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# GEOLOGY AND ORE DEPOSITS OF THE MAGNOLIA MINING DISTRICT AND ADJACENT AREA, BOULDER COUNTY, COLORADO

*by*

ALBERT S. WILKERSON[1]

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## ILLUSTRATIONS

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[1] Rutgers University, New Brunswick, New Jersey.

## INTRODUCTION

The region described in this paper includes an area of approximately 24 square miles immediately southwest of Boulder. The mining camp of Magnolia, 4 miles southwest of Boulder, is in the northwestern part of the mapped area. (See figs. 1 and 2.) Although the production of ore has not been large, the district is of interest because of its production of very high grade gold telluride ore and the variety of the ore minerals, because it was the first camp in Colorado to produce considerable quantities of telluride ore, and because it lies near the northeast end of the Colorado mineral belt. The region is a part of the eastward-sloping upland belt that extends from the upturned sedimentary rocks at the west border of the Great Plains westward to the crest of the Front Range. The altitude ranges from 5,500 feet to 8,750 feet. Boulder Mountain, elevation 8,640 feet, and Green Mountain, elevation 8,100 feet, in the extreme eastern part of the region, are prominent and well-known landmarks.

During the summer of 1936 the writer mapped the surface geology, and in 1937 geologic maps of the mines were made. Access to the working mines was made possible through the courtesy of the various operators. The writer is greatly indebted to T. S. Lovering for invaluable aid in the preparation of this paper.

## HISTORY OF THE DISTRICT

Three years after the discovery of gold telluride at Gold Hill in 1872, C. A. Hammill discovered gold telluride ore in the Magnolia district. The discovery was known as the Downs lode. A few days later the Magnolia lode was staked, from which the district was named. Excitement, which ran high during the early days of the camp, did not last long nor did the mining community grow into a large and important camp. Of the many veins discovered since 1875 most yielded little or no ore. Most of the production has been gold telluride but a small amount of tungsten was mined during the World War tungsten boom. The camp is unofficially credited with a total production of approximately $3,000,000. The

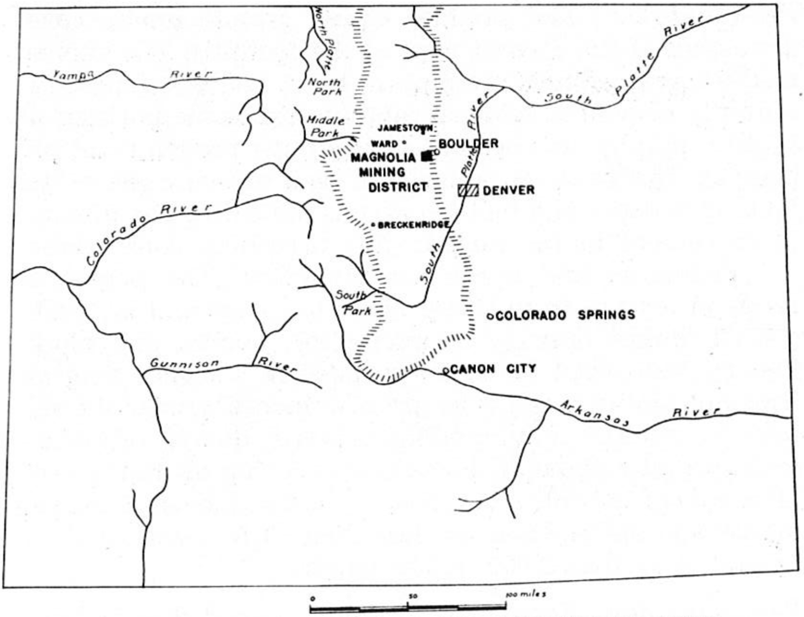

*Fig. 1—Index map of Colorado showing position of Magnolia mining district*

rise in the price of gold during the latter part of 1933 and continuing at $35 an ounce through 1934-37 did not greatly stimulate mining activity. During 1936 and 1937 no mine actively produced ore. Many of the mines were partly filled with water, and many were in a sad state of disrepair. Probably no individual mine has produced as much as $500,000 and none has been a steady producer.

## GENERAL GEOLOGY

Algonkian (?) granite gneiss and accompanying aplites and pegmatites cover most of the district. Paleozoic sediments occur in the extreme eastern part and form the eastward-dipping "Flatirons" of the foothills. A late Cretaceous diabase dike ("Iron Dike") trends northwestward across the southwestern and western parts. Intruded into Paleozoic sediments east of Flagstaff Hill are sheets of rhyolite porphyry of early Eocene age. (See fig. 2.)

*Pre-Cambrian*—The Boulder Creek granite gneiss covers almost all of the district west of the foothills. The gneiss is medium-grained, grey to pink in color, and is composed essentially of quartz, feldspar, and biotite. Some portions are slightly porphyritic, orthoclase being the predominant phenocryst. The gneiss is believed to be a primary gneiss with tabular feldspar and biotite crystals indicating the direction of movement in the magma just preceding consolidation.

Pegmatite and aplite are abundant. The pegmatites range in texture from fine-grained to coarse and invariably consist almost entirely of microcline, quartz, and biotite. Locally individual feldspar crystals are 7 inches long and books of biotite reach a length of 5 inches. Under the microscope, microcline, microcline-perthite, quartz, orthoclase, and a small amount of oligoclase make up all but a negligible part of the aplite. As shown in figure 3, most of the pegmatite and aplite dikes are less than 15 feet wide and few extend more than 2,000 feet in length.

*Pennsylvanian*—Fenneman[2] presents a good description of the Fountain formation, of Pennsylvanian age, which rests unconformably upon the granite gneiss in the extreme eastern part of the region:

> "In general the Fountain sandstone is a rough arkose, the individual feldspar often appearing in large crystals. Locally it passes on the one hand into conglomerate and on the other into quartzose sandstone * * **. Micas are present, especially in the finer portions. The conglomerate phase may have pebbles of granite and schist or of pure quartz only. The conglomerate of fragments of crystalline rocks is found only at the base, and there not universally * * *. The Fountain sandstone is characterized by very thick beds throughout, and cross-bedding may be found at any horizon * * *. The thickness of the "Red Beds" is 500 to 600 feet at Boulder Canyon, where they are vertical, and increase both to the north and to the south, approximately 1,500 feet at Fourmile Canyon, where they dip eastward at an angle of 47°."

