resembles diorite. It is omitted from the map because the boundaries have not yet been traced.

PORPHYRIES

Dikes of porphyry are common in and near the quartz monzonite. They range from a few inches to 50 feet in width and to perhaps half a mile on Mount Aetna. Most of the dikes are less than 30 feet wide. Many are very irregular in their course in the sedimentary rocks and not infrequently follow the bedding planes for some distance as sheets. As a rule outcrops are easily followed on the ridges and upper parts of the slopes, but in the valleys talus and soil cover the dikes too deeply to permit them to be readily traced. There is no doubt that many of the dikes seen on the ridges and higher slopes are continuous through the valleys.

Mineralization is common in many places. Pyrite may be present in considerable quantity in cubes or more usually as irregular grains or masses.

Quartz monzonite porphyry.—Coarse porphyries are common and range in composition from diorite porphyry to soda-granite porphyry. In some instances quartz-bearing porphyry can be traced from the interior of the dike to a fine-grained diorite or diorite porphyry near the walls. The latter rock carries a very small amount of quartz. In a few cases highly quartzose porphyry and quartzless porphyry have been intruded into the same fissure at different times. No satisfactory evidence as to the relative age of the two has been noted.

A very common phase of the quartz monzonite porphyry in the wider dikes is one which carries pink feldspars from 5 to 50 mm. in diameter, smaller white plagioclase phenocrysts, quartz, and hornblende phenocrysts as the megascopic constituents in a crystalline groundmass. In a few instances biotite is present in amount equal to that of the hornblende. The rock bears a striking resemblance to the Lincoln porphyry of Leadville but carries hornblende as the dominant ferromagnesian mineral instead of biotite, and has a coarser groundmass than the Leadville rock.

Many of the pink orthoclase phenocrysts are twinned after the Carlsbad law, and some enclose other minerals of the rock poikilitically. Not infrequently by the aid of a lens twinning striae can be seen on cleavage faces of the plagioclase. The quartz phenocrysts vary from a few millimeters to a centimeter

in diameter and are generally rounded by re-solution. The quartz is very irregularly distributed. Locally it is an abundant constituent, but it is absent from the rock in many places. Hornblende occurs in crystals up to one centimeter in length. This mineral is always present in considerable quantity but is frequently chloritized.

In thin section the hornblende is brownish-green, and many crystals show orthopinacoidal twinning. The plagioclase is in part labradorite, but probably more sodic varieties predominate. The groundmass is holocrystalline and commonly even-granular. When plagioclase exceeds orthoclase in amount in the groundmass it occurs in small rectangular forms while the orthoclase is packed in the interstices. The ratio of orthoclase to plagioclase varies greatly in groundmass as well as phenocrysts.

In addition to the megascopic constituents the microscope shows accessory magnetite, titanite, zircon, and apatite.

There are several variations from the rock described both in texture and mineral composition. On Clover Mountain and in Hoffman Park the coarse acidic porphyry appears to grade toward the dike walls into a very fine-grained diorite, or microdiorite, carrying great numbers of long, slender hornblende crystals, hypautomorphic plagioclase crystals, and a small amount of interstitial orthoclase and quartz. On the southeast slope of Taylor Mountain is a dike of what might be termed micro-monzonite. It is very fine in texture, even-grained and composed of hornblende, orthoclase and plagioclase with no quartz.

In a few dikes, at least part of the rock has a coarser groundmass and smaller phenocrysts than the first variety described. It is composed essentially of white orthoclase and hornblende. Taken alone it would properly be called syenite porphyry.

Latite and latite porphyry.—The dikes mapped as latite and latite porphyry range in composition from andesite to rhyolite, and in texture from felsitic to moderately porphyritic. The greater part of the rock carries orthoclase and plagioclase in approximately equal amounts. Free quartz occurs sparingly but is absent from the greater part of the rock. Hornblende is present in most of the rock, but is accompanied in some cases by much biotite. Rarely biotite occurs to the exclusion of hornblende. Titanite, magnetite, and apatite occur as accessories.

The groundmass is composed mainly of poorly individualized feldspar microlites with a variable amount of interstitial feldspar. Secondary quartz is present in some cases. The ratio of groundmass to phenocrysts is large, and in several dikes phenocrysts are all but absent from the rock. The rock in a few dikes closely resembles the Leadville "white porphyry". In many

specimens the advanced stage of alteration prevents the accurate determination of the constituent minerals.

BRECCIA

On the ridge north of Clover Mountain in the vicinity of the Mason mine, the greater part of the rock is breccia which carries angular fragments ranging from microscopic dimensions to masses many feet across. The fragments are mainly shale, sandstone, and arkose, but considerable gneissoid granite or quartz monzonite like that on the east slope of Mount Aetna, is present. The matrix is greenish and much weathered. The few specimens examined are too badly altered for specific identification but appear to be andesitic or latitic in composition.

QUATERNARY DEPOSITS

MORAINES

Glacial deposits are widely distributed within the area covered by the map and are found in greater quantity several miles east. The moraines are composed of glacial clay with a large proportion of sub-angular boulders which show but little, if any, facetting. Boulders high on the slopes were probably deposited by ice masses of considerable size.

The glaciers were local and moved from the west and north. One of the largest had its source near Mount Aetna and moved down Middle Fork. Another moved down Lake Fork. One, and perhaps two, reached Monarch from the west. The large amount of morainal material southeast of Cree Camp shows that a glacier had its source either on Taylor Mountain or at the head of the gulch toward the northeast.

Much of the glacial deposits has been removed by erosion, and it is probable that the moraines within the district are nowhere very deep. Near the old Columbus mill-site on Middle Fork a tunnel driven about 85 feet into the steep north wall of the canyon does not go through the glacial covering, but in many places the streams have cut down to bed-rock. Many of the smaller patches of ice-deposited debris are not represented on the geologic map.

ROCKSLIDES AND LANDSLIDES

Large masses of sliderock occur on several of the steeper slopes particularly west of Boss Lake, on Mount Aetna and the north slope of Taylor Mountain. The longest of these extends

from the top of Aetna to Middle Fork where it may be seen from a long distance as a light-colored streak in contrast with the darker weathered rock on both sides.

Near the top of the Continental Divide are accumulations of loose rock which have apparently been deposited at the front of large banks of snow or ice which may or may not have been in motion. Subsequent melting of the snow or ice left depressions which now contain small bodies of water up to 50 feet or more wide. It is assumed that these rock masses are the accumulations of many years.

Typical landslides are not common. On Monarch Hill a short distance south of the entrance to the Madonna No. 6 tunnel is a mass of the siliceous shaly stratum of the Ouray limestone mentioned on page 15. This stratum carries a layer of quartzite and strangely enough has lodged almost directly above the "parting quartzite" cut by the tunnel. The thinness of the quartzite bed at the surface and difference in dip and strike from that underground, together with the presence of the chocolate-colored shale at the surface, prove that the exposed rock has come from a higher position.

STRUCTURE

Owing to the scarcity of extensive underground workings and the abundance of talus and drift the details of structure have not been worked out as fully as desirable, but the general features have been determined. In addition to the processes of sedimentation and the changes in conditions which accompanied those processes the principal factors to be considered in the structural geology of the region are folding, faulting, jointing, solution, and igneous intrusion. A phenomenon less important for the purpose of this paper is the moderate regional metamorphism of the pre-Cambrian granite.

FOLDING

Next to the mountain-making movements which have left marine sediments more than two miles above sea level, tangential movements have perhaps been the most prominent. These horizontal movements were accompanied by vertical movements. Until studies are carried westward and northward it is impossible to say to what extent the folds of the Monarch district are part of a larger structural unit. It appears from the evidence at hand

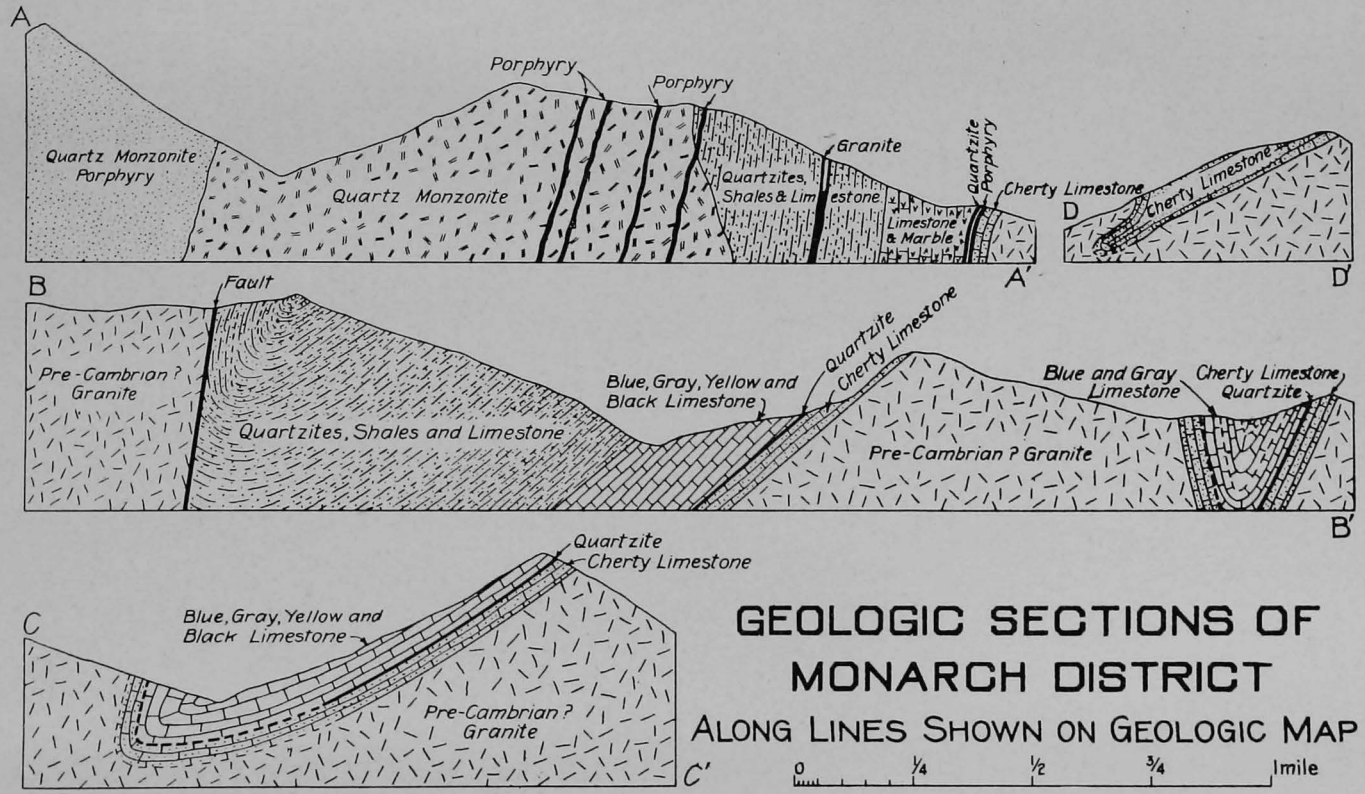
that there were two directions in which strong forces acted, namely, east-west and north-south. The result of these stresses was a synclinal fold having a general north-south axis, with minor echelon folds.

The sedimentary beds have been tilted through an angle which ranges from 15° to 90° and even more in a number of instances. On Monarch Hill the dip is moderate, ranging from 30° to 45° for the most part. East and north of Garfield the strata are nearly vertical. In the Lilly mine the granite floor on which the sediments were laid down now stands vertical or but slightly inclined from vertical toward the west. In the Garfield tunnel driven northward along the limestone-granite contact from the creek below Garfield the dip is toward the west near the tunnel entrance, but near the breast the granite forms the hanging wall with an eastward dip of 73°. Similar overturns are not uncommon in a number of places.

The most extreme case occurs on Monarch Hill where it can be well seen in the Hawkeye mine. The Hawkeye tunnel was driven several hundred feet to the granite contact and thence along the contact where the granite forms the hanging wall with a westward dip of 40° to 60°. In the upper part of an upraise from the end of the main tunnel the granite hanging wall can be seen dipping westward 25°. A crosscut to the east limb of the fold found the granite footwall dipping westward 28°. In the Madonna No. 6 tunnel the quartzite of the northwest limb of the fold dips 60° N. 53° W.

From this point northward the boundary between the granite and limestone cannot be accurately determined at present. Alluvium in the creek and drift toward the north, conceal the bedrock, while no serious prospecting has been done along the contact. It is probable that in this vicinity there is a sharp fold which passes into the fault toward the north. The broken lines in CC, Plate III, indicate the possible attitude of the beds if they are not indeed faulted along this line.

East of Cree Camp the limestone-granite contact offsets more than a quarter of a mile while holding its northward trend. Faulting first suggests itself to the observer. However, a short distance northeast of the cabins of Cree Camp an opening exposes the contact which dips toward the northeast swinging gradually but sharply from north toward east. Alluvium and morainal material conceal the contact between this outcrop and the Clinton mine, but it is inferred that an echelon fold connects



GEOLOGIC SECTIONS OF MONARCH DISTRICT

ALONG LINES SHOWN ON GEOLOGIC MAP

the limestone of the Clinton mine with that at Cree Camp (Fig. 1). The possibility that this sharp fold may have culminated in a fault is conceded.

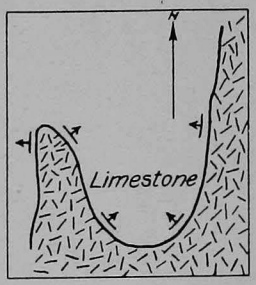


Fig. 1. Diagram to show probable trend of limestone—granite contact east of Cree Camp.

FAULTING

Local faults of small throw are numerous in mines in all parts of the sedimentary area. Movement has been in practically all directions as can be determined by slickensided surfaces.

A few of the larger faults are represented on the map. The one which has the greatest throw passes southward from Boss Lake an undetermined distance. From the divide southward its exact position cannot be determined because of the surficial material, and hence its position on the map is only provisional. On the north slope the granite is exposed very near the upended sedimentary rocks, and the position of the fault here can be determined with reasonable accuracy. As it is represented in section BB, Plate III, the hade toward the west is only tentative. It is probably even greater than the figure indicates. It will be seen from the section that the sedimentary beds of Syncline Hill are about 4,800 feet thick. Even if no allowance be made for the erosion of sedimentary rocks which formerly overlay the granite west of the fault the throw and stratigraphic throw must be nearly or quite a mile.

