[Presented before the Society November 28, 1931]

PRELIMINARY MAP SHOWING THE RELATIONS OF ORE DEPOSITS TO GEOLOGIC STRUCTURE IN BOULDER COUNTY, COLORADO[1]

T. S. LOVERING[2]

During the course of detailed mapping by the writer in the region near Nederland and by E. N. Goddard in the Jamestown district the common association of ore bodies with regional northerly or northwesterly faults was observed. Rumors of similar associations in other parts of Boulder County led to a reconnaissance in October and November, 1931, when with the help of L. B. Graff and Bert Stegeman, the writer traced out some of the most prominent northwest faults in the region just west of Boulder. The work was halted by snow before it was completed, and as there is little likelihood of carrying it on in the near future a summary of the results so far obtained is given here. The structural features worked out are shown on the accompanying map, which is believed to give an adequate presentation of the larger factors in the local problem of ore hunting; but as there are considerable areas that the writer was unable to visit, it is probable that further work will disclose additional significant structural features and extensions of those already found.

GENERAL GEOLOGY OF THE REGION

At Boulder the eastern edge of the Front Range trends nearly north and south and structurally has the appearance of a simple, sharp monoclinal flexure. At the western edge of the city vertical or steeply dipping Paleozoic and Mesozoic sediments border pre-Cambrian rocks, which extend for more

[1]Published by permission of the Director of the U. S. Geological Survey, the Directors of the Colorado Metal Mining Fund, and the Colorado Geological Survey board.
[2]Associate Geologist, U. S. Geological Survey.