*Cretaceous*—The "Iron Dike", so-called because of its dark brown to greenish-black color and its magnetic properties which are due to its high magnetite content, is easily traced from the east side of a private road three-fourths of a mile

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[2] Fenneman, N. M., Geology of the Boulder district, Colorado: U. S. Geol. Survey Full. 265, pp. 22-3, 1905.

northwest of Walker ranch to the mouth of Black Tiger Gulch west of Wheelmen. From here it continues northwestward and is found beyond Estes Park, about 30 miles to the northwest. The maximum width is 50 feet along most of its length, narrowing to 25 feet about 1½ miles west of Kossler Lake, and gradually thinning to only a few inches at its known southeast extremity. At most localities the dike is a quartz diabase, dark brown to greenish-black in color, and varies in texture from medium- to fine-ophitic. Laths of feldspar, which parallel the walls of the dike, lie in a mosaic of pyroxene and magnetite. On weathering the surfaces are consistently a rusty brown, accentuating the feldspar crystals. The dike is closely jointed and the numerous outcrops weather to a characteristic talus of small brown blocks.

Approximately 1 mile east of lower Magnolia a branch of the dike grades along its strike into basalt porphyry. Here it varies in width from 8 inches to 5 feet. Under the microscope, the basalt is found to be a porphyry with hyalopolitic texture. Feldspar and augite occur as phenocrysts, forming 20-25 percent of the rock. Phenocrysts of laboradorite frequently contain basaltic glass between the cleavages and twinning planes.

*Eocene*—On the east side of Flagstaff Hill, about 100 feet above the base of the Fountain formation, is an intrusive sheet of rhyolite porphyry.[3] It extends northward from Gregory Canyon to approximately half a mile south of Boulder Creek. The sheet varies in width from 10 to 60 feet. The trend of the sheet is N. 10° E. and the dip is 55° E.

## STRUCTURAL GEOLOGY

### *Regional Structure*

The Front Range is a long narrow dome composed largely of pre-Cambrian granitic intrusives and metasedimentary rocks. The crystalline rocks are surrounded by Paleozoic and Mesozoic sediments which dip away from the

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[3] Palmer, C. S. and Fulton, Henry. The quartz porphyry of Flagstaff Hill, Boulder, Colorado: Colorado Sci. Soc. Proc. vol. 3, p. 365, 1888-1890.