The faults of Monarch Hill have been mapped largely from surface indications. Unfortunately the plans of the mines do not show the positions of the faults underground and the accessible workings do not disclose the relationships of the most important ones. While of comparatively small throw, these faults are important in that they accompany fissures which formed channels for the circulation of mineral solutions. The crushing of the rock which accompanied the faulting furnished open ground favorable to ore deposition.

The Madonna fault appears to be a thrust fault hading toward the southwest, that is, with the upthrow on the southwest side. The Mayflower fault is probably a gravity fault with the downthrow on the southwest. It can be most easily seen where the quartzite offsets from the Eclipse discovery shaft almost to the entrance of Eclipse No. 1 tunnel. It is probable that a

shorter fault striking northwest, crosses the saddle between these two and meets the Madonna fault at Zero level.

According to Mr. A. Eilers the block between the Madonna and Mayflower faults has dropped downward through a vertical distance of 200 to 250 feet and is badly broken. There is no regularity in dip and strike and the bedding planes are not continuous. Mr. Eilers also states that the Madonna fault continues into the underlying granite as shown in a number of levels, and that the granite on the southwest side of the fault extends some 200 feet farther northwest than it does on the northeast side.

Figure 2 is a graphic attempt to show the possible history of these faults. As stated above, the stresses which developed the folds were principally north-south and east-west. The resultant would be a compressive force in a northeast-southwest direction. Such a stress would naturally produce a system of thrust faults at right angles to the force, as shown in Figure 2, *a*. After this stress was relieved through folding, faulting, and probably other causes, there would naturally be a subsidence of the fault blocks and 1 and 2 of Figure 2 could very easily drop together to the position shown in *b*. There may also have been differential movement between 1 and 2 which would only necessitate a greater thrust along the Madonna fault than that indicated in *a*.

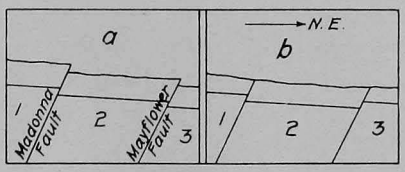


Fig. 2. Diagram to illustrate faulting on Monarch Hill. *a*, probable position of blocks when first faulted; *b*, present position.

It is possible that another considerable fault extends from a point a short distance east of Garfield and near the creek to a point not far from the Columbus mill-site. The abrupt change in dip of the few outcrops along this line indicates either a sharp fold or a fault. Southeast of Garfield near the extremity of the synclinal fold there has been much local faulting. The sudden disappearance of the "parting quartzite" which, where exposed, can usually be readily seen with the underlying limestone, suggests bedding faults. At the head of Taylor Gulch and in the vicinity of the Last Chance mine there has been much local faulting which cannot be represented on a small scale map.

The major part of the faulting probably accompanied or closely followed the folding, but there have been some slight displacements since the ore was deposited.

JOINTING

In some parts of the quartz monzonite the blocks are of large dimensions, up to 15 or 20 feet across, but all the other rocks are much jointed. Locally the jointing of the limestone presents considerable regularity, but in the main the joint-planes intersect at irregular angles. In those parts of the sedimentary rocks least affected by folding and faulting the joints are usually tight, and here also the mineralization is least.

CAVES AND UNDERGROUND CHANNELS

The formation of caves and development of subterranean drainage are genetically connected with jointing, folding, and faulting which formed fractures and thus facilitated the circulation of ground waters. Limestone is taken into solution and removed by these waters with comparative ease. The caves thus formed are small in this district. The largest noted was cut in the Shamrock mine at the limestone-granite contact and is about six or eight feet wide by 50 feet high. Another, perhaps somewhat smaller, was found in the same mine. Others may be seen at the creek level in Garfield.

Just below the stone quarry west of Garfield a large stream issues from beneath the limestone south of the creek. This may or may not have direct connection with the creek higher up. A short distance south of Garfield a stream emerges from beneath a mass of granite talus and doubtless has flowed some distance through the limestone. At Monarch a short branch of the creek has its visible source in an excellent spring which furnishes the village with water for domestic use and could adequately supply a town many times larger. A somewhat smaller stream issues from the limestone half a mile east of Garfield. This is probably the exit of the underground channel which drains the bench-like area three-fourths of a mile south of the spring. This area is nearly flat for a considerable extent as may be seen from the topographic map (Pl. I). Morainal material forms a barrier along the north side except at the northeast corner where there is a small ravine presumably an outlet for storm waters only.

During the field season no water was running through this outlet although there was an abundance of melting snow above.

Underground streams, perhaps in fault-planes, are indicated in the upper part of Taylor Gulch and below a depression heading toward Taylor Mountain where there is little or no surface drainage during the season of melting snow.

IGNEOUS INTRUSION

The occurrence of diorite and syenite dikes in the pre-Cambrian granite has been mentioned. Subsequent to the principal folding of the region and at an undetermined geological time the large mass of quartz monzonite described above was forced upward through the sedimentary rocks now exposed, and extended into the granite on each side of the synclinal fold. The longer axis of this stock extends diagonally across the syncline.

Whether magma from this mass reached the surface above the once overlying sediments as an effusive rock or whether it was intruded as a plutonic rock and has since been uncovered by erosion, is not known. Nor has the form of the mass been determined. Indications on the east slope of Mount Aetna point to a westward dip of the west contact. The existence of the several dikes of granite on the east slope of Taylor Mountain suggests the extension of the stock at depths to a considerable distance east of its boundary at the surface. That the stock divided the syncline is clearly shown by the occurrence of metamorphosed sediments on the east slope of Mount Aetna and north of Clover Mountain.

Later, both the sedimentary rocks and existent igneous rocks were cut by porphyry dikes which trend, for the most part, in a general northeast direction. The focus of this activity appears to have been about where Aetna now stands. Near the east border of the quartz monzonite the dikes dip westward or are nearly vertical.

On the east slope of Aetna and on Clover Mountain and northward, the quartz monzonite porphyry, near its border, encloses portions of pegmatite and sedimentary rocks, which range from microscopic fragments to masses scores of feet across. The breccia in the vicinity of the Mason mine perhaps represents one phase of this vulcanism.

Contact metamorphism.—The effects of metamorphic agencies are shown in the sedimentary rocks to a distance of perhaps a quarter of a mile from the quartz monzonite stock. Shales have

been baked almost to porcellanite, sandstone has been changed to quartzite, and it is probable that some marble was formed through the agency of heat from the quartz monzonite. But the fact that the best marble and largest quantity occurs near the porphyry dikes, indicates that the porphyry has been more effective in transforming the limestone than has the quartz monzonite.

Epidote, garnet, magnetite, and feldspar have been developed in considerable quantity and asbestos, wollastonite, diopside, titanite, and zircon in less amount. Perhaps all the ores on the west side of Taylor Gulch and a small amount of others are contact-metamorphic deposits.

The subject of contact metamorphism in this field will be taken up more fully in a later report.

ECONOMIC GEOLOGY

CHARACTER OF THE ORES

Nearly all the ores of the region are basic ores, and all that are now being mined are shipped directly to the smelters. More or less silica from the alteration of chert is present in the ores which occur in limestone, and quartz in small amount is present in some of the contact deposits. Zinc silicate occurs in small quantity. Aside from the lime which is intimately associated with some of the ores in variable amount, there is generally more than enough iron to satisfy the silica present. The "excess iron" commands a price dependent on the demand for basic ores. By excess iron is meant the quantity present after deducting sufficient, as shown by assays, to satisfy the silica content. Manganese in oxide form in the Clinton and Rainbow-Eagle Bird mines increases the value of the ore by lessening the treatment charges.

There are no mills in the district. Formerly the ore of the Columbus mine was concentrated in the company's mill which was sold and removed after the mine was shut down.

Hitherto the greater part of the product of the district has been oxidized ore, chiefly silver-bearing lead carbonate, in which bunches of sulphide have been found at any depth. In some cases solid galena occurs within a few feet of the surface. On Monarch Hill galena is the only sulphide in considerable quantity present in the ore bodies now being mined. In Taylor and Columbus gulches sulphides of iron, copper, lead, and zinc occur.

Monarch Hill produces mainly ores of lead, silver, gold, and zinc, with some copper in the Madonna and Eclipse mines. The ores of Taylor Gulch are of copper, silver, gold, and lead. A promising discovery of zinc ore has been made on the New York claim but no shipments have been made at the time of writing. Columbus Gulch has produced silver, gold, copper, and lead.

During the period of greatest activity there were no zinc smelters in Colorado, and much zinc ore was left in the mines. Part of this is now being taken out. The silver of much of the silver-zinc and silver-lead-zinc ores was recovered by mixing these ores with lead and silver-lead ores and at the same time keeping the zinc content below the limit fixed by the smelters.

TENOR OF THE ORES

Since so few records of tonnage and values have been kept, it is impossible to determine accurately the average value of the ores. An estimate of the average value based on data in hand from a number of mines would be about $20 to $25 per ton for the ores of Monarch Hill and considerably higher for those of Taylor Gulch. Most of the shipping ores carry a value between $8.00 and $30.00 a ton. The Madonna ores have averaged $24.20 per ton. (See p. 47.) The copper ores of the Lilly mine average about 10 per cent in copper. Ore worth $7.00 a ton can be mined at a profit under present conditions.

The range in value is very great. One carload from the Fairplay mine carried 130.75 oz. silver per ton, 39.95 per cent zinc and 10.05 per cent lead, by smelter returns. The best car from the Little Charm mine returned from the smelter .48 oz. gold and 226.2 oz. silver per ton, 24.5 per cent lead, 7.65 per cent zinc and .15 per cent copper. A sample from a narrow streak below the fifth level of the Madonna, assayed in the Survey laboratory, yielded 16 per cent lead, .50 oz. gold and 816.25 oz. silver per ton.

The moisture content ranges from 5 to 20 per cent. The greater part of the ores carries between 10 and 14 per cent moisture.

MINERALOGY OF THE ORES

In describing the minerals it is intended to mention only those characters which the minerals of this region possess. The iron and manganese minerals are included in this list because they add to the value of the ore. For the convenience of miners and prospectors in the district who may not have at hand a textbook of mineralogy, the metallic content of the pure mineral is given for each variety.

COPPER MINERALS

Azurite, basic cupric carbonate $2CuCO_3.Cu(OH)_2$, copper 55.3 per cent. This mineral occurs as a blue coating on surfaces of jointed limestone and disseminated in the mineralized limestone near the copper ore bodies. It is also present in massive form associated with malachite.

Chalcocite, cuprous sulphide, Cu_2S, copper 79.8 per cent. Good chalcocite was seen by the writer only in the Hercules tunnel where it fills a narrow fissure in the quartz monzonite. It is nearly black, and friable.

Chalcopyrite, copper-iron sulphide, $CuFeS_2$, copper 34.5 per cent. It occurs in the lower workings of the Lilly and probably in the Columbus. It is brass-yellow and massive.

Chrysocolla, copper silicate with water, $CuSiO_3.2H_2O$, copper 36.1 per cent. This is found as a sky-blue mineral coating the walls of small cavities in the Lilly mine and filling narrow fissures in the other copper ores. Chrysocolla of good quality is sometimes used as a gem.

Copper, native, Cu. Native copper has been reported from the Columbus mine.

Copper-bearing pyrite, sulphide of iron with a variable amount of copper, FeS_2. It is found in the Lilly mine in bunches surrounded by oxide of iron derived from it. It is massive and brass-yellow, sometimes shows purple tarnish.

Cuprite, cuprous oxide, Cu_2O, copper 88.8 per cent. This is present in the Lilly mine both as a soft red mineral intimately associated with iron oxide, and as purer harder mineral in the upper workings.

Malachite, basic cupric carbonate, $CuCO_3.Cu(OH)_2$, copper 57.54 per cent. This green carbonate is present in nearly all the mines which have produced copper, particularly the Lilly and the Madonna. It is found in considerable quantity associated with other oxidized copper minerals and disseminated through the limestone as a replacement, in sufficient quantity to make payable ore.

Tenorite, melaconite, cupric oxide CuO, copper 79.8 per cent. Black earthy melaconite occurs in the Lilly and Shamrock mines associated with other copper minerals. It is very impure from the admixture of other substances.

GOLD

No gold minerals have been reported from the district, but the smelter returns from most of the ores now being shipped show .02 to .50 oz. gold per ton and in some of the contact deposits the gold content is many times greater. Since the ores are largely oxidized and no tellurium has been reported[1], it is inferred that the gold is present in the native state.

[1]Since this paper was written, tellurium has been reported from Madonna, No. 6, but no special tests have been made.

IRON MINERALS

Hematite, ferric oxide, Fe_2O_3, iron 70 per cent. Hematite was not seen associated with the ores, but much black specular hematite is present on a dump a few yards south of the Ingersoll. A large part of the mineral is practically pure.

Limonite, ferric oxide with water, $2Fe_2O_3.3H_2O$, iron 59.8 per cent. Brown limonite and, to a less extent, the yellow ocherous variety occur in nearly every ore-body discovered. Much of it carries a small quantity of silver. Very large bodies of limonite are present in the Madonna mine.

Magnetite, a compound of ferrous oxide and ferric oxide $FeO.Fe_2O_3$, iron 72.4 per cent. This mineral was not seen by the writer in any of the ore deposits, but it is present as a contact mineral on the southeast slope of Taylor Mountain, and forms a vein two or three feet wide just east of Boss Lake.

Pyrite, iron disulphide FeS_2, iron 46.6 per cent. Both as crystals and in the massive form pyrite is found in the Lilly and Garfield, in smaller quantity in the Madonna, and perhaps in other mines. Its rarity on Monarch Hill is explained by the fact that nearly all the ore mined comes from the zone where the pyrite has been oxidized to limonite.

Turgite, hydrous ferric oxide, $2Fe_2O_3.H_2O$, iron 66.2 per cent. Red, earthy turgite occurs with limonite in the Madonna mine below No. 5 level.

LEAD MINERALS

Anglesite, lead sulphate, $PbSO_4$, lead 68.3 per cent. In the summer of 1909 Mr. Thomas Penrose found in the Little Wonder mine a small group of anglesite crystals near the center of a mass of galena weighing several hundred pounds. These had a dull surface due perhaps to the formation of carbonate, but within, the mineral was pure water-clear anglesite. The largest crystal was nearly two inches long.

Cerussite, lead carbonate, $PbCO_3$, lead 77.5 per cent. This mineral, in the form of soft carbonate with an admixture of limonite and carrying silver, has been produced in far greater quantity than any other in the district. Hard carbonate occurs in but few mines. Crystallized cerussite was noted by the writer only in small amount on a few specimens of galena from which it is derived.