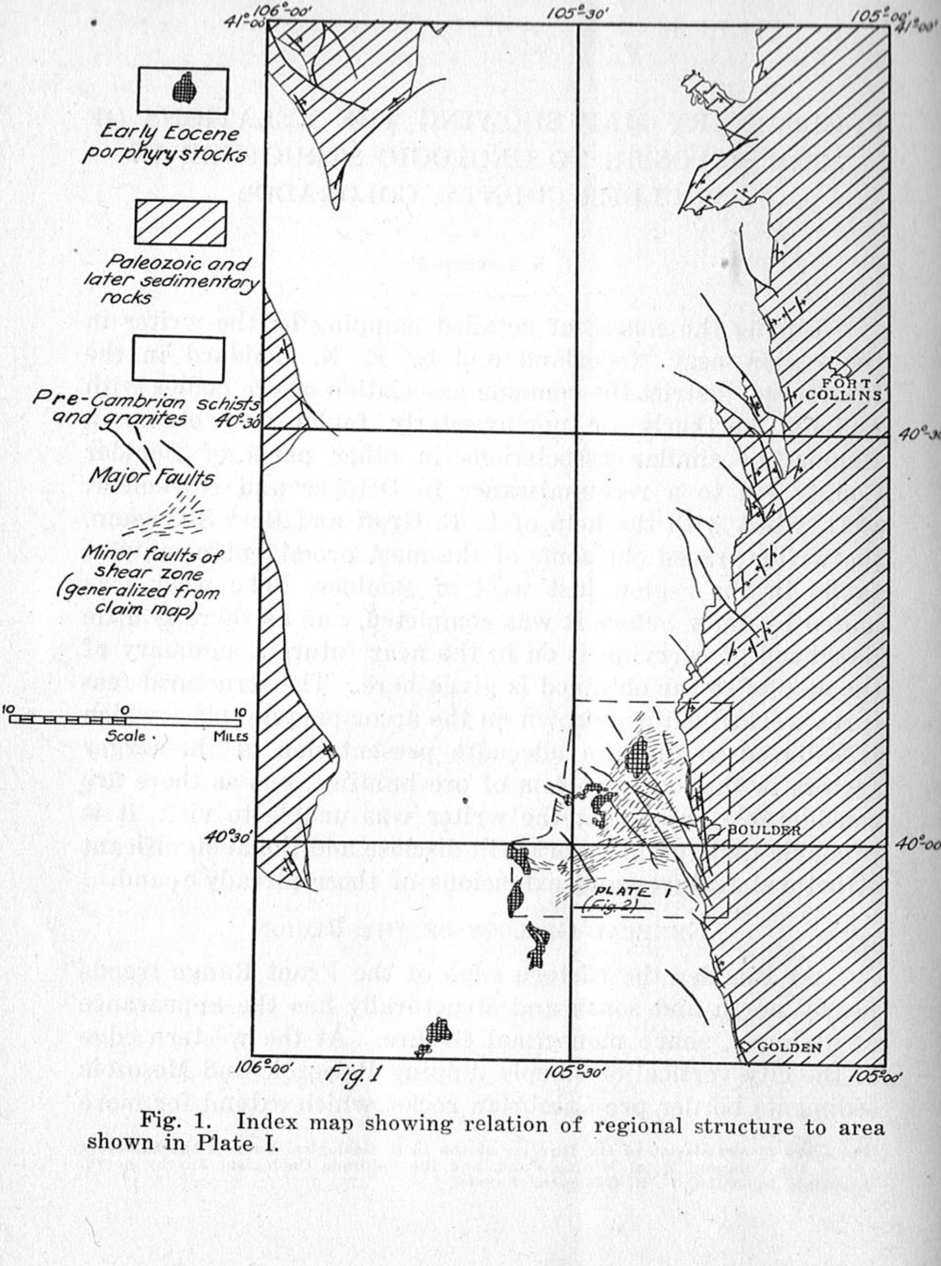


Fig. 1. Index map showing relation of regional structure to area shown in Plate I.

than 30 miles to the west. As the Front Range is followed north from Boulder a series of northwestward trending folds arranged en échelon gradually carries the contact between the pre-Cambrian and the Paleozoic toward the east. (See Fig. 1.) Where the first of these échelon folds is found, about 15 miles north of Boulder, it is closely compressed and broken by a northwestward-trending fault that has dropped the west side. Such faults are characteristic of the other échelon folds, although the deformation and faulting become less and less to the north. At Boulder northward-trending thrust faults cut out a large part of the sedimentary section, but so far as known these faults do not swing west into the pre-Cambrian terrane. A few miles south of Boulder, however, on Green Mountain and South Boulder Peak (Pl. I), the sediments are repeated along northwestward-trending faults whose arrangement and displacement are the same as those of the faults that break the échelon folds farther north. These faults, as shown in Plate I, have been traced northwest for several miles.

Two large masses of granite occur in the region west and northwest of Boulder and are separated by a belt of schist that trends west and southwest. As the writer was unable to trace the northwesterly faults across this belt of schist in any locality, it is believed that the two masses of granite acted as separate units during the early Eocene mountain-building when the faults were formed. A belt of cross-breaking porphyry stocks extends southwestward across the Front Range from Jamestown to Breckenridge. These stocks are of different sizes and shapes and are irregularly spaced but have a very definite regional alinement. Most of the ore deposits and most of the porphyry dikes of the mineral or porpyhry belt of the Front Range occur on the southeast side of the belt of stocks, although the economically important ore deposits at Ward and some deposits north of Jamestown occur on the northwest side. The occurrence of nearly all the porphyry dikes on the southeast side of the belt of stocks suggests the presence of subjacent magmatic chambers in this region and their absence in the country to the northwest. The localization of most of the ore deposits in the same part of the porphyry belt suggests that they were derived from the emanations of the subjacent chambers of magma. The deposits at Ward and Jamestown are close to exposed porphyry stocks or within the narrow regional belt of stocks. They may be genetically related to deeper parts or the exposed stocks or to porphyry masses not yet exposed by erosion.