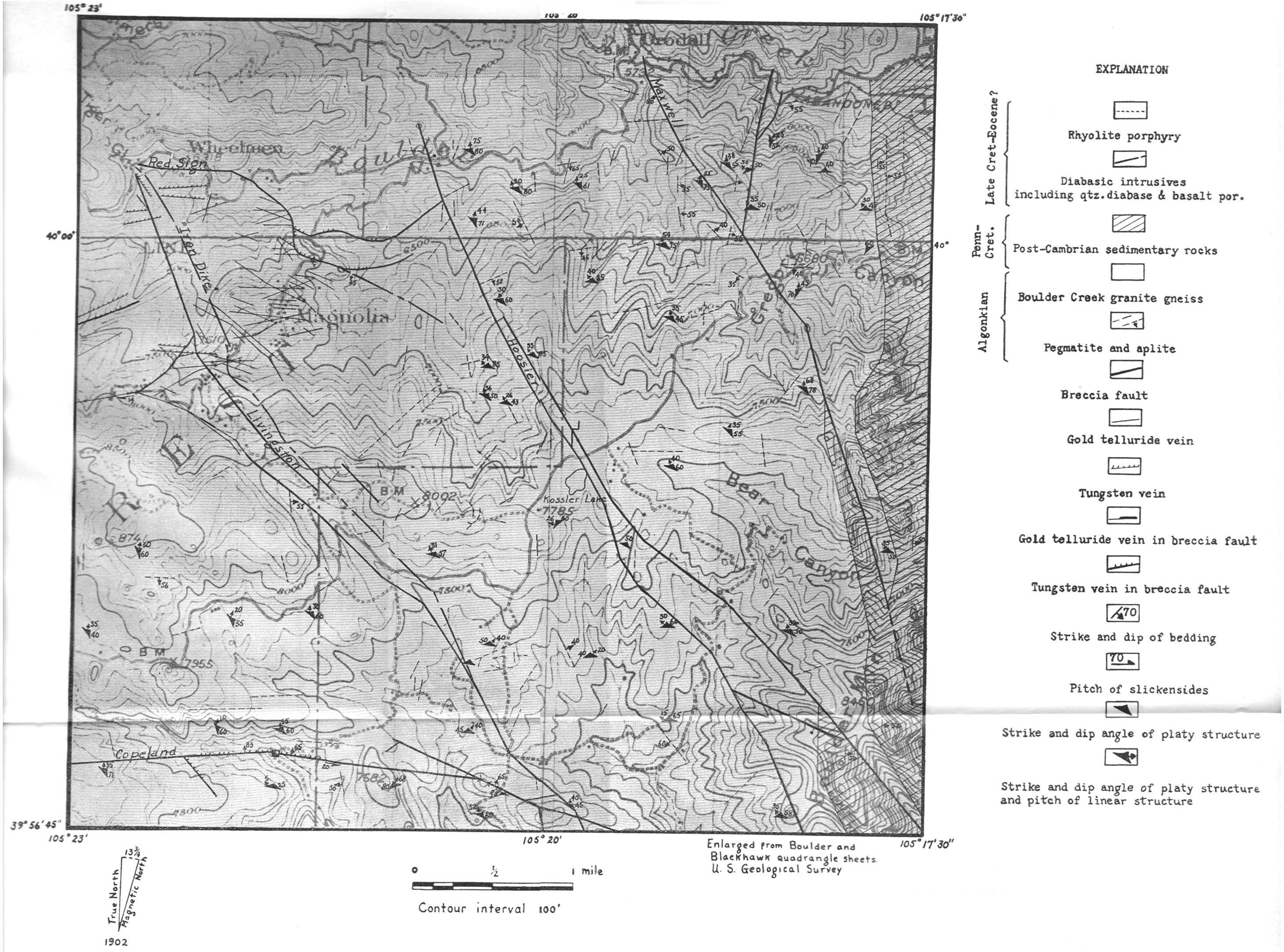
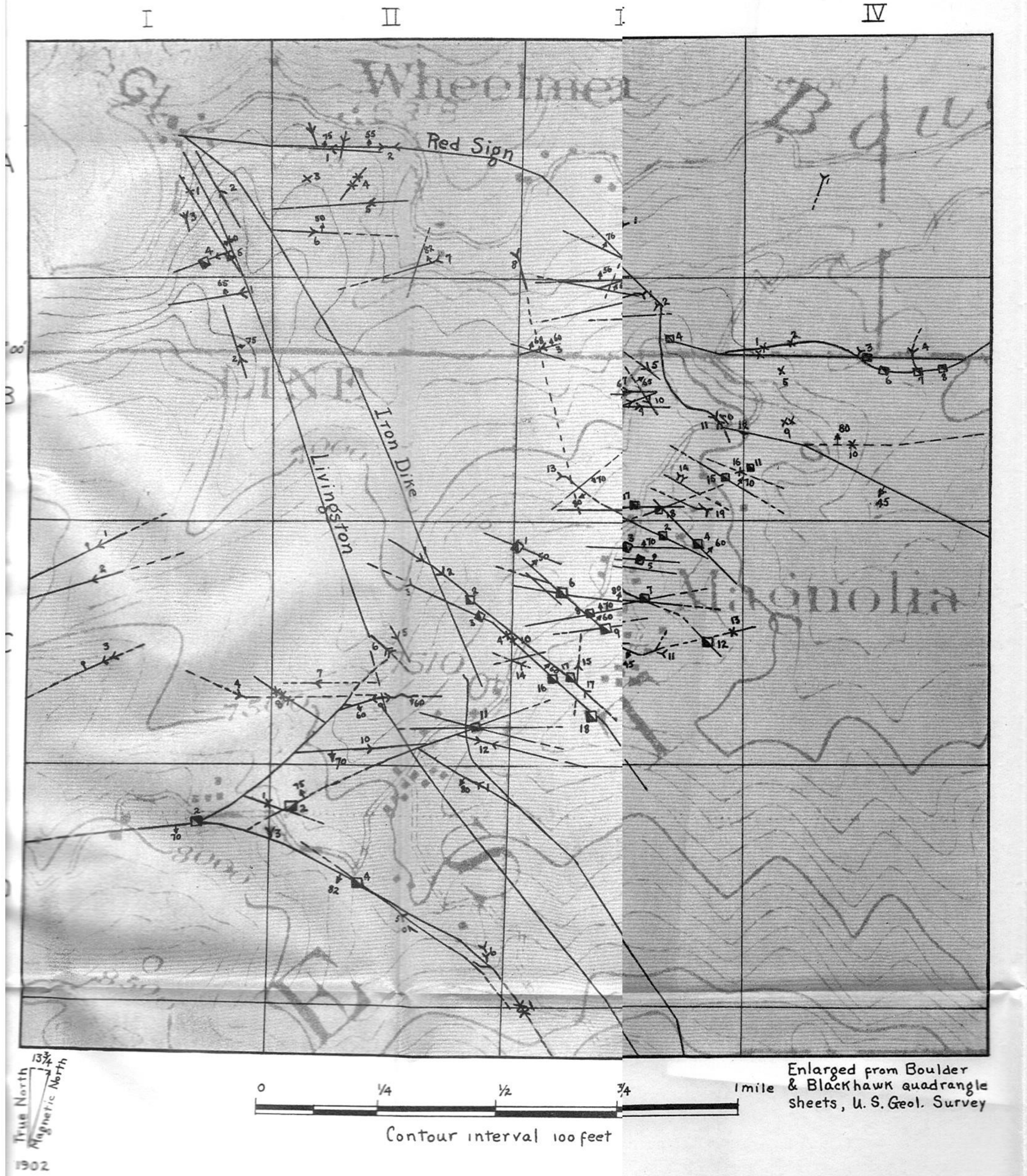


FIG. 2—GEOLOGIC MAP OF MAGNOLIA MINING DISTRICT, COLORADO



Enlarged from Boulder & Blackhawk quadrangle sheets, U. S. Geol. Survey

Contour interval 100 feet

TOPOGRAPHIC MAP OF MAGNOLIA MINING DISTRICT,
FIG. 2A—COLORADO, SHOWING MINE LOCATIONS

### MINES ALPHABETICALLY

Acme III-A 1
Anthracite IV-B 5
Audophone II-D 4
Aztec I-A 2
Barney IV-B 9
Belmont III-B 4
Ben C. Lowell II-C 11
Bituminous IV-B 2
Black Bear II-C 5
Bonnie Blue Flag II-A 5
Boodle III-C 12
Caledonia III-B 1
California II-D 2
Carnival II-A 3
Cash III-C 4
Chipmunk III-B 6
Chuzzlewit III-B 14
Clara May III-C 13
Cold Spring IV-B 6, 7, 8
Crownpoint III-B 12
Dardanelle III-B 3
Dove II-A 2
Dunraven III-B 17
Eclipse II-D 6
Empress I-A 1
Eskimo II-C 10
Ferberite II-A 1
Floyd I-A 3
Fortune III-C 6
Gold Bug III-B 2
Gold Coin II-A 4
Golden Eagle III-B 16
Golden Glow III-B 7
Golden Scepter IV-B 11
Graphic III-B 15
Hereafter III-C 17
Homestake I-C 3
H.R.B. I-B 2
Humbug II-C 2
Interocean III-C 15
Iron Age IV-B 3, 4
Jay Bird I-C 4
Kansas City III-C 1
Kekionga I-D 2
Keystone III-C 18
Kingston I-B 1
Lady Franklin III-C 3
Lawrence I-A 4
Little Maud III-C 2
Little Pittsburg III-C 9
Maggie III-D 1
Magnolia II-D 3
Marchioness tunnel IV-A 1
Mary V III-C 11
May Blossom #2 II-D 1
Mountain Lion II-C 4
    III-C 10, 14, 16
Nanna IV-B 10
New Year III-C 5
Oneonta I-C 1
Ophir III-C 8
Otego I-C 2
Pickwick III-B 19
Poorman III-B 13
Poor Mans Fortune II-C 8
Ridge I-A 5
Sac and Fox III-B 18
San Diego I-D 1
Senator Hill III-C 7
S.F.C. II-A 6
Silent Fried III-B 11
Sister Emma II-C 7
Snow Flake II-C 1
Spring Bear II-C 6
Sylvanite tunnel II-A 8
Telephone II-D 5
Tungsten King II-C 9
Twin Brothers II-A 7
Unknown #1 III-B 10
Unknown #2 III-B 8
Unknown #3 III-B 5
Unknown #4 III-B 9
Van Campen IV-B 1
Washington II-C 12
Ward H. Lamon II-C 3