Galena, lead sulphide, PbS, lead 86.6 per cent. Coarsely crystallized galena is present in practically all the mines which

produce lead. In nearly every case it is surrounded by lead carbonate. Most of the galena is silver-bearing.

Mimetite, a double salt of lead arsenate and lead chloride, $3Pb_3As_2O_8.PbCl_2$, lead 69.5 per cent. Mimetite occurs in small quantity in the Lilly mine and on one of the Jewell claims, as a yellow to green earthy mineral intimately associated with limonite and insoluble material.

Wulfenite, lead molybdate, $PbMoO_4$, lead 56.4 per cent. This mineral was not seen in any of the mines, but a specimen found on the Hawkeye dump contained many yellow tabular crystals of wulfenite coating galena. It has also been found in the Madonna mine.

MANGANESE MINERALS

Psilomelane, perhaps H_4MnO_5, manganese nearly 40 per cent, occurs as a black massive mineral carrying considerable lime carbonate and iron in the Rainbow-Eagle Bird, and possibly other mines.

Pyrolusite, manganese dioxide, MnO_2, manganese about 79 per cent. Pyrolusite in earthy form is found with psilomelane in the Rainbow-Eagle Bird and possibly without psilomelane in the Delaware mine.

SILVER MINERALS

The best silver ores of the district were mined many years ago and good specimens are now very scarce. Although native silver probably occurs in the oxidized ores, halogen salts of silver were common in those of highest grade. Chlorides and bromides appear to have been present in considerable amount. A few small pieces of green silver mineral picked from the dump of the Little Charm closely resembled silver iodide, but the specimens were lost before an analysis could be made. Silver sulphide has been reported from the Song Bird mine, and stephanite from the Little Wonder.

ZINC MINERALS

Calamine, hydrous zinc silicate, $H_2Zn_2SiO_5$, zinc 54.2 per cent. Calamine in small tabular crystals occurs in narrow veins in the smithsonite. A part of the massive zinc mineral with which the crystals are associated may also be calamine.

Smithsonite, zinc carbonate, $ZnCO_3$, zinc 52.2 per cent. This is the most common zinc mineral which the district is now producing. It occurs as a hard, massive, dark gray mineral, as a

softer yellowish to brownish mineral, and as small crystals in vugs and narrow veins.

Sphalerite, or *zinc blende,* zinc sulphide, ZnS, zinc 67 per cent. Crystals of sphalerite with galena occur in the Columbus mine and the massive mineral is found on the New York claim, associated with garnet.

GANGUE MINERALS

Calcite, "spar", calcium carbonate, $CaCO_3$. Coarsely crystallized calcite is common at the border of ore bodies, and is considered a favorable indication when encountered in prospecting. It is in some cases slightly mineralized, carrying small amounts of galena, pyrite, or silver mineral. Calcite is also present in considerable amount in many of the prospects in which no ore has been found.

Dolomite, carbonate of calcium and magnesium, $(Ca,Mg)CO_3$. Brown, coarsely crystallized dolomite is associated with the ore in the Rainbow-Eagle Bird.

Quartz, silica, SiO_2. Quartz in large amount is associated with the ores in the fissure veins in the quartz monzonite. It also occurs in small amount with some of the contact deposits.

TYPES OF ORE DEPOSITS

Since there are intergradations no attempt is made here to name the types in the order of importance. Those which have come under observation are:

1. Replacement deposits in limestone.
2. Filling in fault-fissures in limestone and quartzite with more or less replacement of the wall rock.
3. Contact deposits in the sedimentary rocks not far from the intrusive rocks.
4. Deposits at the contact between basic syenite dikes and granite. This type has yielded but little ore.
5. Fissure veins in the quartz monzonite and at the eruptive contact with the sedimentary rocks.

REPLACEMENT DEPOSITS IN LIMESTONE

Excepting those ore bodies in the fault-fissures on Monarch Hill and possibly the Lilly ores in part, all the known deposits in the lowest limestone near the contact with the pre-Cambrian granite, are of the replacement type. Also most of those above

the "parting quartzite" on Monarch Hill are replacement deposits.

In the largest bodies the ore lies in practically continuous shoots which follow the dip of the sedimentary rocks downward, but in most cases bear either to the right or left of the dip. This divergence from direction of dip is but few degrees in every instance noted except in the Lilly mine. Here where the contact is nearly vertical the longest shoot pitches north about 20°. As a rule, the ore bodies near the granite either lie on the granite or are separated from it by but a few feet of limestone, departing from the contact perhaps 20 or 30 feet in rare instances.

Cross-sections of the shoots are sometimes circular but much oftener are elliptical with the longer axis parallel to the strike of the strata. Most of the shoots do not have a constant width and thickness, but pinch and swell. The swells may be lenticular or irregular in form, and connected by a workable body of pay ore or by an iron-stained joint- or bedding-plane in the limestone. Nearly all the shoots show smaller dimensions in the lower workings than nearer the surface, but it is not known that any have completely failed at the greatest depth reached.

Other replacement deposits occur in bunches or pockets which may be roughly tabular, lenticular, or wholly irregular in form, but the longest diameter is generally parallel to the bedding of the limestone. Some of these in their relation to the enclosing rock closely resemble the flats of the zinc and lead ores of the Upper Mississippi Valley, but are highly inclined or nearly vertical conformable to the beds in which they lie. As in the longer and generally larger shoots, a series of these bunches may be connected by an iron-stained joint- or bedding-plane. In some cases a seam of gouge connects two or more ore bodies, and here it is difficult to distinguish between the replacement type and those deposits along faults and shear zones.

In all cases of these replacement deposits it is assumed that there has been a metasomatic interchange between the calcium carbonate of the limestone and the metallic salt in solution in the circulating ground water. In most cases the ore gradually grows leaner toward the periphery with increasing limestone content, and not infrequently passes into disseminated ore near the outer limit of mineralization. The wall is merely the boundary of the ore which can be profitably mined.

FILLING IN FAULT-FISSURES

The largest ore bodies which have yet been opened in the district are of this type, as for example those of the Madonna and the Eclipse. While there has been much local faulting in the vicinity of the Lilly mine it is not definitely known that the Lilly ore bodies lie in fault-fissures. If they do the fault must be parallel to the bedding of the limestone.

There is also in this type much replacement of the wall rock, and the ore is in shoots as in the replacement type described. The essential difference between the two types lies in the probably greater size of the ore bodies deposited in the fissures, because of more favorable conditions for the circulation of mineral solutions.

CONTACT DEPOSITS IN THE SEDIMENTARY ROCKS

Although the ore of this type occurs largely in bunches in so far as it has been mined, it has yielded some of the highest values of the district. Silver, as chloride and sulphide, is the most important metal thus far produced by these deposits which have also contributed the best gold ore of the region, in addition to some lead and copper. Good zinc ore—sphalerite and smithsonite with a little calamine—has been discovered on the New York claim, but no shipments have been made.

This type in most cases replaces limestone, dolomite or shale not far from the porphyry dikes. It is probable that much of the ore on the west side of Taylor Gulch owes its origin to the quartz monzonite toward the west. The sphalerite on the New York is associated with garnet, practically proving its contact-metamorphic origin although perhaps several hundred feet from any known intrusion.

In some cases these ores are in immediate contact with the porphyry, but replacing the sedimentary rocks rather than the porphyry. Like the replacement ores described above, they grade into the enclosing rock; there are no well defined walls.

Examples of contact deposits in addition to those mentioned above are found in the Mountain Chief, Rainbow-Eagle Bird, Major, Shamrock and probably part of the Lilly ores.

SYENITE-GRANITE CONTACT DEPOSITS

Examples of this type are found in the Missouri Boy and perhaps on the Bay State and Independence claims. The underground workings of these claims were inaccessible in 1909.

FISSURE VEINS IN QUARTZ MONZONITE

At least three fissure veins outcrop on the slopes of Taylor Mountain and Mount Aetna, and the ores of the Columbus and Brighton mines have been furnished by these veins. Several shallow prospect pits have been sunk on fissure veins in Hoffman Park and on the east slope of Aetna. These veins can be readily followed on the surface because of the depressions which they occupy. Moreover, gossan is common.

In a shallow prospect on the east slope of Aetna the limonite in a westward dipping vein ranges from a thin seam up to a foot in width. A specimen taken here yielded on assay $7.20 per ton in gold, but no thorough sampling of the vein was undertaken. At the surface the vein dips west 35°. Neither the Brighton nor the Columbus ore bodies could be examined in 1909 but a brief description of the Columbus mine is quoted on page 67 of this report.

TERMS USED TO DESCRIBE ORE SHOOTS

Although ore is found in bunches or pockets in a number of mines, the typical occurrence of the largest bodies is in shoots which dip at a fairly uniform angle toward the north and northwest.

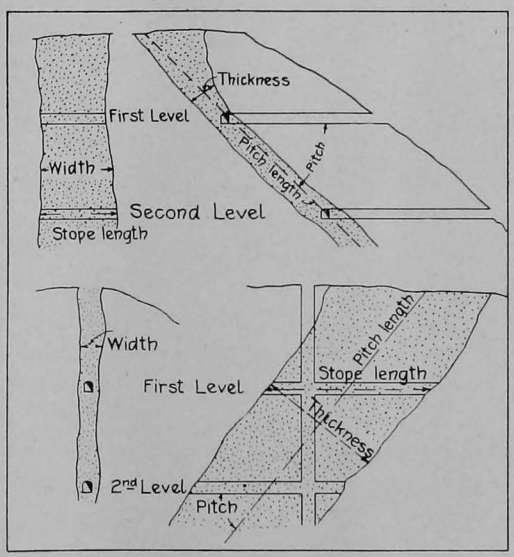


Fig. 3. Diagram to illustrate terms used in describing ore shoots. (After Lindgren and Ransome, modified to suit conditions at Monarch.)

The terms used in the descriptions of these shoots will be those employed by Lindgren and Ransome in their descriptions of the Cripple Creek ore shoots[1], with but one change. The terms width, thickness, stope length, pitch length, and pitch will be used. "The stope length is the distance along the drifts over which payable ore extends; the pitch length, or axial

[1]Geology and Gold Deposits of the Cripple Creek District, Colorado. Professional Paper 54, U. S. Geol. Surv., pp. 205-206.

length, as it might also be termed, is the distance between the two extreme ends of the shoot; the pitch is the angle which the pitch length makes with the horizontal". Width will be understood as the horizontal distance from wall to wall at right angles to the pitch length just as it is used by the authors quoted. The distance across the shoot at right angles to the pitch length and width will be called the thickness. In the Lilly mine and in a few other instances the width is less than the thickness, but ordinarily the width is the greater; in some cases the two are equal. In many mines the stope length is identical with the width. Figure 3 will make clear the relations of the terms used.

AGE OF THE ORES

The contact deposits may have been formed at two different periods. Ore was certainly deposited after the intrusion of the porphyry and probably represents the last stage of this period of vulcanism. Some contact deposits were probably formed immediately after the intrusion of the quartz monzonite and previous to the porphyry intrusions.

Until mining developments are carried deeper all that can be said of the age of the ores of Monarch Hill, the Lilly mine, and a few others, is that they were deposited after the folding and principal faulting of the sedimentary rocks in which they lie. The few fractures and faults seen in the ore bodies are too slight to have been caused by the folding and faulting noted on pages 23-28. Knowing that Mr. Eilers had had opportunities, which do not now exist, to observe the relation of the largest deposits to the faulting, the writer asked him several questions, and received the following definite statements:

"The ore in the Madonna was all deposited, without the slightest doubt, subsequent to the faulting and folding.

"The ore showed no crushing or breaking in any part of the mine.

"There was never found any evidence of more than one period of ore deposition, which was subsequent to the faulting and prior to oxidation.

"The principal ore body in the Madonna down to the fourth level, was in the big fault itself, but small branches went out for some distance to the southwest and northeast into the limestone strata, generally following the planes of stratification to the southwest, and being very irregular in the broken ground to the northeast of the fault.

"The ore bodies themselves were never faulted anywhere in the mine."

GENESIS OF THE ORES

There is little doubt that the ores of the known contact deposits in the sedimentary rocks were deposited from solutions emanating largely from the porphyry, but probably in part from the quartz monzonite. This conclusion is based primarily on the relation of the ores to the intruded porphyry, and their association with minerals of contact-metamorphic origin, such as garnet.

By far the greater part of the known ores of the district are replacements and fault-fissure-fillings, removed a considerable distance from an eruptive contact. Conclusive evidence of their origin is lacking. However, facts mentioned below lead to the inference that the ores have been deposited from ascending solutions which may have had their source in the quartz monzonite toward the northwest. Meteoric waters, highly heated by the intrusive rock, may have had a part in dissolving the metals and carrying them upward.

Although sulphides of copper, iron, lead, and zinc are present in other deposits, they are common minerals in ores which have been deposited from ascending hot solutions. The presence of gold and considerable silver in the Monarch ores indicates a deep-seated source. The ore minerals of Monarch Hill are very similar to the minerals of the contact deposits, a fact which suggests a similar or common source.

While the general northward to northwestward pitch of the ore shoots is in large part due to the structure, it also indicates that the mineral-bearing solutions flowed in a common direction. This direction might possibly have been toward the northwest on Monarch Hill, but there is no conclusive evidence that underground waters would take this course at the time of ore deposition, and previous to erosion. Any considerable downward movement of ground water toward the north in the Lilly and Clinton mines, at a time when the intrusive rocks were probably still at a high temperature, would be anomalous. Hence the inference is that the mineral-bearing solutions moved upward and southeastward. The solutions which reached Monarch Hill may have followed bedding planes in the rocks, but it is more probable that they passed along the fault-plane which extends southward from Boss Lake.

So far as is known, the base metals were almost entirely deposited as sulphides. Probable exceptions are the mimetite and wulfenite both of which occur in small quantity. Some distance above the "parting quartzite" is a stratum of fossiliferous limestone which emits a bitumenous odor when broken. This stratum and other fossiliferous strata may have furnished sufficient hydrogen sulphide to precipitate all the base metals as sulphides from solutions made alkaline by the dissolved limestone. Or, ascending solutions may have carried the metals in the sulphide form, while a combination of causes may have brought about their precipitation. Among these, supersaturation due to decrease in temperature and pressure, and increased alkalinity due to the limestone, would be important factors. Whatever may have been the primary cause of precipitation the limestone has certainly exerted an important influence.