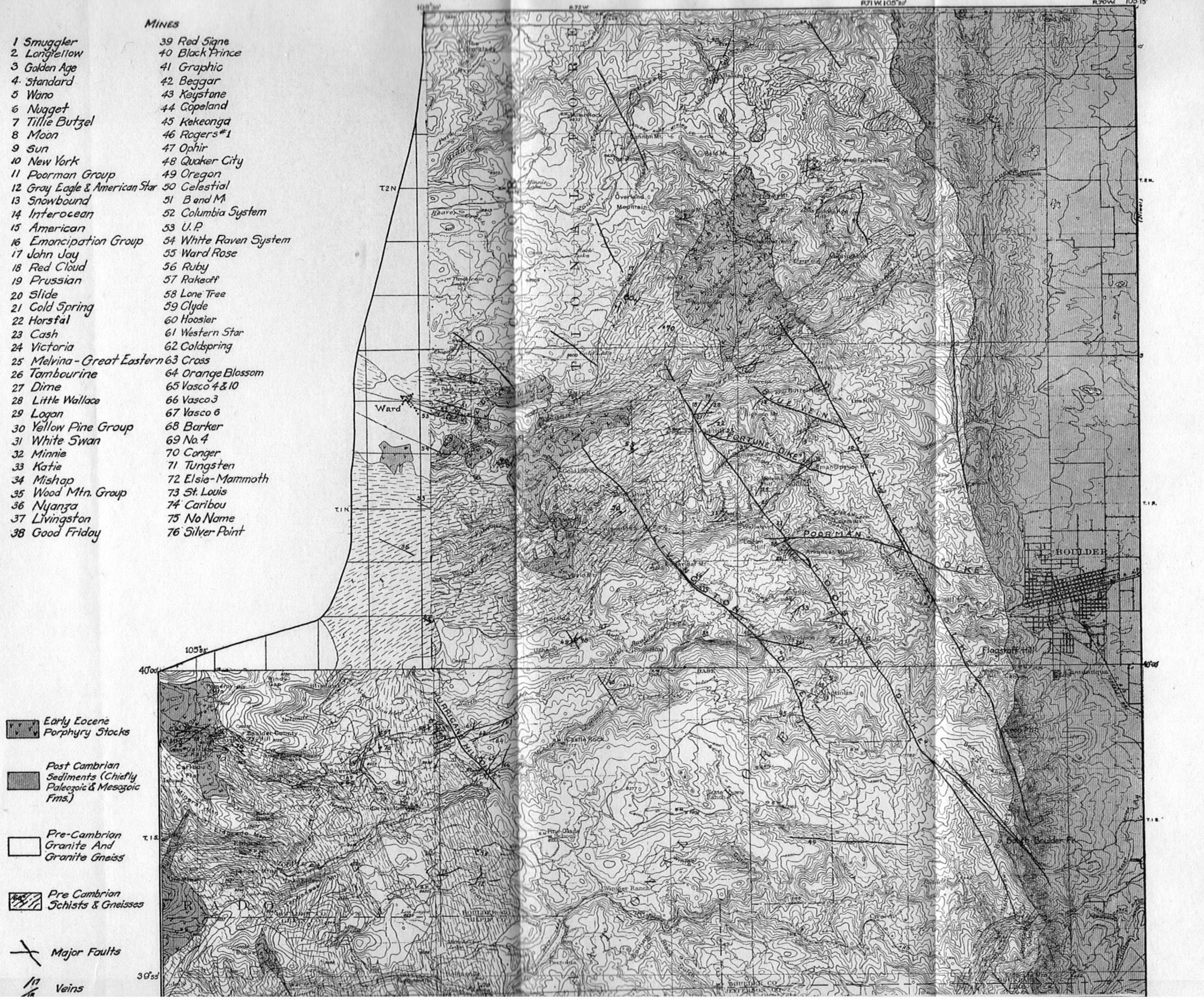
Although the regional distribution of the ore deposits is dependent on the regional distribution of the porphyries, the localization of the ore bodies is directly related to faults and fractures that have made openings in the rocks through which the mineralizing solutions could ascend toward the surface. The most persistent faults in the region are those of northwesterly trend that correspond in arrangement and displacement to the échelon folds and faults farther north. Associated with these northwesterly faults are faults of westerly to west-northwesterly trend along which the amounts and directions of displacement have not yet been determined. As nearly as can be told the age of this system is the same as that of the northwesterly faults. The two systems are probably the earliest Tertiary fractures in the region and are clearly older than the cross-breaking porphyry stocks. The northwesterly faults are nearly vertical but those of the westerly system commonly dip north at steep or moderately low angles. Faults of both systems are marked in most places by silicified rock and minor amounts of hematite. The silicified rock ranges from fine-grained chalcedonic quartz to dense, glassy quartz that resembles the bull quartz of pre-Cambrian pegmatites, and in places coarse-grained, vuggy comb quartz is abundant. The granite, where thoroughly brecciated along these faults, has been cemented by fine-grained, hematite-stained quartz. The fault material has approximately the same appearance and presents the same resistance to erosion as the country rock and is very difficult to distinguish from adjacent granite. At other places the glassy quartz, typical of quartz formed at high temperature, resembles pre-Cambrian pegmatitic quartz and its late age has not generally been recognized. Probably because of this kind of silicification the faults have commonly been called dikes by the miners, although they are not igneous intrusions; however, as the term "dike" has been widely used in reference to these silicified faults and as many of them have received individual names, such as "Hoosier dike" and "Maxwell dike," the writer will use the term "dike" in quotation marks throughout this paper when referring to these silicified faults.