### MINES BY COORDINATES

I-A
1. Empress (Ferberite gr.)
2. Aztec (Ferberite gr.)
3. Floyd (Ferberite gr.)
4. Lawrence (Ferberite gr.)
5. Ridge (Ferberite gr.)

I-B
1. Kingston (Ferberite gr.)
2. H.R.B. (Ferberite gr.)

I-C
1. Oneonta
2. Otego
3. Homestake
4. Jay Bird

I-D
1. San Diego (California gr.)
2. Kekionga

II-A
1. Ferberite (Ferberite gr.)
2. Dove (Ferberite gr.)
3. Carnival (Ferberite gr.)
4. Gold Coin (Ferberite gr.)
5. Bonnie Blue Flag (Ferb. gr.)
6. S.F.C. (Ferberite gr.)
7. Twin Brothers
8. Sylvanite tunnel

II-C
1. Snow Flake
2. Humbug
3. Ward H. Lamon
4. Mountain Lion
5. Black Bear
6. Spring Bear
7. Sister Emma
8. Poor Mans Fortune
9. Tungsten King
10. Eskimo
11. Ben C. Lowell
12. Washington (B. C. Lowell gr.)

II-D
1. May Blossom #2 (B. C. Lowell gr.)
2. California
3. Magnolia
4. Audophone
5. Telephone
6. Eclipse

III-A
1. Acme

III-B
1. Caledonia (Acme gr.)
2. Gold Bug (Acme gr.)
3. Dardanelle
4. Belmont (Tungsten gr.)
5. Unknown #3
6. Chipmunk
7. Golden Glow
8. Unknown #2
9. Unknown #4
10. Unknown #1
11. Silent Friend
12. Crownpoint (Tungsten gr.)
13. Poorman
14. Chuzzlewit
15. Graphic (Sextonia gr.)
16. Golden Eagle (Sextonia gr.)
17. Dunraven
18. Sac and Fox
19. Pickwick

III-C
1. Kansas City
2. Little Maud
3. Lady Franklin
4. Cash
5. New Year (Lady Fr. gr.)
6. Fortune
7. Senator Hill
8. Ophir (Sen. Hill—Ophir gr.)
9. Little Pittsburg
10. Mountain Lion
11. Mary V
12. Boodle
13. Clara May
14. Mountain Lion
15. Interocean
16. Mountain Lion
17. Hereafter
18. Keystone

III-D
1. Maggie

IV-A
1. Marchioness tunnel

IV-B
1. Van Campen (Tungsten gr.)
2. Bituminous (Tungsten gr.)
3. Iron Age (Tungsten gr.)
4. Iron Age (Tungsten gr.)
5. Anthracite (Tungsten gr.)
6. Cold Spring (Tungsten gr.)
7. Cold Spring (Tungsten gr.)
8. Cold Spring (Tungsten gr.)
9. Barney (Tungsten gr.)
10. Nanna (Tungsten gr.)
11. Golden Scepter (Sextonia gr.)

range at moderately steep angles but are locally vertical and even overturned.

According to Lovering[4] who has briefly discussed its general structure and history, the Front Range gained its present outline as a result of the Laramide revolution. Regional compression from a northeast-southwest direction during this time folded and faulted parts of the range, especially in the foothills region. Folds and faults of northwesterly trend are common along both borders of the range. Along the east side, especially from the Wyoming line south to Boulder Creek, en echelon flexures of northwesterly trend become more numerous and more closely folded and faulted, and the igneous-sedimentary contact is deflected westward. In Boulder County these faults are abundant and have steep dips with the down-thrown side on the west. As shown in figure 2, three of these faults pass through the Magnolia district and are known as the Maxwell, Hoosier, and Livingston faults or "breccia dikes". The first two mentioned are northwestern extensions of the Green Mountain and Boulder Peaks faults, respectively. Westward- to west-northwestward-trending reverse faults of probably the same age also occur. They dip steeply northward.

Shortly after the formation of these faults a northeast belt of porphyry stocks was intruded in the western half of Colorado, extending across the Front Range from the vicinity of Boulder and Jamestown southwestward to Breckenridge. These stocks are believed to be approximately parallel with the deforming force of the Laramide revolution.[5]

### *Local Structures*

*Pre-Cambrian structures*—Cloos's method of mapping the internal structures of igneous masses was applied to that part of the Boulder Creek batholith which lies within the

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[4] Lovering, T S., The structural relations of the porphyries and metalliferous deposits of the northeast part of the Colorado mineral belt: Ore deposits of the Western States, Am. Inst. Min. and Met. Engrs., pp. 301-305, 1933.

[5] Lovering, T. S., Geology and ore deposits of the Montezuma quadrangle, Colorado: U. S. Geol. Survey Prof. Paper 178, p. 304, 1935.

Magnolia district, and a reconnaissance survey of the structures of the batholith as a whole also was made.