PRACTICAL INFERENCES AND SUGGESTIONS

There is a limit to the depth at which metallic minerals are likely to be precipitated from solution, and the thickness of rock that has been removed by erosion since the Monarch ores were deposited, cannot be determined from observed facts. Nevertheless, a number of features noted in connection with the ore bodies, when considered with reference to the general structure, justify the statement that, in the faulted ground in the southwestern part of the field, ore shoots may be expected to extend considerably below the level of ground water and possibly to the bottom of the synclinal fold. While the gold and silver values may grow less with increasing depth, recent developments in the Madonna point to a possible increase in the value for a short distance at least.

It is also probable that a greater or less degree of mineralization extends along the axis of the fold from the southwest down to the point at which mineral-bearing solutions entered the syncline. Uncertainty as to the precipitating agents prevents an unqualified prediction, but along this line the limestone may be expected to be considerably broken and hence favorable to ore deposition. It is probable that comparatively deep prospecting will be required to determine the presence or absence of ore along the fault-plane toward Boss Lake. Should ore be found at the bottom of the syncline it might be confidently

looked for toward the north where the fault-plane passes through the limestone.

Other ore shoots between the granite and "parting quartzite" on Monarch Hill and in Taylor Gulch will probably continue to a depth dependent on the degree of fracturing of the limestone.

Although large contact deposits have been mined in a number of districts, in general this type tends to be bunchy. In regard to the persistence of the contact deposits of the Monarch district, only one thing is known, namely, that the contact itself goes down. Of contact deposits Lindgren[1] says:

> Although cases may be easily conceived in which the deposits would continue in depth and length for several thousand feet it is far more common to find them irregular and spotted in their mineralization, so that while there is no genetic reason why they should not be continuous to the greatest depth attainable by mining they will as a matter of fact often give out when least expected. Owing to the irregular surface of contact the finding of the continuation of lost ore bodies is often very difficult. Slight changes of composition and texture of the rocks influence their susceptibility to contact metamorphism to a very surprising degree. Few mines on contact deposits have been worked at a greater depth than a few hundred feet. Oxidizing surface waters may greatly enrich contact deposits of poor grade by the development of oxidized ores; this especially refers to copper deposits although such oxidized ores rarely extend downward more than a few hundred feet at most and this only in very dry climates.

Nevertheless, indications at the surface and in the shallow workings of the mines of the Monarch district in which contact deposits are found, fully justify a moderate outlay in development work.

Aside from known ore bodies, the possibilities of discovery in the district are not exhausted. Although blind leads have not been encountered, and may never be found in the region, there are a number of places, where talus or glacial material overlies the bed-rock, that should be prospected. Wherever faulting or extreme folding may be present in the limestone below and immediately above the quartzite or in the vicinity of porphyry dikes, there is a possibility of finding ore. The fold (or possible fault) southwestward from the Clinton mine would appear to be a favorable location. (See Fig. 1.) A shaft through the glacial debris into the limestone, and a few crosscuts in addition, would cost a comparatively small amount. Although there

[1]Lindgren, Waldemar, Ore Deposits and Deep Mining, Economic Geology, Vol. I, p. 37.

may be no ore here, the structural features and the position between the Lilly and Clinton ore bodies offer encouragement.

DESCRIPTION OF MINES

Many of the mines which formerly were producers have been idle for a number of years. The ore bodies and stopes of these were inaccessible during the summer of 1909 because of their caved condition or bad air, or both. This statement also applies to the earlier workings of all the large mines operating at the present time. Because of the heavy rains which shortened the field season the mines of Middle Fork were not visited, and hence must be omitted from the present description.

A few mines have been worked through vertical shafts, a number through inclines, but by far the greatest part of the ore mined has been hauled out through tunnels.

The ground water level has probably not yet been reached in any of the mines, except on Taylor Mountain, and it is said that there has never been a pump in the district. Surface water from the melting snow which continues late into the summer is in many cases a detriment in that it gives to the ore of the more open ground a high moisture content.

No timbering is required in many cases where the tunnels pass through barren rock, but the walls are not self-supporting adjacent to the ore bodies. Here square sets are generally used both in the drifts and in the larger stopes. A few of the smaller stopes are stulled but many of the larger ones are several sets high and many sets wide.

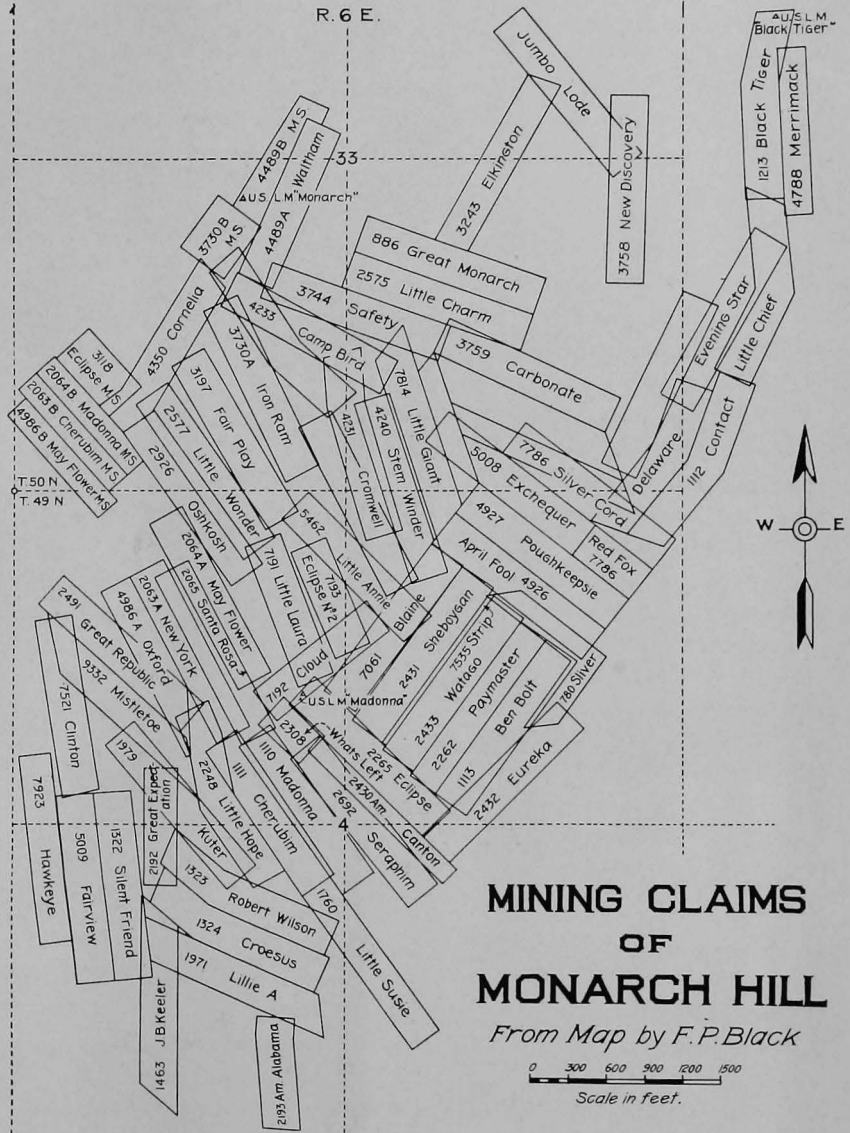
For convenience the mines will be considered in groups of the following localities: Monarch Hill, Taylor Gulch, Cree Camp, and Columbus and Kangaroo gulches with Hoffman Park.

MINES OF MONARCH HILL

The mines on Monarch Hill which were producing ore in the summer of 1909 are the Madonna, Silent Friend-Fairview, Wilson, Little Wonder and Great Monarch. Of these only the Madonna was shipping daily. Late in the year the Eclipse was leased by the Giant-Eclipse Mining Company, and shipping from this mine began in December.

Madonna mine.—Soon after the discovery of the Madonna mine by Smith and Gray it was sold to a company of New York and Iowa men who erected a small smelter at the foot of the hill for the purpose of smelting the ores from their mine. Be-

COLORADO GEOLOGICAL SURVEY BULLETIN 1 PLATE IV



cause of the lack of siliceous ores that were needed to flux the basic Madonna ores, in addition to the high cost of coke which had to be hauled twenty miles by wagon, the smelter was not a success. The ore which the Madonna was then producing was of too low grade to pay for the necessarily long haul to the railway at Maysville, and consequently the output was comparatively small before the mine was purchased by Mr. Eilers and his associates in 1883. From that time, the mine was worked under the management of Mr. Eilers, by the Colorado Smelting Company which included the former operators.

From 1883 to 1894 production was continuous. Since 1894 the mine has been closed for short intervals, but ore has been produced every year. Various leasers have operated the mine for nearly fifteen years. Since 1908 it has been operated by the Monarch-Madonna Mining Company under the management of Mr. K. E. Burton.

Mr. Eilers has kindly prepared a table taken from the books of the Colorado Smelting Company, and showing the output of the Madonna by years. On page 47 this table is given with modifications. Short tons are substituted for pounds given in Mr. Eilers' table, and gross values take the place of net proceeds. The percentage of lead and zinc, and the ounces per ton of gold and silver are based on net weight, that is, the gross weight less moisture. The average commercial value in New York, for each year is given for silver, lead, copper, and zinc. The coinage value of gold is given.

The Madonna has been worked through six adits (Nos. 0 to 5, Pl. V). The vertical distance from the surface above Zero level to the bottom of a winze sunk 250 feet below No. 5 level, is 1,070 feet. A seventh adit (No. 6), 450 feet below No. 5, has been driven about 1,500 feet to the limestone-granite contact where ore was recently encountered. During the summer of 1909 ore was shipped daily from No. 4 and No. 5 levels, part of which was hoisted through the winze below No. 5. At the time of writing several carloads have been taken from No. 6.

The mine is equipped with electric lights, electric hoist, and an electric drill which is used only in development work. The ore from the higher levels is lowered to the railroad over a gravity tramway. It is proposed to build a spur from the railroad to the portal of No. 6 tunnel.

The largest shoot of the Madonna mine lies in and near the Madonna fault-fissure, but other payable ore bodies occur be-

PLAN OF MADONNA MINE

PRODUCTION OF THE MADONNA MINE

Year	Gross Weight Short Tons	Per Cent. Moisture	GOLD			SILVER			LEAD			COPPER		ZINC			GROSS VALUE
			Fine Ounces	Ozs. Per Ton	Value	Fine Ounces	Ozs. Per Ton	Value	Pounds	Per Cent.	Value	Lbs.	Value	Pounds	Per Cent.	Value	
1883 Incl. Jan '84	8,160	13.70	.....	.....	.....	44,117.87	6.26	$ 48,970.84	4,242,944	30.13	$ 182,022.30	.....	.....	.....	.....	.....	$ 230,993.14
1884	18,822	13.52	.....	.....	.....	97,252.11	5.97	108,241.60	10,195,244	31.32	380,282.60	.....	.....	.....	.....	.....	488,524.20
1885	34,307	14.69	.....	.....	.....	192,390.15	6.57	204,895.51	18,114,934	30.95	715,539.89	.....	.....	.....	.....	.....	920,435.40
1886	29,399	15.83	.....	.....	.....	141,759.33	5.73	141,759.33	12,222,086	24.69	565,882.58	.....	.....	.....	.....	.....	707,641.91
1887	23,130	14.81	.....	.....	.....	115,434.05	5.86	113,125.37	8,884,761	22.54	397,148.82	.....	.....	.....	.....	.....	510,274.19
1888	15,367	12.75	.....	.....	.....	94,232.22	7.03	88,578.29	7,187,383	26.81	316,963.59	.....	.....	.....	.....	.....	405,541.88
1889	17,946	12.91	.....	.....	.....	86,118.66	5.50	80,607.07	4,910,366	15.67	186,839.43	.....	.....	.....	.....	.....	267,446.50
1890	9,397	12.97	.....	.....	.....	40,427.47	4.95	42,287.13	2,285,544	14.00	99,078.33	.....	.....	.....	.....	.....	141,365.46
1891	6,660	12.25	.....	.....	.....	24,528.40	4.20	24,234.06	1,096,115	9.38	47,406.97	.....	.....	.....	.....	.....	71,641.03
1892	6,615	11.20	12.498	.....	$ 258.33	30,482.48	5.19	26,672.17	1,031,959	8.80	41,794.34	.....	.....	.....	.....	.....	68,724.84
1893	6,776	12.70	1.710	.....	35.35	38,393.63	6.50	30,023.82	1,812,897	15.30	65,445.58	.....	.....	.....	.....	.....	95,504.75
1894	5,165	14.30	.....	.....	.....	17,854.26	4.00	11,248.18	1,031,098	11.60	32,170.26	.....	.....	.....	.....	.....	43,418.44
1895	299	14.80	.....	.....	.....	1,341.99	5.30	876.32	110,212	21.70	3,559.85	.....	.....	.....	.....	.....	4,436.17
1896	2,392	16.20	.....	.....	.....	5,321.31	2.60	3,570.60	147,801	3.68	3,369.86	.....	.....	.....	.....	.....	6,940.46
1897	2,500	14.80	43.144	.....	891.79	5,311.50	2.50	3,176.28	238,595	5.60	8,541.70	.....	.....	.....	.....	.....	12,609.77
1898	571	14.10	.....	.....	.....	3,254.62	6.60	1,896.14	263,938	26.90	9,976.85	.....	.....	.....	.....	.....	11,872.99
1899	133	11.10	.....	.....	.....	535.09	4.60	318.80	67,094	28.40	2,999.10	.....	.....	.....	.....	.....	3,317.90
*1900	587	12.60	8.078	.....	166.97	4,401.09	8.60	2,702.71	255,908	24.90	11,183.18	.....	.....	.....	.....	.....	14,052.86
†1900	393	14.44	22.809	.068	471.46	2,406.19	7.16	1,477.64	137,378	20.40	6,003.42	2,546	$ 412.20	.....	.....	.....	8,364.72
1901	696	14.75	14.435	.024	298.37	5,018.33	8.52	2,958.30	132,662	11.30	5,744.26	40,242	6,482.99	.....	.....	.....	15,483.92
1902	1,383	13.20	86.169	.071	1,781.11	10,450.12	8.70	5,450.78	161,057	6.70	6,553.41	46,918	5,454.69	.....	.....	.....	19,239.99
1903	5,519	15.60	509.826	.109	10,538.00	25,326.97	5.44	13,676.56	93,833	1.00	3,975.70	6,213	822.29	.....	.....	.....	29,012.55
1904	1,610	14.37	31.357	.023	648.15	6,673.84	4.84	3,857.48	246,464	8.90	10,735.97	.....	.....	.....	.....	.....	15,241.60
1905	2,050	18.18	33.081	.020	683.78	14,533.48	8.64	8,865.42	827,443	24.59	38,666.41	.....	.....	.....	.....	.....	48,215.61
1906	3,235	15.05	368.124	.133	7,609.12	26,940.08	9.80	18,211.49	359,402	6.54	20,485.91	.....	.....	.....	.....	.....	} 81,242.10
1906	923	10.30												563,659	34.04	$ 34,935.58	
1907	500	12.80	23.360	.053	482.85	2,105.61	4.81	1,389.70	127,462	14.60	6,908.44	.....	.....				} 170,569.94
1907	4,885	9.80												2,713,669	30.78	161,788.95	
1908	1,057	13.60	13.996	.015	289.30	4,049.49	4.44	2,146.23	183,543	10.05	8,619.66	.....	.....				} 39,269.60
1908	1,013	13.90							21,687					597,004	34.20	28,214.41	
1909	3,979	16.40	290.367	.087	6,001.88	22,056.30	6.63	11,358.99	451,080	6.78	22,447.13	.....	.....				} 104,162.02
1909	1,997	11.48							74,614	2.10				1,149,179	32.57	64,354.02	
	217,476		1,458.954		$30,156.46	1,062,716.64		$1,002,576.81	76,915,504		$3,200,345.54	95,919	$13,172.17	5,023,511		$289,292.96	$4,535,543.94

* To September.
† October to December.