The silicification of the northwesterly faults is regarded as an early barren stage of vein formation. In some places, as at Glendale, the quartz has a low content of gold; in others, as along the Hurricane Hill "dike" near Nederland, base-metal sulphides are found, and it is probable that the strong veins near Ward that are characterized by base-metal sulphides also represent slightly later mineralization along the west-northwesterly fault system.

After the early barren period of mineralization, a disturbance closely associated with the intrusion of the porphyry stocks produced a wide zone of discontinuous northeastward-trending faults on the southeast side of the belt of porphyry stocks. These northeasterly faults may be in part contemporaneous with the intrusions but are certainly in part later. They are commonly characterized by nearly horizontal movement of the walls. Few of the single faults can be traced for more than a few thousand feet although the fault or shear zone as a whole is persistent. A multitude of the northeasterly shear faults were mineralized to some extent, and a large number of them are now covered by mining claims. A claim map of Boulder County brings out clearly the northeast and east-northeast trend of the greater number of the veins, as well as the continuity of the fracture belt. This belt is indicated on Figure 1, but is not apparent on the geologic map, Plate I, where only the more productive veins are shown.

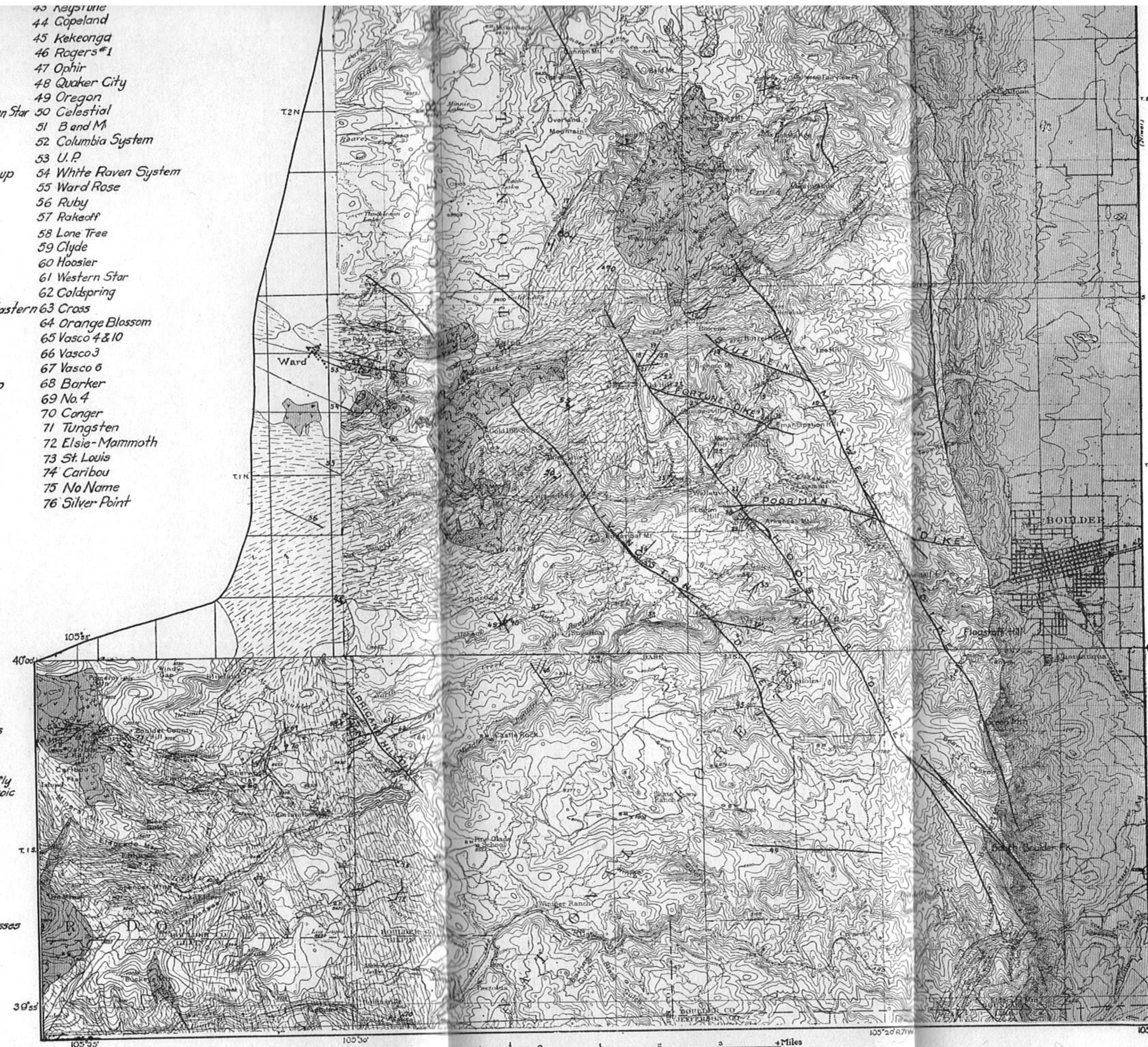
Divergences from the average northeasterly strike are common, and accordingly many of the fractures have branches or intersect one another. The points of branching and intersection are in general more open than other parts of the fractures, and nearly all the gold and tungsten ore-shoots in Boulder County have been found in such places. The writer has tried to show on the accompanying map all the veins that have produced more than $50,000. Nearly all occur within less than half a mile from one or another of the northwesterly or west-northwesterly faults. Such a grouping indicates a causal relationship. The persistence of these faults along the strike suggests a persistence in depth as well, and the nonpersistence of individual fractures with a northeasterly trend suggests a lack of persistence of individual fissures in depth. It seems probable, therefore, that the fractures of northwest trend tapped the sources of supply and guided the rising ore-forming solutions toward the surface. As the faults were in large part clogged during the early barren stage of mineralization, the later solutions were compelled to make their way as best they could along these tight but deep fissures until they reached some of the less persistent but more recent and therefore more open northeasterly faults, through which they found an easier way toward the surface. In a few places, as at the Livingston mine on the Livingston "dike," the northwesterly fractures were themselves reopened and gold telluride ores were deposited in them. A series of east-northeast fractures are of later age than the northeasterly gold telluride veins and are most prominent south of the northeasterly shear faults in a belt trending east-northeast from Nederland to Boulder. The walls and vein material in these fractures are marked by horizontal or gently dipping grooves, indicating nearly horizontal movement. Most of the tungsten ores of Boulder County occur in veins of this group, but tungsten ores also occur in some of the veins of the earlier fracture systems that were reopened at the time the easterly fractures were formed. Gold telluride and ferberite (iron tungstate) seldom occur in the same fissure, but in the few places where they have been