Within the Magnolia district many of the aplite and pegmatite dikes parallel the linear structure but all of the longest, and the greatest number, of the dikes are normal to the pitch of the linear structure. Remarkably often the dip is complementary to the pitch of these lines. (See figs. 3 and 5.)

The foliated Boulder Creek granite gneiss is cut by a great number of non-foliated aplite and pegmatite dikes. A few aplites, however, are themselves foliated parallel with their own contacts but across the platy structures of the gneiss. The change in strike and dip of many of the dikes, in strict correspondence with the changing direction of pitch of the flow lines of the gneiss, indicates a genetic relation between the dikes and the flow lines.

Under the microscope, the gneiss shows an order of crystallization characteristic of igneous rocks. The minerals are not granulated nor recrystallized. Throughout the district numerous small inclusions of schist parallel the linear or platy structures. The Boulder Creek granite gneiss thus seems unquestionably to be primary.

As shown in figure 3, in the Magnolia district the trend of the platy structure is west to N. 45° W. although locally, as in the northeastern part, it is often north of east. The dip is northward usually at a high angle, and the average is approximately 60°. The linear structure pitches slightly west of north to slightly east of north at angles that range from 5° to 75° but at most places closely approaches the average, 35°. Detailed study of the gneiss within the Magnolia district and a reconnaissance of the batholith as a whole indicate that the magma ascended at a steep angle in the vicinity of Bighorn Mountain and Butzel Hill, to the north of the district, and spread laterally largely to the south. (See figs.4 and 6.)

### *Post-Cambrian Structures*

*Foothills monocline*—In the eastern extremity of the Magnolia district the Fountain formation rests unconform-

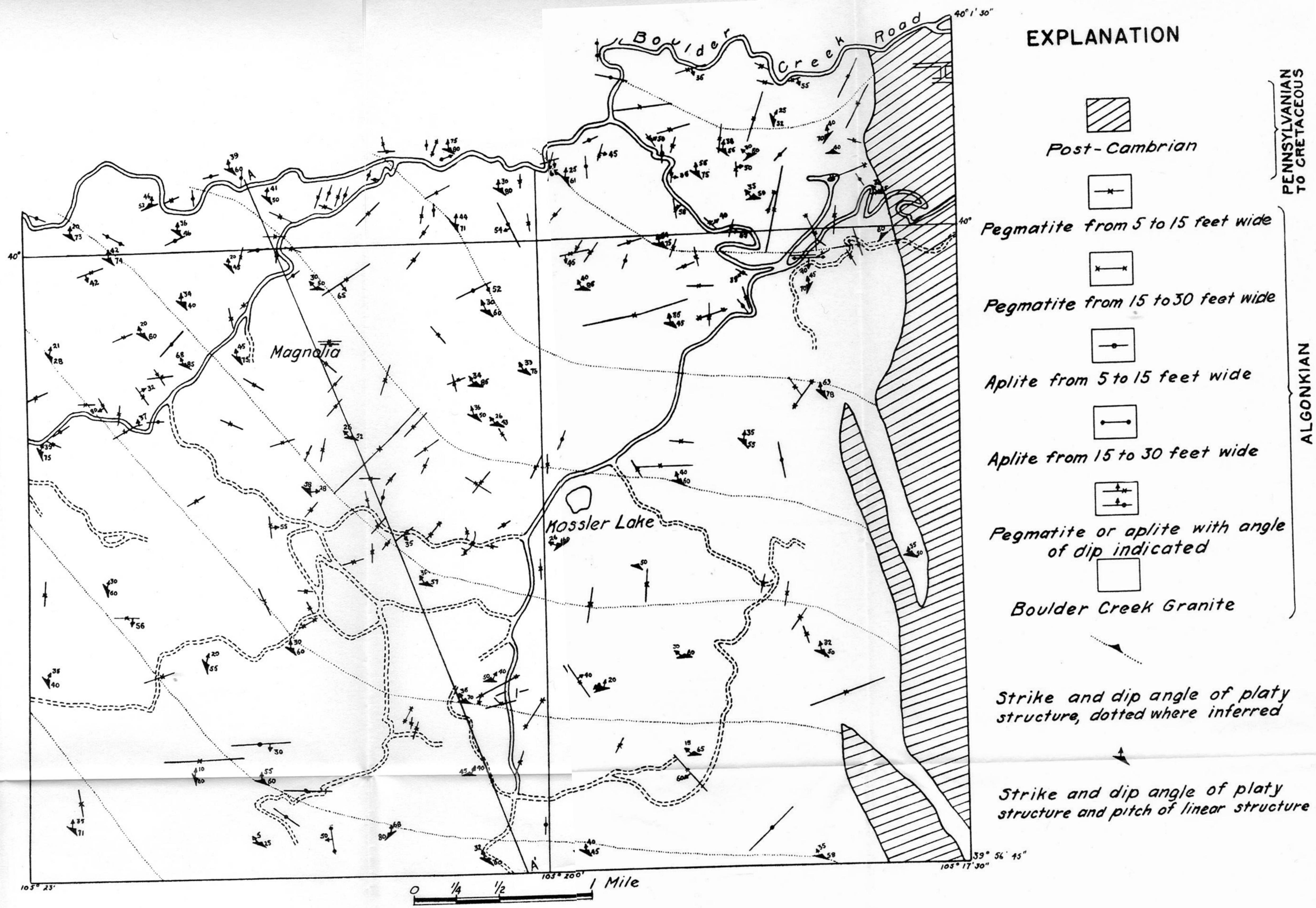

FIG. 3—PRE-CAMBRIAN STRUCTURAL FEATURES OF THEE MAGNOLIA MINING DISTRICT

ably upon the gneiss and dips on an average of 50° eastward. The foothills monocline and en echelon faults have been well described by Marvine,[6] Eldridge,[7] Fenneman,[8] Ziegler,[9] and others.