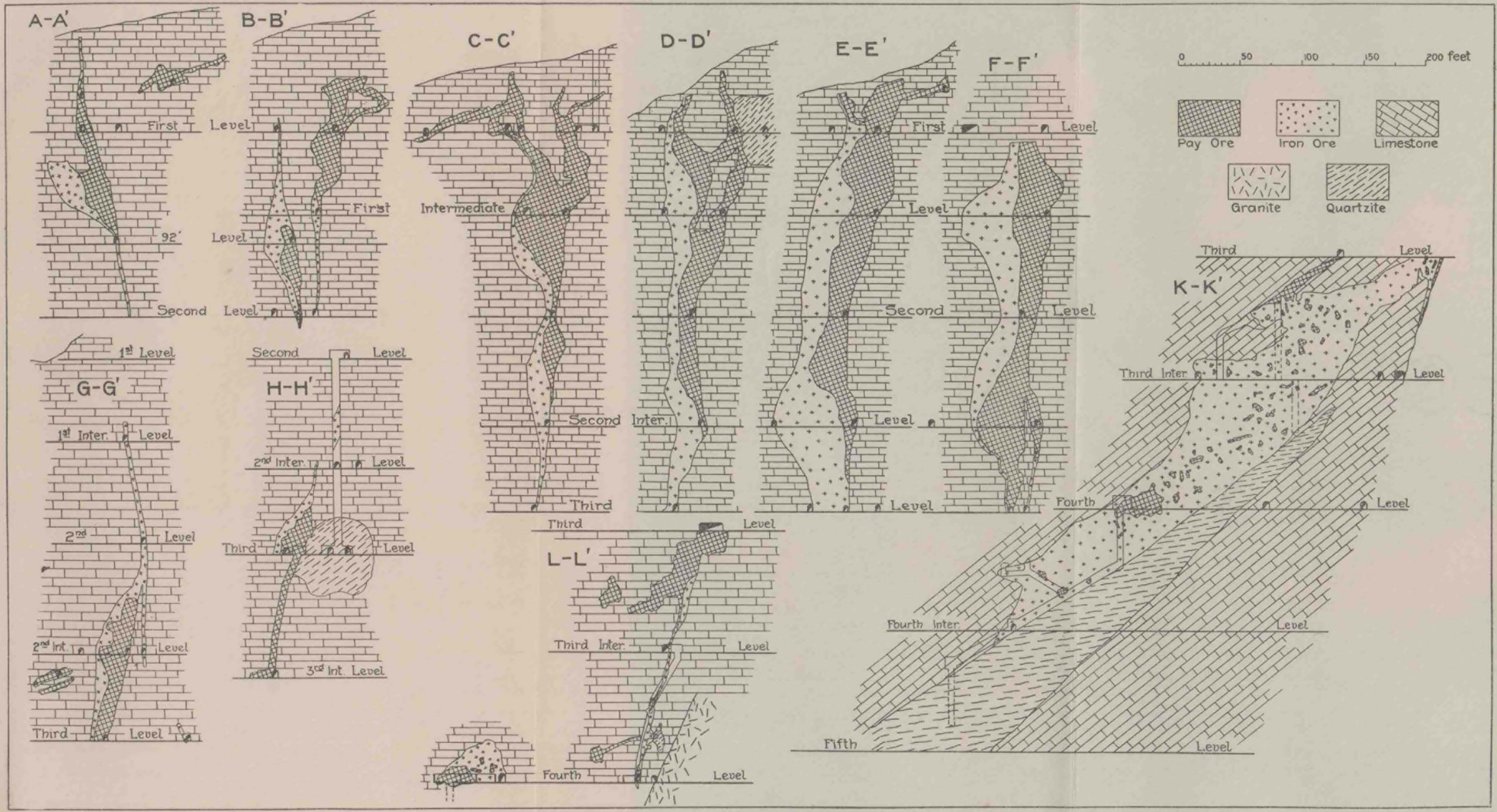
tween this and the Mayflower fault. Many branches extend from the main shoot into the limestone on each side. These branches are said to follow the stratification planes on the southwest, but they are more irregular in the broken ground on the northeast side. Plate VI shows the broken character of the rock by the position of detached masses of quartzite surrounded by ore, and also the size and position of the largest ore body.

The main shoot kept its course in the fault-fissure down to No. 4 level at a nearly constant distance above the granite, but on No. 5 level it was nearer the granite. Below this point it extends out into the limestone toward the northeast and divides into several branches. The stope on the 150-foot level (below No. 5) was 45 feet high and 40 feet wide when visited. This is not far below the quartzite. Only one branch of the ore body had been opened on the level at the bottom of the winze, and was about 6 feet thick by 25 feet wide. The ore grades into the limestone without well defined walls, and is limonite and lead carbonate with some galena, all of which carry values in gold and silver. At the lowest point reached a small amount of pyrite was enclosed by limonite.

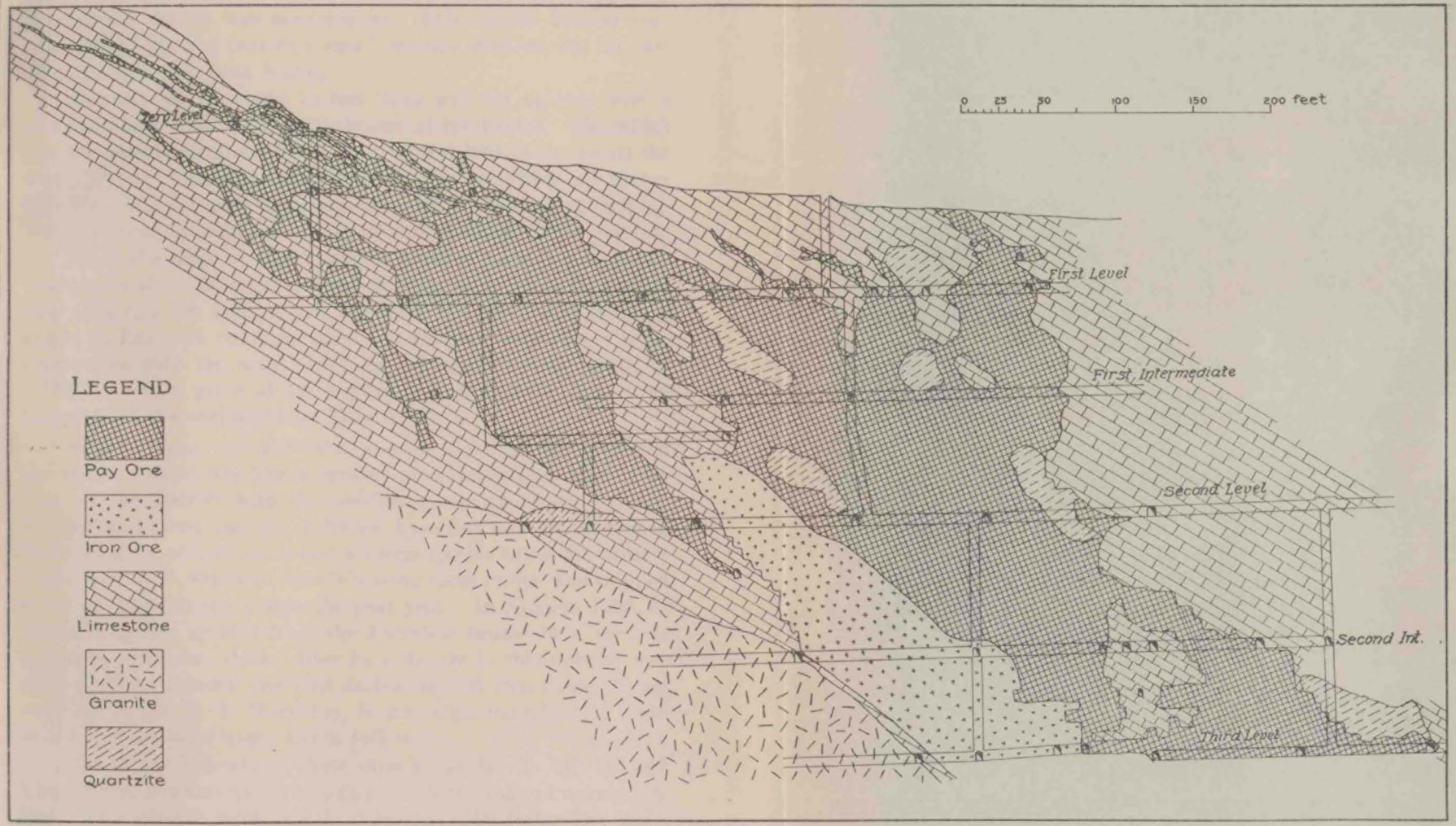
The zinc produced in 1909 came largely from No. 4. No zinc ore has been found below No. 5. The ore, which runs 30 to 42 per cent in carload lots, is in the form of carbonate and silicate. It is comparatively soft, and most of it can be broken with picks. The zinc ore which is on the foot-wall of the main shoot, extends upward several hundred feet. Zinc minerals on the highest dumps indicate that the ore may extend nearly to the surface. The largest stope in this ore is 11 sets (61 feet) wide by 13 sets long. It holds this size upward four or five sets, but grows smaller above.

In addition to the zinc the main shoot carries lead and silver, but not much gold on No. 4 level. The stope is 20 to 60 feet wide by 170 feet long. A lens nearly parallel to the largest shoot, which may be a branch, carries .04 to .25 oz. gold and 5 to 6 oz. silver per ton, and 2 per cent lead on No. 4. The ore increases in value downward. Ore on the level at the bottom of the winze below No. 5, averages .43 oz. gold and 31 oz. silver per ton, and 30 per cent lead. The quantity of iron decreases with depth.

Some distance northeast of the largest ore body on No. 5, near the Mayflower fault, a copper ore shoot was encountered. The ore is immediately above the granite in the limestone which



CROSS SECTIONS OF THE MADONNA ORE BODIES



VERTICAL PLAN OF THE MADONNA MINE ABOVE THE THIRD LEVEL

has an unusually high dip at this point. The shoot is 3 to 6 feet thick by 60 to 70 feet wide and about 150 feet long.

The ore bodies on the highest levels are now inaccessible, but plates VI and VII show their size and relationships.

In August, 1909, No. 6 tunnel had been driven to a point a few feet below the quartzite where a considerable body of coarsely crystallized calcite was encountered. This calcite showed considerable pyrite and carried a small amount of silver, but no payable ore had then been found.

Recently an ore shoot 12 feet thick was cut on this level a short distance southwest of the breast of the tunnel. The width has not been determined but a drift 60 feet long is in ore all the way. The ore lies on the granite at the contact which has a very high dip. Six carloads have been shipped at the time of writing. The first four averaged .51 oz. gold and 28.40 oz. silver per ton.

Since the hade of the Madonna fault is unknown it is impossible to state its exact position at this level. But it is probable that this ore body is not far from the fault, and is hence nearly in line with the main shoot. If this ore body proves to be continuous with the main shoot, by taking a vertical depth of 1,520 feet and a pitch of 35° a pitch length of 2,650 feet is obtained from the surface above Zero to No. 6.

Silent Friend and Fairview mines.—Next to the Madonna the Silent Friend has had a greater production than any other mine in the district with the possible exception of the Eclipse. The Silent Friend and the Fairview have not been worked on a large scale for several years and we were unable to see the largest stopes. Mr. J. F. Sundbye, who is leasing these mines, has shipped a few carloads of ore within the past year. In August, 1909, he was driving an upraise from the Fairview tunnel in a vertical vein about two feet thick. Over half the ore in this upraise was galena, the remainder was lead carbonate and iron oxide. I am indebted to Mr. D. F. Hamilton, former superintendent of these mines, for the brief notes which follow.

The Silent Friend ore shoot dips about 45° N. 34° W. and was worked continuously through a vertical range of nearly 700 feet. This gives a pitch length of nearly 1,000 feet. The shoot was 15 to 50 feet thick and was square set throughout the entire distance through which it was worked. The shoot, following a somewhat spiral course, was in part close to the granite but ran out into the limestone 40 to 60 feet in places. It was thinnest when dipping toward the granite. The best ore was galena which

carried 20 oz. silver per ton and about 70 per cent lead. When the ore was near the granite it carried a small quantity of gold.

Hawkeye mine.—This mine is a recent producer and although idle at present all the workings except the winzes may be readily examined. The main tunnel was driven about S. 45° E. 550 feet in granite to the limestone-granite contact and thence along the contact 300 feet, bearing S. 20° to 25° W. the greater part of the distance. Along the contact the granite forms the hanging wall, the plane of contact dipping northwestward 40° to 60°. Near the breast of the tunnel an ore shoot was encountered which has been worked upward nearly 200 feet along the pitch and also some distance below the tunnel level. The ore body removed would average perhaps 6 to 8 feet each way in cross-section. Granite forms the hanging wall which dips northwesterly 25° to 40°.

Five hundred seventy feet from the tunnel entrance a cross-cut was driven through the limestone to the east limb of the synclinal fold where it cut an ore shoot lying on the granite foot-wall which dips northwestward 28° to 40°. A winze has been sunk a short distance and the ore has been stoped out above the tunnel level for 166 feet along the pitch. The ore body was largest a short distance above the tunnel level with a maximum width of 66 feet. The stulls here are 4 to 9 feet long with an average of perhaps 6 feet. Through the last 70 feet of the stope the stulls will average about 7 feet in length, while the stope is about 10 feet wide. The ore pinches to 4 or 5 feet in width at the extreme upper end.