PLATE I


MINES
1 Smuggler
2 Longfellow
3 Golden Age
4 Standard
5 Wano
6 Nugget
7 Tillie Butzel
8 Moon
9 Sun
10 New York
11 Poorman Group
12 Gray Eagle & American Star
13 Snowbound
14 Interocean
15 American
16 Emancipation Group
17 John Jay
18 Red Cloud
19 Prussian
20 Slide
21 Cold Spring
22 Horsfal
23 Cash
24 Victoria
25 Melvina - Great Eastern
26 Tambourine
27 Dime
28 Little Wallace
29 Logan
30 Yellow Pine Group
31 White Swan
32 Minnie
33 Katie
34 Mishap
35 Wood Mtn. Group
36 Nyanza
37 Livingston
38 Good Friday
39 Red Signe
40 Black Prince
41 Graphic
42 Beggar
43 Keystone
44 Copeland
45 Kekeonga
46 Rogers #1
47 Ophir
48 Quaker City
49 Oregon
50 Celestial
51 B and M
52 Columbia System
53 U.P.
54 White Raven System
55 Ward Rose
56 Ruby
57 Rakeoff
58 Lone Tree
59 Clyde
60 Hoosier
61 Western Star
62 Coldspring
63 Cross
64 Orange Blossom
65 Vasco 4 & 10
66 Vasco 3
67 Vasco 6
68 Barker
69 No. 4
70 Conger
71 Tungsten
72 Elsie-Mammoth
73 St. Louis
74 Caribou
75 No Name
76 Silver Point
Early Eocene Porphyry Stocks
Post Cambrian Sediments (Chiefly Paleozoic & Mesozoic Fms.)
Pre-Cambrian Granite And Granite Gneiss
Pre Cambrian Schists & Gneisses
Major Faults
Veins
R.72 W.
R.71 W. 105°20'
R.70 W.
105°15'
105°35'
40°00'
39°55'
T.2 N.
T.1 N.
T.1 S.
Ward
BOULDER
Flagstaff Hill
Overland Mountain
POORMAN DIKE
FORTUNE DIKE
BLUE VEIN
HURRICANE HILL
South Boulder Pk.
Castle Rock
Caribou
Winiger Ranch
BOULDER CO.
JEFFERSON CO.