*Breccia faults*—Several fault zones trend diagonally northwestward across the district and continue for a number of miles. At least two of these faults are traceable southeastward to echelon faults in the foothills. One is known to die out in an echelon fold in the sedimentary beds at the foot of the mountains. The foothills echelon faults were recognized early but their extensions into the gneiss area were not followed for many years. Lovering[10] was the first to describe the faults in any detail. The northwestward-trending faults are known as the Maxwell, Hoosier, and Livingston faults or "breccia dikes". Two eastward-trending faults are known locally as the Copeland and Red Sign faults or "breccia dikes".

The *Maxwell fault* is an iron-stained silicified fault zone that is generally 10 to 30 feet wide, and has been traced for more than 20 miles from Green Mountain northwestward to north of Allen's Park. In the Magnolia district this fault zone can be traced from Green Mountain to that part of Boulder Canyon which is south of Orodell. (See fig. 2.) The strike of the fault is approximately N. 30° W. throughout much of this distance, and the fault plane dips at a high angle. What may be a branch passes through Artist Point, a quarter of a mile west of Flagstaff Hill, bifurcates and continues northward to Boulder Canyon road and beyond. The Maxwell fault is best exposed on the west side of the Kossler Lake road, a few hundred feet south of where the road

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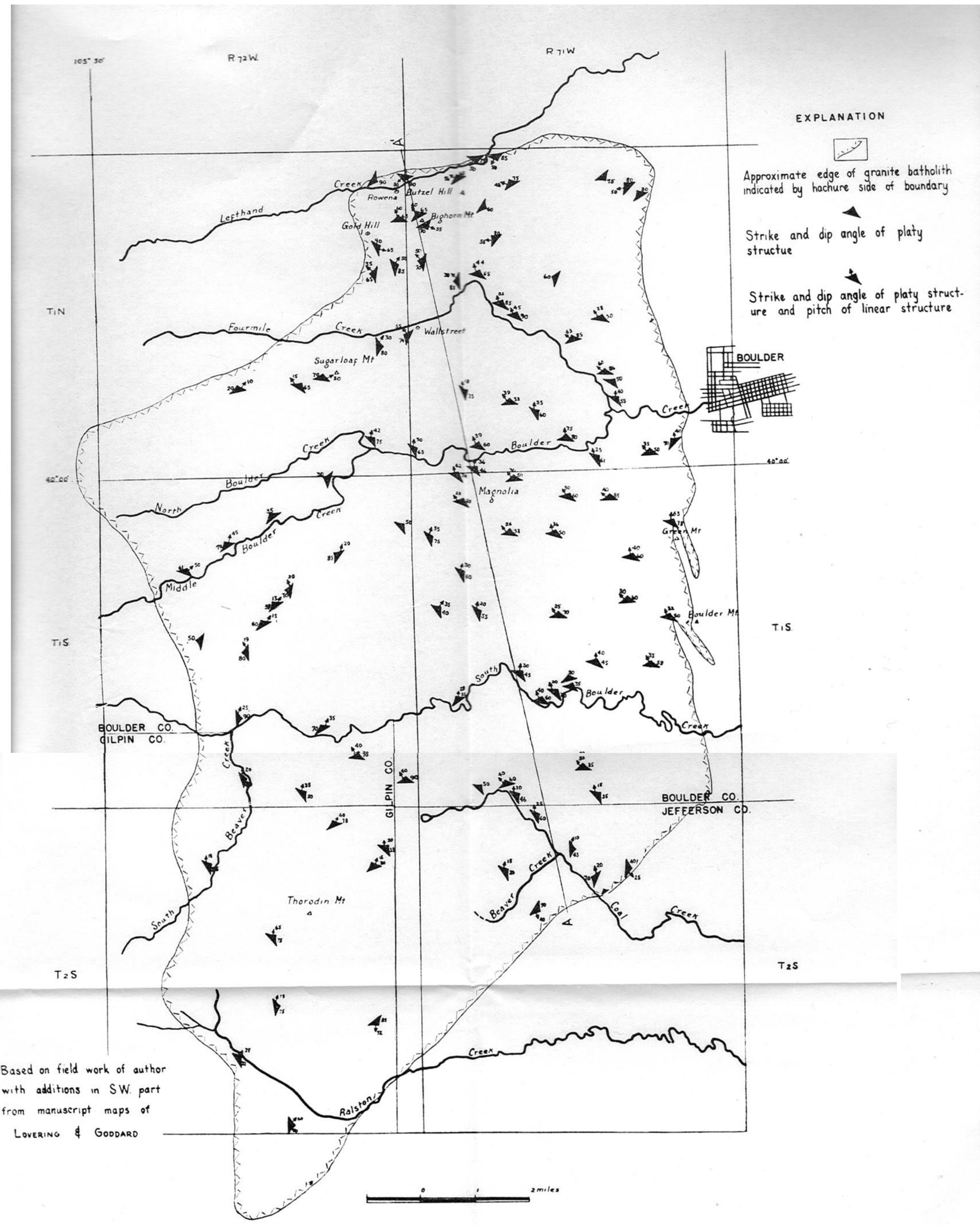
[6] Marvine, A. R., Seventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., p. 135, 1873.

[7] Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 115-118, 1896.

[8] Fenneman, N. M., op. cit., pp. 46-47.

[9] Ziegler, Victor, Foothills structure in northern Colorado: Jour. Geology, vol. 25, no. 8, pp. 715-740, 1917.

[10] Lovering, T. S., Preliminary map showing the relations of ore deposits to geologic structure in Boulder County, Colorado: Colorado Sci. Soc. Proc., vol. 13, no. 3, pp. 80-81, 1932.