When considered with reference to the ore bodies of the district as a whole, this increase in size with increasing depth is encouraging even though it may be local. Had this shoot been worked from higher levels by underneath stoping and by timid operators, in all probability it would have been abandoned at about 160 feet or more above the level of the Hawkeye tunnel. In this connection it is significant that previous to the discovery of ore in Madonna No. 6 tunnel, the greatest depth reached on any ore shoot immediately overlying the granite was in the Hawkeye.

The mine is equipped with electric lights and electric hoist and fan.

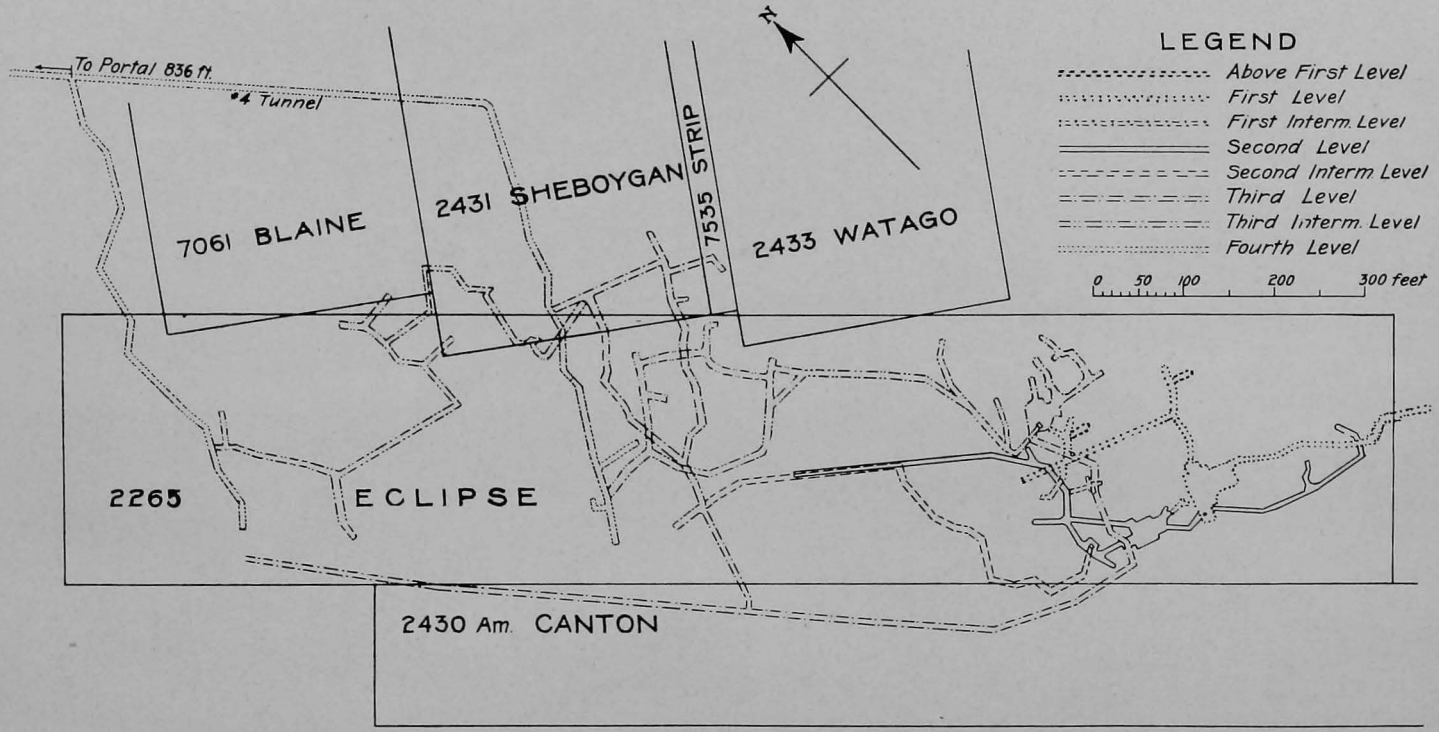
Eclipse mine.—Although but a small part of the lower workings of the Eclipse was accessible in 1909 a good idea of the geological conditions may be had from examination of the hori-

zontal and vertical plans (Plates VIII and IX). The ore is found in two distinct shoots—one lying on the granite, the other just below the quartzite. The granite shoot extends below the fourth level while the quartzite shoot was lost several hundred feet above. At this point a thrust fault hading S. 58° W. brings the ore up against the end of the quartzite stratum which forms the footwall on the northeast. In this fault-fissure the ore was galena with lead carbonate. Several pieces of solid galena four to five inches in diameter may still be seen. A few feet below in the same stratigraphic position is a large body of limonite reported to carry a small amount of silver and gold but of too low grade for shipping. No effort has been made to determine whether or not the ore body continues below the quartzite northeast of the fault.

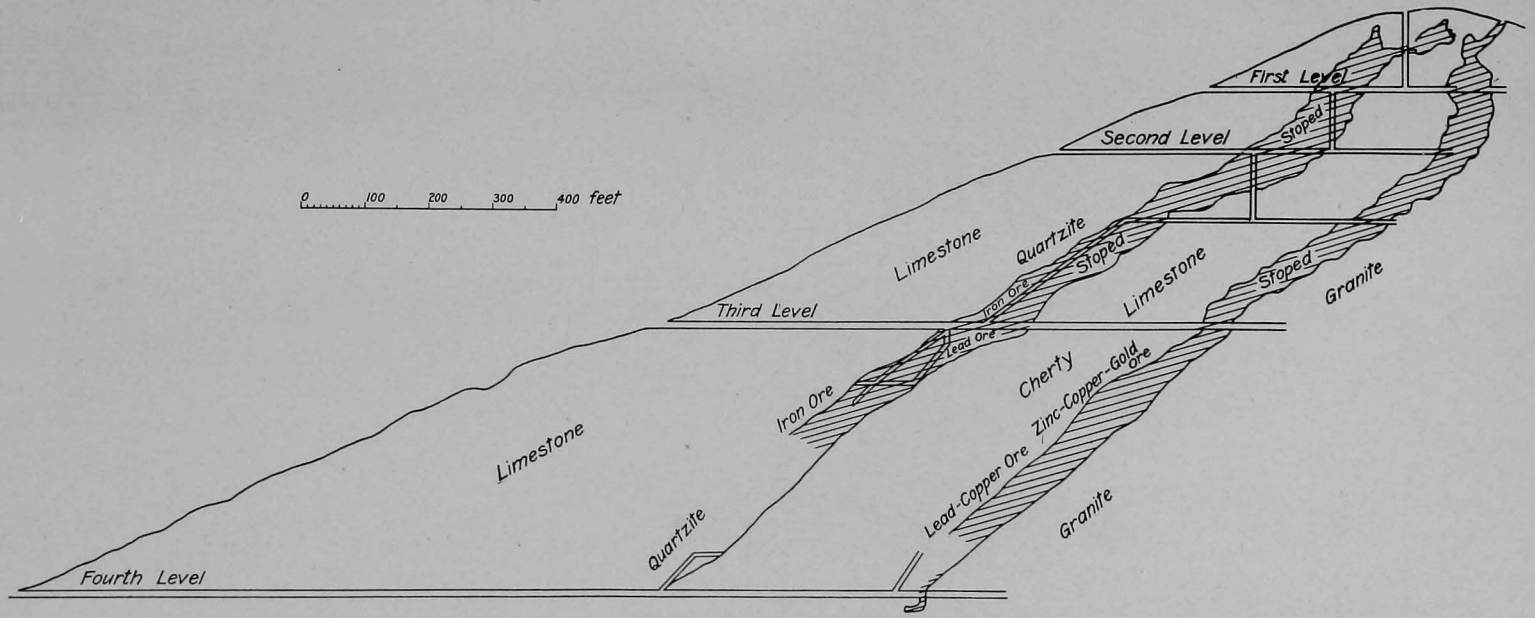
It is not clear whether the faulting at this point occurred before or after the ore deposition. Indications point to the former, but the evidence noted was insufficient to justify a conclusion. A short distance southeastward higher up in the stope, grooves on the hanging wall indicate that the faulting has been at least in part comparatively recent.

Mr. J. L. Farrell, former superintendent for the Company, gives the following information concerning the mine. The quartzite shoot, discovered at the surface, was cut successively by Nos. 1, 2, and 3 levels. On No. 2 level there were 110 square sets (4x5 ft.) on the sill floor in the quartzite shoot, and the size of the ore body remained practically the same up to No. 1. The shoot grew narrower below No. 2 where it formed a stull stope 5 to 12 feet thick from No. 2 to No. 2 intermediate. Below this the ore was somewhat bunchy. The granite shoot was cut successively by levels Nos. 2, 3, and 4. The thickest part of this shoot was encountered on No. 3 level where it was about 25 feet thick by 80 feet wide. Both shoots bear slightly to the right of the dip as they descend.

The bulk of the ores shipped carried their chief values in lead and silver. Before 1893 the shipments carried 25 to 50 per cent lead, but later, ore was shipped which carried only 5 per cent lead. About half the lead content was in the carbonate form, the remainder was sulphide. In general, the higher the lead content, the greater were the silver values. The highest silver returns in a carload lot were 28 oz. per ton. The silver averaged about 8 oz. per ton. The ore shipped since 1893 has carried a small amount of gold.



HORIZONTAL PLAN OF THE ECLIPSE MINE



VERTICAL PLAN OF THE ECLIPSE MINE

A considerable body of zinc carbonate and zinc silicate was found above the silver-lead ores in the granite shoot from No. 2 intermediate to No. 4 level. This ore carried silver values and was sometimes mixed with the lead ores in such proportion that the zinc content was kept below the 10 per cent limit fixed by the smelter. Excepting a few cars shipped recently the zinc ore was never sold as such by the company, but in 1905-6 the Paul brothers, who were working the mine under lease, shipped considerable zinc ore. A small amount of copper ore occurs in the granite shoot also, but no zinc or copper was found in the quartzite shoot.

Recently this mine has been leased by the Giant-Eclipse Mining Company, the old levels and stopes are being cleaned out and several carloads of ore have been shipped. There is a large amount of low grade zinc ore in sight.

No record of tonnage or gross values has been preserved by the Eclipse Company. But Mr. W. K. Spinney has kindly given the figures for the net receipts (gross value less freight and treatment charges) by years from 1887 to 1907, and Mr. Clyde H. Jay of the leasing Company, has furnished the smelter settlement sheets from December, 1909 to February 7, 1910. Some ore is reported to have been shipped before the mine was purchased by the company but no records are available. The net receipts since the purchase in 1887 have been $581,811.79.

Fairplay mine.—This mine was located in 1878 by the Boone brothers and is reported to have shipped a considerable tonnage in the eighties. No figures are available for that period. Since the present owners have operated it the production has been 728 tons with a gross value of $14,974.00. It has been closed since 1908 and hence was not examined in the present survey.

Great Monarch mine.—The Great Monarch vein outcropped in a conspicuous fissure in a limestone cliff, and has been developed through a shaft and adit to a depth of perhaps 200 feet. Mr. Thomas Penrose states that the shoot was 8 to 10 feet wide for the first 30 feet, but narrowed to 2 inches for the next 60 feet. Below the adit level a winze was sunk 60 feet on the shoot which remained rather narrow but did not pinch out. The ore was galena and lead carbonate carrying about 200 oz. silver per ton. Within the past few years several carloads of zinc ore have been shipped from near the surface.

A tunnel has been driven some 1,200 feet just above the creek level on this property, but has not yet cut any payable ore bodies.

Little Charm mine.—This mine is on the same lead as the Great Monarch and has been worked partly through the discovery shaft and partly through the Great Monarch adit. The ores of this mine were similar to those of the Great Monarch but ran somewhat higher in silver. According to Mr. Penrose both silver chloride and stephanite were present.

The Little Charm claims the record for high grade ore in a carload lot (10 tons). Mr. J. Scott Boyd, General Manager of the Monarch Pool Mining Co., gives the following as the smelter returns from this car: 0.48 oz. gold and 226.2 oz. silver per ton, 2.45 per cent lead, 7.65 per cent zinc and 0.15 per cent copper.

Little Wonder mine.—This mine has produced several carloads of ore from near the surface but the ores are pockety like those of other mines which have not yet been developed below the quartzite. In 1909 several tons of galena were taken from a pocket within 20 feet of the surface.

Wilson mine.—This mine has been developed through two tunnels on the Wilson and Kuter claims. In the summer of 1909 leasers were shipping from the lower tunnel a few carloads of zinc-lead ore which had been left on the hanging wall when the mine was formerly producing. The total thickness of the vein, where seen, was five to six feet. All but about two feet from the upper part had been removed several years ago.

Evening Star mine.—The Evening Star ore shoot was discovered on the Little Chief claim from which it was worked through an inclined shaft sunk on the ore body. The Evening Star tunnel, driven later, along the contact, crossed the old workings about 70 feet above the end of the incline, but no ore has been taken from the tunnel. At the tunnel level the ore body was nearly two feet thick with a stope length of 12 or 13 feet. A little galena, in rotten granite, can be seen on the foot wall. Below this point the shoot is reported to narrow north and south and thicken at right angles to this direction.

It is possible to descend 120 feet or more from the collar of the incline at the present time. As a rule the ore lay close to the granite, but in the limestone. Some galena and limonite can still be seen in the limestone walls as a replacement. At 120 feet below the surface the stope length is 50 feet or more. The thickness is much greater than that at the tunnel level below.

Mr. William Miller, one of the owners, states that low grade zinc ores extended from 40 to 130 feet below the surface but not at greater depth. He reports a total output of 600 tons which averaged $20.00 a ton. The principal values were in silver and lead; two cars yielded 90 cents a ton in gold.

Delaware mine.—This mine was also worked through an inclined shaft which is now caved. Mr. Miller reports output and values approximately the same as those of the Evening Star. At the bottom of the shaft oxide of manganese was encountered, but carried no values.

Black Tiger mine.—This mine is reported to have produced 8 or 10 carloads of lead-silver ore in 1881. Judging from the workings, which were in part accessible in 1909, the main shoot was 3 or 4 feet thick at the tunnel level and had a stope length of 9 feet. The ore lay in limestone about 3 feet from the granite. The croppings show quartz and a little iron stain and galena.