5 Wano
6 Nugget
7 Tillie Butzel
8 Moon
9 Sun
10 New York
11 Poorman Group
12 Gray Eagle & American Star
13 Snowbound
14 Interocean
15 American
16 Emancipation Group
17 John Jay
18 Red Cloud
19 Prussian
20 Slide
21 Cold Spring
22 Horsfal
23 Cash
24 Victoria
25 Melvina - Great Eastern
26 Tambourine
27 Dime
28 Little Wallace
29 Logan
30 Yellow Pine Group
31 White Swan
32 Minnie
33 Katie
34 Mishap
35 Wood Mtn. Group
36 Nyanza
37 Livingston
38 Good Friday

43 Keystone
44 Copeland
45 Kekeonga
46 Rogers #1
47 Ophir
48 Quaker City
49 Oregon
50 Celestial
51 B and M
52 Columbia System
53 U.P.
54 White Raven System
55 Ward Rose
56 Ruby
57 Rakeoff
58 Lone Tree
59 Clyde
60 Hoosier
61 Western Star
62 Coldspring
63 Cross
64 Orange Blossom
65 Vasco 4 & 10
66 Vasco 3
67 Vasco 6
68 Barker
69 No. 4
70 Conger
71 Tungsten
72 Elsie-Mammoth
73 St. Louis
74 Caribou
75 No Name
76 Silver Point



Early Eocene Porphyry Stocks

Post Cambrian Sediments (Chiefly Paleozoic & Mesozoic Fms.)

Pre-Cambrian Granite And Granite Gneiss

Pre Cambrian Schists & Gneisses

Major Faults

Veins

Geologic base compiled from U.S. Geol. Survey Prof. Pap. 94, Colo. Geol. Survey Bull. 21, and unpublished manuscript maps by E.N. Goddard and T.S. Lovering. Veins, faults, and structure of schists by T.S. Lovering assisted by L.B. Graff and Bert Stegeman.

RELATION OF BOULDER COUNTY GOLD AND TUNGSTEN VEINS TO MAJOR NORTHWESTERLY FAULTS OR "DIKES" OF SILICIFIED BRECCIA

(Prelimary Map, Data Incomplete)

observed together, as at the Kekeonga and Red Signe mines, the ferberite is later than the gold telluride ore. The writer has done detailed work only in the western part of the tungsten district, but there a noticeable concentration of the ore deposits occurs close to the northwestward-trending Hurricane Hill "dike."

The history of faulting in the region suggests a somewhat varied response to nearly horizontal compression applied from the west-southwest. The early northwesterly faults, by virtue of their relations to the échelon folds farther north, suggest compression under sufficient load to cause folding accompanied by faulting. The later fractures furnish evidence that compression either was focused on the region near Boulder or lingered for a longer period of time in this locality than elsewhere. The discontinuous shear faults suggest fracturing under a lighter load than that which existed during the epoch of northwesterly faulting. The development of these two kinds of deformation and the resulting fractures can best be pictures as follows: As the persistent northwesterly faults associated with the folding are found both north and south of the mineral belt and are plainly related to the earlier stages of mountain formation, they may be considered the results of failure at the edge of the region of folding that was produced by the uplift of the Front Range during the Laramide revolution; the northeasterly shear fractures are localized in the mineral belt and are probably the result of relatively westward movement of the wedge-shaped mineralized area during long-continued compression. (See Fig. 1). Failure along the northwest side of the wedge produced the northeasterly shear faults, and failure along the southern edge produced the late easterly fractures.

The sequence of mineralization is in harmony with the ages of the faults. The early, base-metal deposits are found in the early northwesterly faults, the intermediate gold-telluride deposits occur along the northeasterly faults, and the late tungsten deposits are chiefly along the late easterly fractures.