EXPLANATION

Approximate edge of granite batholith indicated by hachure side of boundary

Strike and dip angle of platy structue

Strike and dip angle of platy structure and pitch of linear structure

Based on field work of author with additions in S.W. part from manuscript maps of Lovering & Goddard

FIG. 4 — PLATY AND LINEAR STRUCTURE IN THE BOULDER CREEK GRANITE BATHOLITH

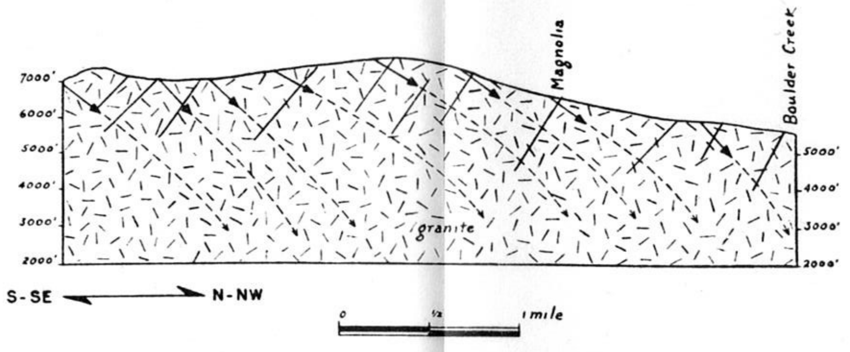


FIG. 5 GENERALIZED SECTION ALONG LINE A-A', FIG. 4, THROUGH THE BOULDER CREEK BATHOLITH WITHIN THE MAGNOLIA DISTRICT, SHOWING THE PITCH OF THE LINEAR STRUCTURAL FEATURES AND THE RELATION OF THE STRETCHING TO THE JOINTING.

EXPLANATION

Tension joints containing pegmatite

Linear structure, dashed where inferred

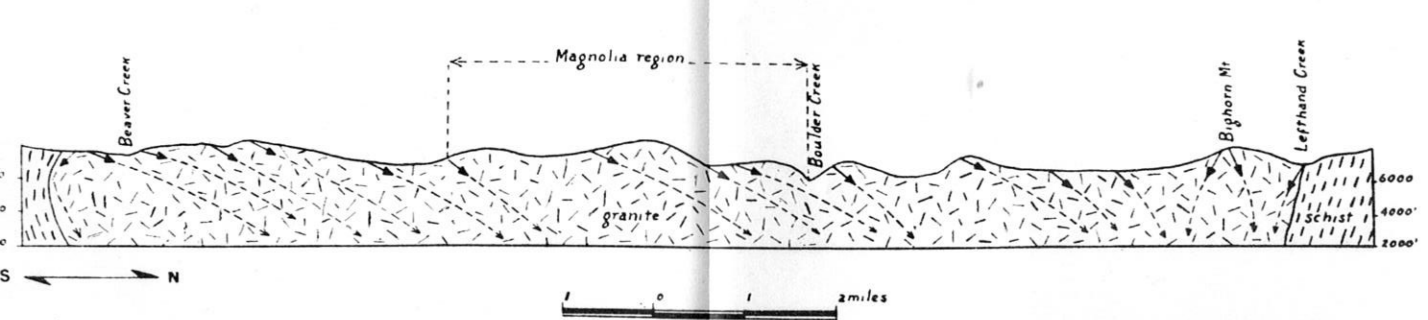


FIG. 6 GENERALIZED SECTION ALONG LINE A-A', FIG. 4, THROUGH THE BOULDER CREEK BATHOLITH SHOWING THE PITCH OF THE LINEAR STRUCTURAL FEATURES AND THE HYPOTHETICAL SUBSURFACE OF THE IGNEOUS MASS.

branches from the Flagstaff Hill road, and in a road-cut on the south side of the Boulder Canyon road several hundred feet east of where it crosses Boulder Creek south of Orodell. The southeastern extremity of the fault deflects the igneous-sedimentary contact to the west and repeats the Fountain formation. Here it is known as the Green Mountain fault.

The exposure of the fault zone in Boulder Canyon shows it to be a shear zone about 90 feet wide and to be marked by sheared, partly chloritized, slightly silicified and iron-stained granite gneiss. The more highly silicified portion is approximately 25 feet wide and stands at the surface as a resistant wall about 15 feet high. The zone strikes N. 30° W. and dips 80° SW. The footwall is highly polished and locally grooved, and the evidence indicates a movement of the hanging wall, with reference to the footwall, down dip about 70° northwestward.

Microscopic examination of this part of the fault zone shows it to be a highly brecciated and fractured gneiss, the largest unbroken fragments studied seldom exceeding 1.5 mm in diameter. Although highly brecciated, microcline, orthoclase, oligoclase, quartz with undulatory extinction, magnetite, and a very small amount of zircon are recognized. Much of the feldspar is altered to epidote. Leucoxene is an alteration product of perhaps both titanite and ilmenite. The breccia is silicified with cherty quartz, and iron oxides fill many of the fractures. A portion of the fault zone at Artist Point is marked by brecciated aplite.

The *Hoosier fault*, like the Maxwell fault, is an iron-stained silicified fault zone, generally 20 to 50 feet wide, which can be traced from Boulder Mountain to Lefthand Creek, about 1 mile west of Rowena. As shown in figure 2, in the Magnolia district the zone extends from Boulder Mountain northwestward to a few hundred feet east of the junction of the Magnolia and Boulder Canyon roads. It trends N. 35° W. and is vertical throughout much of this distance. Approximately parallel with this main fault zone is another that is several hundred feet north of it. This zone can be traced from Shadow Valley heading between the Boulder Peaks, northwestward to approximately half-way between Kossler Lake and Boulder Creek. The Hoosier fault zones are well exposed along the northwestern slope of Boulder Mountain, about an eighth of a mile north of the west end of Kossler Lake, and a few hundred feet east of the junction of the Magnolia and Boulder Canyon roads. The fault between the Boulder Peaks deflects the igneous-sedimentary contact to the west and repeats the Fountain formation forming two peaks instead of one. Here the fault is known as the Boulder Peaks fault.

The Hoosier fault zone changes greatly in composition and texture along its strike, varying from a slightly fractured to a highly comminuted granite gneiss, but all varieties are impregnated with much hematite and silica. Quartz was introduced twice; the first was accompanied by hematite, the second lacked hematite and was slightly coarser than the first. At several localities, as north of Kossler Lake, the fault zone has the appearance of a dense scoriaceous rhyolite, due to the weathering of portions of the granite fragments which leaves numerous cavities in an iron-stained microfelsitic groundmass. At other localities the fault zone is characterized by much glassy quartz that resembles the "bull" quartz of pre-Cambrian pegmatite and contains many criss-cross veinlets of hematite.