Other mines.—The April Fool, Ben Bolt, Elkington, Paymaster, and Oshkosh have produced more or less ore, but all were idle in August, 1909, and the ore bodies were inaccessible. Several of these have had an output greater than a few that have been briefly described.

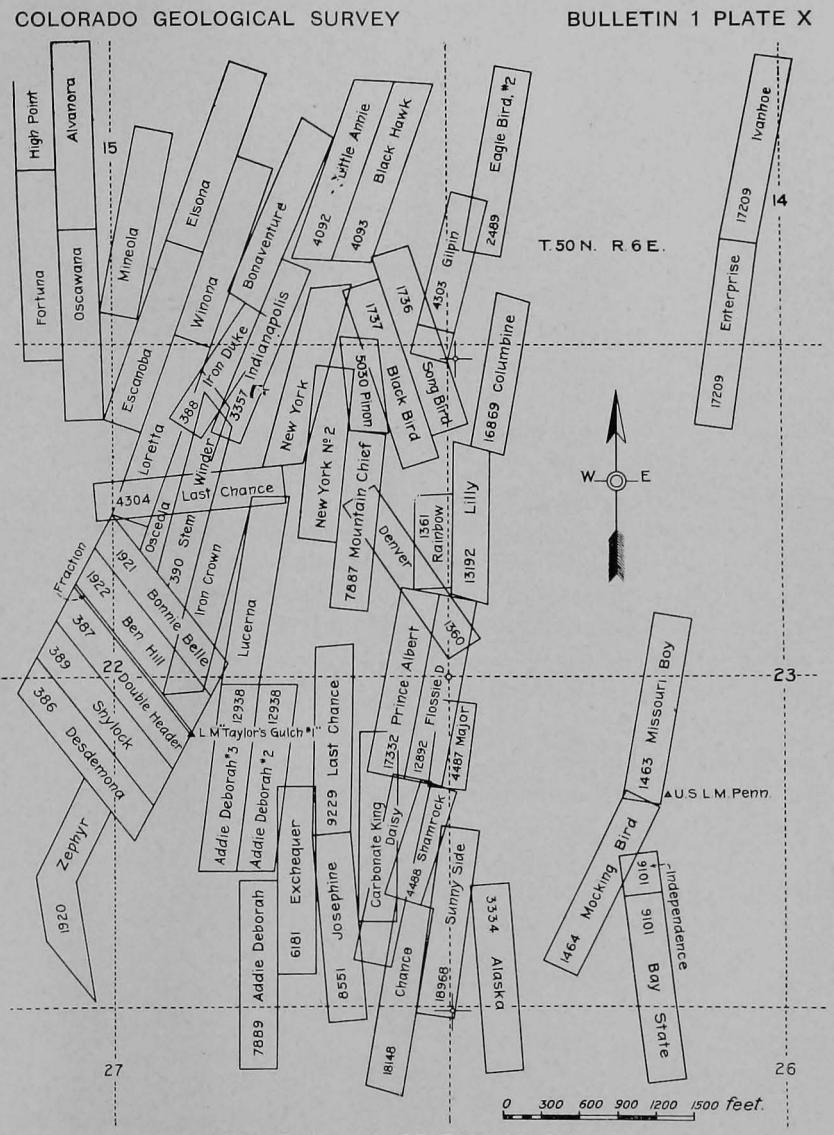
The Ingersoll mine south of Garfield is reported to have produced a carload of ore. Several tons of ore, galena with some iron oxide, lay in the shaft house in 1909.

The Thirty-Six-Thirty mine southeast of the Ingersoll is reported to have produced considerable ore many years ago. Much prospecting has been done in the vicinity, but no other pay ore has been found.

MINES OF TAYLOR GULCH

The Lilly is the only mine in Taylor Gulch which has been producing steadily for a number of years. In the summer of 1909 a few small shipments of high grade ore were made from the Rainbow-Eagle Bird. At the time of our visit to the Last Chance mine several tons of ore were sacked and shipments have since been reported. The Jewell Tunnel & Mining Company in August, 1909, resumed work in the Jewell tunnel which is being driven to develop that part of the field west of the gulch.

Lilly mine.—This mine, which is owned by the Taylor Mountain Mining Company, is now worked through a tunnel, 2,530 feet long. A few hundred feet from the breast a winze has been sunk 200 feet or more. The tunnel begins just west of the "parting quartzite", crosscuts the sedimentary beds to the granite



MINING CLAIMS OF TAYLOR GULCH

Patented claims from map by F. P. Black. Data for unpatented claims furnished by M. R. Jewell.

contact, and continues north in the limestone but a few feet from the granite. For nearly the entire distance along the contact the tunnel follows a streak of limonite connecting several bunches and shoots of ore which have a maximum width of 8 or 10 feet on the tunnel level. The thickness is much greater. The best ore bodies on this level are of copper, but workable silver-lead and silver-iron ores have been encountered (Pl. XI). The largest stope on the tunnel level is 35 feet high by 100 feet long. Several stringers lead out into the limestone but have never been followed. A few bunches of ore have been stoped out on the first and second levels below the main tunnel. Foreman Frank Hunter reports the ore on the first level to have carried about 10 per cent copper and 3 to 6 oz. silver per ton. In a letter dated Feb. 24th, Superintendent Geo. H. Purmort states that developments between the 100- and 200-foot levels show that the shoot dips farther out into the limestone and that sulphides are present carrying about 15 per cent copper, 6 to 40 oz. silver and $1.00 to $3.50 gold.

From the surface down to the 230-foot level most of the ore taken from the mine was hoisted through the discovery shaft. At present considerable ore is being taken from this level which is now connected with the main tunnel 138 feet below. Large bodies of ore are reported in the old upper workings but cannot be recovered because of bad ground and rotten timbers.

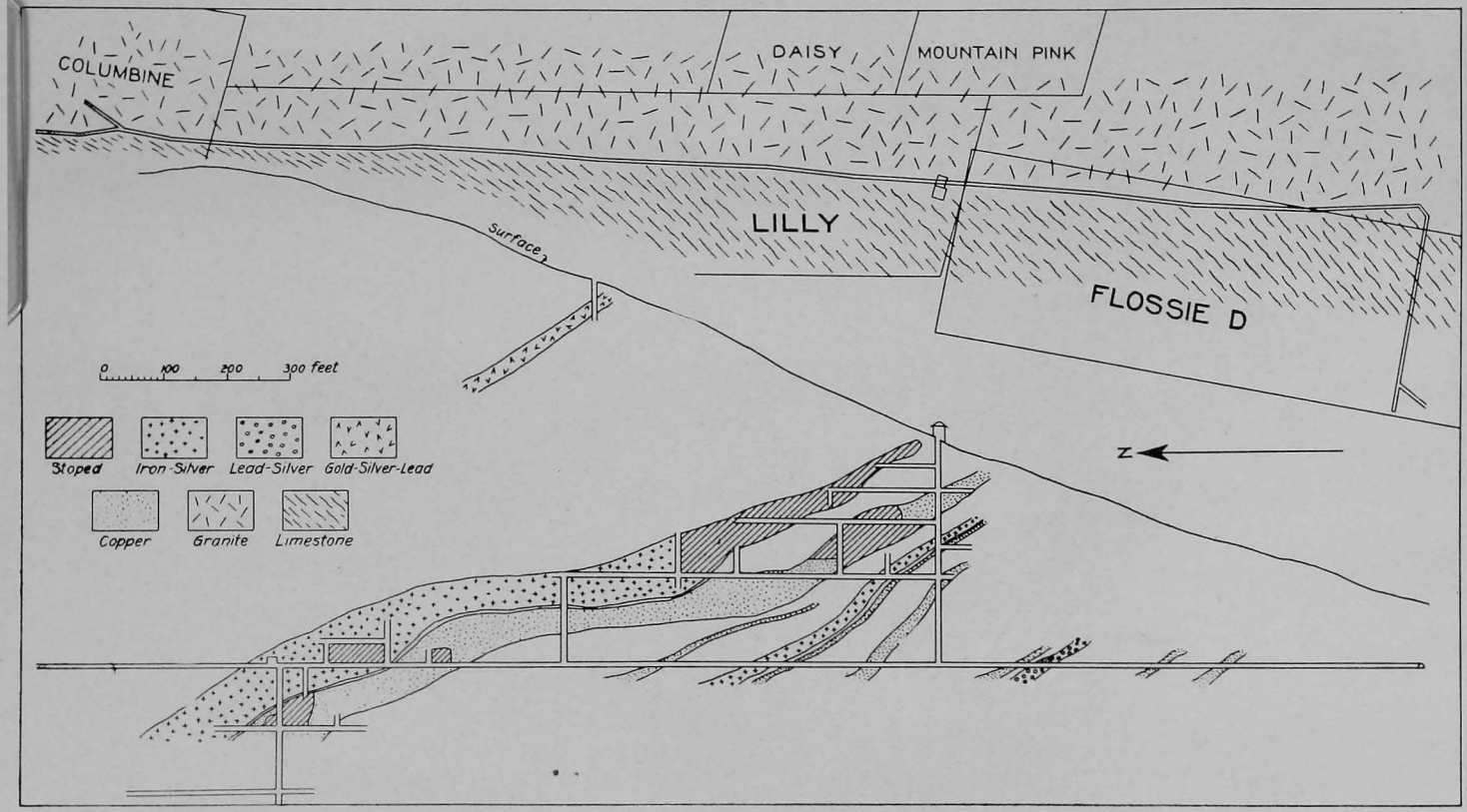
The ores are chiefly carbonates and oxides with some chrysocolla and considerable sulphide. The sulphides, which are chalcopyrite and copper-bearing pyrite have been found below the tunnel level and in smaller quantity nearer the surface. They are found associated with oxidized ores. Much of the chrysocolla is very pure but is usually in thin seams. In at least one instance it occurs as a coating an inch thick or more on the walls of a small cave or fissure in the limestone. The copper ores are partly in limonite gangue, partly disseminated through limonite which also carries silver. About half the ore carries a small amount of gold.

Through the courtesy of President W. F. Norway we are able to give the following figures from the smelter settlement sheets showing the output of the mine from March 17, 1906, to January 18, 1910:

Output, 4,991.65 tons.

Copper, 757,163 lbs. wet assay.

Silver, 17,743.13 oz.



HORIZONTAL AND VERTICAL PLANS OF THE LILLY MINE

Lead, 4,637 lbs.
Gold, 67.44 oz.
Gross value, $103,111.20.
Average value per ton, $20.66.
Output from 1888 to Jan. 18, 1910:
Total tons produced, 8,827.15.
Gross value, $173,898.71.
Average value per ton, $19.70.

About two-thirds of the ore has carried an average of 10 per cent copper. The remaining one-third was silver ore which carried very little copper. Until the end of 1907 the ore carried 30 to 40 per cent excess iron. In 1909 the mine produced 1,832 tons with a gross value of $26,121.34. This is the largest output for any one year in the history of the mine.

As a rule quartzite lies against the granite wall wherever ore occurs and varies in thickness from a few inches to perhaps six feet. It may be continuous but there are no crosscuts to it from the tunnel where ore is not found. A narrow porphyry dike follows the contact more or less continuously, sometimes in the limestone, sometimes in the granite. The limestone is considerably broken, movement having taken place in practically every direction as shown by the slickensiding.

The mine is equipped with motor, compressor to operate the machine drills, an electric fan for ventilation, electric lights, and at the shaft an electric hoist. The ore is carried by gravity over an aerial tramway 7,174 feet long to the railroad at Garfield.

Rainbow-Eagle Bird mine.—Although very little work has been done on this property it is reported to have produced about $15,000-worth of ore. It is worked through two short tunnels near the surface. The ore occurs in a brown, ferriferous, crystalline dolomite overlying the "parting quartzite" and within 8 to 30 feet of an overlying porphyry dike or sheet which dips westward. It is a contact deposit replacing the dolomite. The best ore body seen by the writer was 18 inches to 2 feet thick in a vein parallel to the bedding of the sedimentary rocks. Mineralization has extended a foot or more into the enclosing rock on each side of the good ore. Two samples of the dolomite taken from the dump and assayed in the laboratory of the State Survey carried 4.25 oz. silver and a trace.

Although lead is present in considerable quantity the chief values of the ore are in gold and silver. The lead occurs largely as galena. Some of the best silver values are carried by a streak

of manganese oxides which extends throughout the length of the tunnel, 8 to 30 feet below the porphyry dike. The principal manganese mineral is psilomelane. Some quartz is present as a gangue mineral.

Very high values are reported from this mine and a few samples assayed by Mr. Butters, gave the following results:

1. Highly manganiferous ore, silver 169.75 oz. per ton.

2. Galena with a little carbonate; lead 61 per cent, gold 0.29 oz., silver 3.50 oz. per ton.

3. Quartz with galena and lead carbonate: gold 1.81 oz., silver 16.75 oz. per ton. It is probable that these results are considerably below the average. The ore is somewhat pockety, and the mine was visited at an unfortunate time for the examination of the largest bodies.

Two shafts on the Eagle Bird claim north of the breast of the tunnels have opened a body of silver-manganese ore which has not proved sufficiently valuable to mine under present conditions. A sample taken from the dumps yielded on assay 7.50 oz. silver, 24.70 per cent manganese and 5.71 per cent iron; some silica and much lime carbonate were present. Two other samples which were not run for manganese assayed 1.75 oz. and 2.60 oz. silver.

Mountain Chief and Pinyon mines.—The Mountain Chief was one of the earliest producers, and is reported to have yielded some of the highest grade ore of the district. It is stated that the first lot was packed on burros to Garfield, thence hauled 73 miles by wagon to Canon City, and shipped by rail from Canon City to the smelter at Omaha. Notwithstanding this heavy expense it netted a large profit. Mr. E. Gimlet states that Mr. J. L. Emerson later shipped 20 tons from this property, which returned a gross value of $10,600.

When visited last summer the shaft was half filled with ice, but the tunnel below could be entered. At about 60 feet from the entrance, the tunnel was filled with waste from a crosscut in a porphyry dike which overlay the ore. Mr. Gimlet, a former superintendent at this mine, states that the ore was in a pocket and mostly within 70 feet of the surface. Its thickness at the upper part was about two inches and at greater depth was three feet. This mine and the Pinyon are reported to have produced together $150,000-worth of ore.

The Pinyon, which joins the Mountain Chief, is said to have produced $22,000-worth of ore from one pocket which pinched

out. No further work has been done. This pocket was but a few feet thick, having its greatest diameter parallel to the strike of the enclosing brown limestone. This limestone is a coarsely crystalline ferriferous rock similar in appearance to the dolomite of the Rainbow-Eagle Bird but carries little or no magnesia.