Local Details

The Maxwell "dike" is a silicified fault that has been traced from the Green Mountain fault northwestward to the large porphyry mass whose south edge forms the summit of Nugget Hill north of Left Hand Creek. This "dike" is well exposed in the saddle just west of Flagstaff Hill, in a road cut on the south side of the Boulder Canyon road a few hundred feet west of its junction with the road up Fourmile Creek, in the small knob a mile due east of Emancipation Hill, and in the saddle at the head of the gulch leading down to Glendale, where the Sunshine-Rowena road swings sharply to the west as it descends into the canyon of Left Hand Creek. It is cut off by a large porphyry stock about a mile north of Glendale. In most places the Maxwell "dike" is from 8 to 20 feet thick and is an iron-stained silicified breccia that can easily be mistaken for granite. The most productive properties on the Maxwell "dike" are the Poorman, Sun, Moon, Tillie Butzel, and Nugget. A northwesterly fault approximately in line with the Maxwell "dike" has been found on Cannon Mountain, several miles northwest of Nugget Hill, but has not been followed southeastward to the porphyry stock. Its general alinement suggests that it may pass through Bueno Mountain and that it is related to the Maxwell "dike," but proof of its southward continuation to the porphyry stock must await further field work.

The Hoosier "dike" has been followed northwest from the divide between North Boulder Creek and South Boulder Creek to Left Hand Creek, about a mile west of Rowena. Its thickness ranges from 15 to 50 feet. In many places it is similar in appearance to the Maxwell "dike," but commonly it contains more glassy quartz. In some localities—for example, southeast of Gold Hill, near Summerville—the "dike" is almost wholly vein quartz resembling the bull quartz of pre-Cambrian pegmatites. A close examination, however, shows that it is brecciated and contains numerous criss-cross veinlets of hematite and that it lacks the coarse-grained orthoclase and muscovite intergrown with the quartz that are characteristic of the pre-Cambrian pegmatite. South of the Flagstaff Hill-Magnolia road the dike splits into several minor fractures. Cross veins containing fluorite and barite are present close to the junction of the Hoosier "dike" with its western branch near South Boulder Creek, but no important mineralization is known to have taken place along it south of Boulder Creek. Good exposures of the Hoosier "dike" may be found on Arkansas Mountain and in many localities to the northwest between Fourmile Creek and Gold Hill. It is especially conspicuous south of Summerville and where it crosses the road to Gold Hill, about half a mile west of Summerville. Many productive gold-telluride and tungstein veins have been found close to the Hoosier "dike." Mines shown on the map include the Ohio and White Swan tungsten veins, Yellow Pine group of silver and gold veins, Logan gold vein, Dime, Tambourine, Great Eastern and Melvina, Victory, Cash, Slide, Cold Spring, and Red Cloud gold telluride veins. The important Horsfal and Prussian veins occur within a half mile of the "dike." So far as is known, the Hoosier "dike" does not extend across the band of schist northwest of Gold Hill. A "dike" of similar appearance was found near Gold Lake to the west of the schist, and has been correlated with the Hoosier "dike" by many miners, but the writer was unable to find a connection between them. If it persists across the schist belt it seems more probable that the silicified fluoritic fault breccia found by Goddard northwest of the John Jay mine (Pl. I) is its northwest continuation. It is believed that the Hoosier "dike" loses its identity in the relatively incompetent schist, and that the northwestward-trending fault breccias found in the granite mass to the northwest correspond only in a general way to the faults mapped in the granite east and south of the schist.

The Poorman 'dike' is a silicified fault breccia that has been followed eastward from the Hoosier "dike" on Logan Hill to its junction with the Maxwell "dike" north of the Poorman mine. East of this junction it bends slightly to the south and continues across the ridge into Sunshine Canyon.

Although easily traced to a point within a short distance of the foothills, it was not found in them. The Poorman "dike" varies greatly in thickness and in character. At Logan Hill it is a very much silicified fault breccia and is reported to contain small quantities of gold. Near the Poorman mine it is an iron-stained fault breccia, cemented by fine-grained quartz, but on the hillside south of the road in Sunshine Canyon it is a conspicuous coarse breccia cemented by white glassy quartz. In the last-named locality Tertiary porphyries not shown on the map have been intruded alongside the fault breccia, and it is worthy of note that igneous rocks of early Tertiary age also cut the sedimentary rocks directly in line with the fault. The Poorman "dike" continues west of Logan Hill for some distance and is known to extend farther west than it is shown on the map, but time did not permit the writer to trace it in that direction.

The Fortune "dike" trends east-southeastward from its junction with the Hoosier "dike" a short distance north of the Cash mine. It dips about 45° N.-N.E., in marked contrast to the other "dikes," which are nearly vertical. It is from 4 to 10 feet thick and is followed with considerable difficulty to the Emancipation mine. Its extent to the southeast is unknown.