Last Chance mine.—But little work has been done on this claim. When examined a tunnel had been driven about 100 feet and several tons of ore had been taken out. The large body of limonite (gossan) at the surface, the fracturing of the sedimentary rocks and evidence of faulting, all indicate the possible presence of a workable ore body. It is reported that a tunnel to develop this property, has been started lower down on one of the Jewell claims.

Bonnie Belle, Ben Hill, Fraction, Desdemona mines.—These mines, which are on one lead, produced some ore in the 80's and but little since. Only the Fraction, the least important of the group, could be examined in 1909. This was worked through a short tunnel and a winze about 50 feet deep. A vein three feet thick was found in a short drift toward the north. This vein is parallel to the bedding of the enclosing sedimentary rocks which dip 56° N. 75° W. A bedding fault is indicated by the slickensided hanging wall. This movement probably occurred after the ore was deposited. I am indebted to Mr. Everett Anderson for the following notes on the other mines of this group.

The Ben Hill shaft is 275 feet deep. Drifts were run north and south at 125, 175, and 225 feet from the surface. At the 175-foot level a drift running northward 125 feet is the longest in the mine. At 30 feet from the shaft on this level 3 feet of galena was cut, which carried an average of 85 oz. silver per ton and 73 per cent lead. This ore was in the form of a shoot pitching northward and extending upward practically to the 125-foot level. Carbonate ore occurred on the border and in some places graded into the galena. The average tenor of the carbonate was 22 to 28 oz. silver per ton and 30 per cent lead. Between the 175- and 225-foot levels the ore was spotted. In the bottom of the shaft 7 feet of ore was struck which assayed 90 oz. silver per ton and 60 per cent lead. Water stopped the work here and a tunnel was driven to cut this lead about 400 feet below the bottom of the shaft, but at the time of writing this report no ore in payable quantity has been found in the tunnel.

The Bonnie Belle shaft is down 146 feet. At 60 feet, 6 feet of galena similar to that in the Ben Hill was discovered. With

this was associated oxide of iron which enclosed masses of galena. In places some carbonate of lead occurred with the galena. This ore was in the form of a northward pitching shoot having a stope length of 60 feet. The vertical distance covered by the ore in the shaft was 40 to 50 feet.

The Desdemona shaft is 118 feet deep. Drifts extend north and south at 60 and 100 feet from the surface. The ore was largely galena in streaks and bunches with occasional large pockets of carbonate ore.

The total output of these claims is not known, but the Ben Hill shaft has produced $12,000-worth of ore.

Ore seen on the dumps and platforms at these mines was galena with both hard and soft lead carbonate. At the Bonnie Belle there is considerable breccia having sedimentary fragments in a granite matrix, indicating the proximity of the ore to the granite. Granite dikes occur a short distance west.

Shamrock mine.—This mine has been worked through a tunnel about 900 feet long from which extend several drifts, a few upraises and winzes. Considerable ore was hoisted through a shaft before the tunnel was driven.

The limestone is much broken and apparently faulted. A porphyry dike having an easterly trend passes through the mine, and shows very abrupt changes in dip and strike. Mr. F. C. Watson, who is leasing this mine, states that he took a carload of ore, carrying 1.58 oz. gold and a few ounces of silver per ton, from a pocket just above the porphyry. The greater part of the ore which has been found in the mine was in pockets. The tunnel follows a lead several hundred feet, but the vein exposed in the roof is less than three feet wide.

The best ore found, lay near the porphyry and quartzite, and in the quartzite. Prospecting near the granite has not been profitable here. No ore was found in the caves mentioned on page 28.

Major mine.—The Major mine is operated through two shafts, one of which is about 40 feet deep. The ore is a contact deposit replacing the limestone not far from a porphyry dike which is probably the same as the dike in the Shamrock.

The ore seen by the writer lay below the dike in the limestone in a body about 5 feet thick, consisting of limonite, lead carbonate, and copper oxides and carbonate. This pocket had produced at least one carload of ore that carried 8 per cent

copper. Two carloads of copper ore are reported from the mine in addition to the copper of the lead-silver ores.

Most of the ore from the Major and Shamrock carries values in gold, silver, lead, copper, and iron. The total output of the two mines is about 1,000 tons averaging $15.00 a ton net.

Garfield mine.—This mine was closed during the summer of 1909 and the ore bodies were inaccessible. It has produced a small quantity of sulphide ore. Considerable pyrite and a little galena were seen on the dump. From the creek east of Garfield village a tunnel, through which it is proposed to work this property, has been driven over 2,200 feet along the limestone-granite contact, but the breast of the tunnel is still a considerable distance from the known ore bodies. No workable ore was found in the tunnel along the contact. However, a small amount of galena and zinc blende was discovered out in the limestone by cross-cutting.

The tunnel is equipped with electric lights, fan and machine drills.

Alaska mine.—The Alaska was worked principally from 1886 to 1888. In 1898 Harrington and Anderson shipped a little more than a carload from this mine. Mr. Anderson gives the following information:

Forty-five feet west of the granite a shaft was sunk 110 feet on an east-west streak of ore. In all, there are about 1,000 feet of drifts at 30, 60, and 100 feet below the surface. The ore was galena, hard carbonate, and oxidized iron. The carbonate ore occurred in a shoot about 10 to 18 inches thick, extending along the north-south drift 30 feet. The shoot pitched north about 3 feet for each foot of vertical descent. A few tons shipped by Harrington and Anderson ran $37.00 in gold, 14 oz. silver, 18 per cent lead and 32 per cent iron. The west wall was limestone; the east wall was gouge material which extended to the granite. The galena, which carried 20 to 25 oz. silver, 60 per cent lead and no gold, was found in pockets of oxidized iron above and below the carbonate shoot. The iron ore carried $7.00 to $11.00 in gold and about 10 oz. in silver per ton.

Missouri Boy mine.—It is reported that about $3,000.00-worth of ore was shipped from this property from shallow workings which are now caved. The deepest shaft, which is on the contact between a basic syenite dike and the pre-Cambrian granite, is reported to be 70 feet deep. The values are said to have

been in gold, silver, and lead. A few specimens on the dump show a little copper.

In 1909 Mr. T. N. Hubbard was prospecting this contact on the Mocking Bird claim south of the Missouri Boy. At the time of our visit he had found a little galena and cerussite with some pyrite, but no pay ore.

Still farther south the Bay State and Independence tunnels have cut a dike similar to, and perhaps the same as that mentioned above. Two or three tons of ore were lying on the platform at the upper tunnel which was caved when visited. The ore is galena and probably silver chloride in vein quartz.

Other mines.—Several claims in Taylor Gulch produced small amounts of ore in the early days. The Denver-Rainbow, Indianapolis, and Stem Winder have each produced a carload or more. The ore in these claims was found near the surface in pockets or narrow veins, and but little work has been done to determine the extent of mineralization.

Prospects and developments in Taylor Gulch.—A shaft was sunk on the Exchequer claim to a considerable depth in mineralized limestone in what would appear to be favorable ground, but no payable ore was found. Material on the dump indicates that a considerable body of limonite is present. A porphyry dike was cut in the shaft, and is probably the same dike as that with which the ores of the Major and Shamrock are associated.

The Jewell Tunnel & Mining Company holds a group of twenty-five claims on the west side of Taylor Gulch where several leads have been opened. For the most part the ore replaces beds of the sedimentary rocks which dip at a high angle toward the west.

No shipments have yet been made by the company, but the group of claims includes several of the old small producers mentioned above and also the Mountain Chief. A tunnel is being driven from near the head of Taylor Gulch to develop these holdings. Because of the high inclination of the strata and the depth of the tunnel level below the surface, these developments will do much toward disclosing the extent of the ore bodies. An electric machine drill has been purchased and will be installed when the tunnel is sufficiently advanced to allow the shooting of machine-drilled holes without damage to the plant.

MINES OF CREE CAMP

Song Bird mine.—Attention was first drawn to this part of the district by the discovery of rich silver ore in the Song Bird in 1878. The deposit was in the limestone above the "parting quartzite" in a zone of local faulting. Although the mine was a producer of good ore for a short time no figures are available as to output. Considerable prospecting was done in the vicinity but results were generally unsatisfactory.

Clinton mine.—The Clinton mine on the northwest slope of Missouri Hill was first opened in the early 80's, but lay idle for a number of years. During 1901 to 1904 it was operated, when, according to Mr. A. B. Brewington, it produced about $12,000-worth of ore. The values were in silver, gold, copper, and lead. The manganese content was sufficiently high to secure a reduction in treatment charges.

The ore occurs in northward dipping shoots in the limestone 6 or 8 feet from the granite. One shoot carried ore practically from the surface to a depth of 300 feet, below which it was not worked. The greatest width of this shoot was 8 or 9 feet but at this point it did not carry values high enough to pay for the necessarily long haul. Were the mine nearer the railroad it is probable that further work would have been done before now.

MINES OF COLUMBUS GULCH AND VICINITY

In the summer of 1909 there were six men employed in development, and a few doing assessment work in this part of the district. No payable ore bodies were exposed at the time of our visit.

Golden Age mine.—A tunnel about 550 feet long in the quartz monzonite and a drift about 40 feet long constitute the developments of this property. The drift is on a shear zone which shows gouge and pyrite in the roof. Mineralization extends through a width of about three feet. A small amount of galena was found in the breast of the tunnel in the country rock. Pyritization was frequently seen in the tunnel.

This property has produced two carloads of ore. According to Mr. Henry L. Acker, the better car netted $30.00 a ton after paying freight and treatment charges.

Darling mine.—One carload of ore is reported from this property, from a shaft 26 feet deep which is now filled with ice.

Good galena was seen on the platform. A tunnel is now being driven below to cut the ore body.

Brighton mine.—This mine, which was once a producer, was worked through a shaft which is now nearly filled with water. The dump is nearly all vein quartz stained with limonite. A small amount of galena and pyrite may be seen.

Columbus mine.—This mine was worked through tunnels on several levels all of which are now caved except the lowest. Bad air in this one prevented an examination by the field party. The workings are, in the main, just east of the eruptive contact between the quartz monzonite and metamorphosed sedimentary rocks. Much vein quartz and a considerable quantity of sulphides of iron, copper, lead, and zinc were seen. Water issuing from the tunnels carries in solution an appreciable amount of copper salts. The following is taken from the Report of E. Le Neve Foster, State Geologist:[1]

> The Columbus mine is situated about 12,000 feet above sea level on the southern slope of Taylor Mountain. Its workings consist of shafts and tunnels and develop a true fissure vein to a depth of 300 feet, and horizontally 1,100 feet. The outcroppings of the vein may be clearly traced upon the surface for this entire distance, with almost unbroken continuity, commencing at its southern extremity in a deep depression in the side of the mountain, and following very crookedly a mean northeasterly course up an ascent of 30°, where it is finally hidden under surface debris. * * *
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> The matrix of the vein is quartz from wall to wall. The clay selvage usually accompanying the walls of fissure veins is in this instance more often lacking, though occasionally present, with a thickness of one-fourth to two inches. For the first 200 feet of depth the quartz is irregularly banded, composed in a great measure of agglomerations of coarse amorphous [xenomorphic ?] crystals, or spongy from the decomposition of pyrite, and deep brown in color from the presence of much iron oxide. The whole width of the vein, from 6 to 20 feet, is productive of good value in silver, which occurs as a sulphuret and contains also varying quantities of gold. At the depth of 200 feet the vein material changes abruptly to a pure white quartz, containing large quantities of pyrite and sphalerite intimately associated, in very perfectly shaped crystals of one-twentieth to one-half inch in diameter. Copper is also found; native, in spongy masses and as a thin coating of blue or green carbonate, while silver is less widely distributed through the thickness of the vein, being confined to certain localities rich in iron and zinc sulphurets. These conditions remain constant in the lowest depths of exploration. A spur or branch of the vein has its apex in the granite [quartz monzonite] to the west and joins the main vein at a depth of 200 feet. Its strike is due north, and its dip about 70° to the east. The vein material

[1]Report of E. Le Neve Foster, State Geologist, 1884, pp. 30-32. Mr. Foster credits the account to Mr. F. G. Bulkley.

here is productive of small quantities of silver, and consists of a compact brownish quartz. No influence seems to be exerted upon the productiveness of the vein by the junction of this spur, either in quantity or quality of the ore.

The mine was operated for several years, the ores being concentrated in a mill on Middle Fork. The mill has since been sold and removed, and the aerial tramway which connected it with the mine is no longer standing. The men who owned the mine when it was operating are now dead, and no record of the output is known to exist. Mr. W. K. Jewett, the present owner, writes: "Tradition says that its gross production during the period of its operation was approximately $300,000, the values being mainly silver and copper."

Alpha and Beta.—An output of 20 tons of silver-lead ore is reported from these two claims in Kangaroo Gulch. The Maverick tunnel below, through which it is proposed to work these leads, has been driven 650 feet.

Uncle Sam mine.—The Uncle Sam in Hoffman Park is reported to have been operated while Maysville was the terminus of the railroad. The workings are now inaccessible but it is probable that the ore was either in the quartz monzonite porphyry or at the contact between the porphyry and the quartz monzonite on the east.

Prospects in Hoffman Park.—There are here a number of shallow shafts and several tunnels, but at the time of our visit only the Hercules tunnel was being driven. This tunnel is in over 600 feet in the quartz monzonite. A narrow vein in a drift near the breast carries galena and chalcocite with a small amount of chalcopyrite.

LIMESTONE

The Ohio & Colorado Smelting & Refining Company owns a quarry at Garfield from which limestone is shipped daily to the company's smelter at Salida. The shipments for the twelve months closing July 31, 1909, were 978 cars of about 25 tons each. Seventeen men were employed almost continuously through the year, and the number was increased in the summer.

The Garfield quarry under lease to Mr. L. W. Hubbard was operated during part of the year, 1909. Ten men are employed when the quarry is working regularly. The limestone is shipped to the smelters at Leadville and Salida, and to the sugar factory at Rocky Ford. The limestone of these two quarries is crystalline and is almost pure calcium carbonate.

MARBLE

There is a large amount of marble in Taylor Gulch and in the vicinity of Cree Camp, but it is not likely that it can be quarried under present conditions in competition with the large quarries of Colorado. A small quantity at the head of Taylor Gulch is blue, but most of the marble is pure white and very coarse in texture. In general the rock near the surface contains too many joints to make a satisfactory building stone.

A quarry near the Exchequer shaft is reported to have furnished a small quantity of marble for the Colorado capitol. A number of tons have been quarried. The largest pieces seen on the dump were about six feet long. The marble is pure white and practically free from chert.

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