The Blue vein extends west-northwestward from its junction with the Maxwell "dike" half a mile east of Sunshine and has been followed northeastward for a short distance beyond the Snowbound mine, about half a mile south of Rowena. It is from 5 to 7 feet thick, consists chiefly of glassy and fine-grained quartz, and dips steeply to the north. The junction of the Interocean and American veins at Sunshine, a short distance south of the Blue vein, caused the formation of valuable ore bodies on both veins.

The Livingston "dike" is a northwestward-trending silicified fault breccia that has been followed from the Kekeonga vein, south of Magnolia, to the edge of the porphyry stock, half a mile northeast of Gold Hill station. This "dike" varies greatly in thickness, and its outcrops range from 2 to 50 feet in width. In most places it consists of coarse-grained glassy quartz seamed with hematite. Locally brecciated masses of granite cemented by quartz-hematite aggregates mark its course, and in a few localities vuggy comb quartz is abundant. The last-named variety is well exposed in the vicinity of the Livingston mill, in Summers Gulch. The Livingston "dike" is followed by a black diabase dike from the Kekeonga mine northwestward to a point south of Black Tiger Gulch. Farther northwest the fault breccia curves to the west, and no other porphyritic masses have been found along it. The most valuable ore deposits found in the Livingston "dike" are the gold telluride mines in the Magnolia district, the Black Prince and Red Signe tungsten mines, and the Nyanza-Livingston gold telluride veins. The Livingston vein is itself part of the Livingston "dike."

No trace of the Livingston "dike" was found in the valley of Left Hand Creek, and the writer doubts whether it is present on the north side of the porphyry that cuts it off to the northeast of Gold Hill station; however, a silicified fault breccia of the same appearance as the Livingston "dike" is found directly in line with it, on the northwest side of Burnt Mountain 2 miles to the northwest. This breccia, like the Livingston "dike," has been locally reopened and in a few places contains sufficient gold to be profitably worked. About a mile northwest of Burnt Mountain this breccia disappears under glacial drift.

A northwestward-trending iron-stained silicified fault breccia crosses the ridge between North Boulder Creek and Middle Boulder Creek about 1½ miles northwest of Castle Rock. Several tungsten veins, including the productive Rogers No. 1, are found close to it. The northwesterly fault has not been followed northwest of North Boulder Creek or southeast of Middle Boulder Creek, but a wide pre-ferberite quartz vein striking northwest has been noted at the Oregon tungsten mine directly in line with the silicified fault breccia and is believed to be its northwest continuation.

The Hurricane "dike" is an iron-stained shear zone marked locally by silicification. It has been traced northwest across Hurricane Hill to a point about 2 miles northeast of Nederland, but has not been followed southeast of Middle Boulder Creek or northwest of North Boulder Creek. With the exception of the tungsten from the Congor-Beddig group of veins, northwest of Nederland, and those in the Beaver Creek district, to the southeast, nearly all the tungsten produced has come from veins close to this shear zone. On the northwest side of Hurricane Hill it contains small quantities of lead, copper, and zinc minerals. These minerals are somewhat more abundant farther northwest. This shear zone is little silicified on the southeast side of Hurricane Hill; where it has been cut in the Vasco No. 5 mine, and in the Clark tunnel, at Tungsten, it is marked by a mass of gouge from 4 to 10 feet wide dipping about 65° N.E. In the Clark tunnel a few thousand pounds of hematite for chemical use was profitably mined from the "dike" during the war.

The Copeland mine, about 2 miles due south of the Kekeonga mine, exploited a low-grade tungsten vein along a nearly east-west vertical fissure. This vein consists of a strongly silicified fault breccia from 5 to 20 feet thick, showing evidence of repeated brecciation. The vein has been traced a little more than 1½ miles east of the Copeland mine and a short distance to the west. The north wall moved downward and to the west.

About 2 miles east of Jamestown a northward-trending iron-stained silicified fault breccia has been traced for a short distance. It dips west at a low angle. Gold telluride ore occurs in some places where the silicified fault breccia has been reopened by later movement. The Golden Age vein system may unite with it about three-quarters of a mile east of the Golden Age mine.

The descriptions given above show that much structural work remains to be done in Boulder County. It is believed, however, that the work already completed indicates the close relation of the regional structural features to ore occurrence, and their importance in prospecting and mine development.