The *Livingston fault* is quite similar to the Maxwell and Hoosier faults. It is often marked by coarse-grained glassy quartz seamed with hematite. The zone is 30 to 70 feet wide and extends from south of Walker ranch to Black Tiger Gulch and thence to half a mile northeast of Gold Hill station. It closely parallels the "Iron Dike" and is virtually vertical. At least two minor branches of the Livingston fault occur within the district; one short branch is about a mile west of Kossler Lake, the other trends southwestward from about a third of a mile west of the Magnolia school to the Kekionga mine and perhaps beyond. (See fig. 2.)

The rocks of the fault zone are minutely fractured and brecciated, and under the microscope mortar and flaser structures are characteristic. Stringers of sutured quartz with strain shadows indicate an introduction of quartz that subsequently was under considerable stress. Hematite occurs in the sheared portions of the rock and along cleavages of the feldspars.

An eastward-trending fault joins the Livingston and Hoosier faults in the northwestern part of the district. It is known locally as the *Red Sign fault or "breccia dike"*. The easily traced fault zone trends eastward from near the mouth of Black Tiger Gulch and gradually swings southward to the Acme mine. About a quarter of a mile south of the portal of the Acme tunnel the fault bifurcates; one branch continues southeast through the Crownpoint mine, and the other branch runs eastward through the Cold Spring and Iron Age properties. The fault zone is 10 to 40 feet wide, locally dips 65° N., and is brecciated and silicified to about the same extent as the other fault zones mentioned. Striations on slickensided hard rock surfaces indicate a virtually horizontal movement of the right wall ahead for that portion of the fault which is just north of the Graphic mine.

The *Copeland fault* is another iron-stained silicified fault zone, generally 45 to 70 feet wide, which is in the central southern and southwestern parts of the area. The fault is easily traced from the broad zone of brecciation at the intersection of the Copeland and Livingston faults, half a mile southeast of Walker ranch, to the westward about a third of a mile where it bifurcates. (See fig. 2.) One branch continues N. 65° W. about half a mile. This branch dips 65° NE. and is 20 feet wide. The other continues to the westward several miles.

On the south and southwest parts of a hill which is slightly less than half a mile southwest of the Walker ranch, the fault zone is conspicuous. The zone of brecciation is 70 feet wide and an exposure of the hanging wall for several hundred feet horizontally and 50 to 80 feet vertically is highly polished, plucked, and striated. The fault plane dips 65° N., and the footwall moved eastward down dip 25°. This movement took place after the introduction of iron oxide. Under the microscope the brecciated rock reveals flaser and mylonitic structures to be common. Repeated fracturing occurred, and at least three periods of mineralization are recognized. The first is hematite with a little quartz, followed by a very fine cherty quartz, and finally by quartz which is slightly coarser and which is accompanied by some ferberite and alunite.

The *Green Mountain and Boulder Peaks faults* are southeastern extensions of the Maxwell and Hoosier faults, respectively. The foothills faults were recognized by the early geologic workers in the region.

Echelon folds, some of which are thrust-faulted, are characteristic of the Front Range, especially north of Boulder. One of the folds, about 15 miles north of Boulder, is closely compressed and broken by a northwestward-trending fault that has dropped its west side. This is characteristic of the other echelon folds, and the amount of deformation is known to become greater and greater as Boulder is approached from the north.[11] The Green Mountain and Boulder Peaks faults have an arrangement and displacement similar to the faults that break the echelon folds to the north. The folds and faults to the north of Boulder are recognized as having originated as a result of the compression that created the master monocline during the Laramide revolution. The writer knows no valid reason for believing that the Green Mountain and Boulder Peaks faults did not originate at the same time, and as a result of the same compressive force, as the other echelon faults and folds. The specific problem of the faults in the vicinity of Boulder is that of the direction of inclination of the fault planes.

Marvine[12] mapped the Green Mountain fault plane in Bear Canyon as dipping eastward at a high angle. Eldridge[13] saw the fault plane in Bear Canyon dipping 60° to 80° W. The present writer mapped the fault closely and believes

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[11] Lovering, T. S., op. cit. p. 79.

[12] Marvine, A. R., op. cit., pl. 2, section 10.

[13] Eldridge, G. H., op. cit., pp. 115-116, 118.

that the plane dips steeply eastward in Bear Canyon, is about vertical near Gregory Canyon, and from there northwestward dips steeply to the west. Everywhere the plane tends toward the vertical. The amount and direction of dip of the fault plane changes along its strike, and perhaps with depth.

Fenneman[14] states that the Boulder Peaks fault plane dips westward, and that the plane can be "clearly seen" in the valley which trends southward from the peaks. Lovering[15] states that a portion of the northwestern extension of the Boulder Peaks fault plane dips 35° NE. The Livingston fault, which is in all respects similar to the foothills faults, dips 50° to 55° NE. about a mile south of the Magnolia district.

All of these various dips of the fault planes are understandable if the planes are undulating surfaces, slightly concave toward the east.

It is generally recognized that the zone of weakness which trends N. 40° E. across the Front Range, and into which the Tertiary stocks were intruded, is the effect of the tensional stresses that resulted from strong regional compression from the northeast and southwest at the time of the Laramide revolution. At approximately the same time the stresses caused the rocks to fail along planes of maximum shear that trend east to N. 30° to 35° W. Since slickensides on some of the fault surfaces indicate movement in the vertical direction, i.e., oblique slip movement, the same compressive forces that first found release in horizontal movement along steeply inclined planes of maximum shear, later found release partially in vertical movement.

*Mineralized fissure zones*—The trends of the ferberite and gold telluride fissure zones are diagrammatically shown in figures 7 and 8, respectively. The diagrams were made by calculating the approximate area (average width multiplied by estimated length) of each vein of similar trend and mineralization, and then scaling off in appropriate directions dis-

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[14] Fenneman, N. M., op. cit., p. 46

[15] Lovering, T. S., Oral communication.

tances proportionate to the sum of the various areas. The extremities of the lines were then joined in succession. These figures indicate that the major gold telluride fissures trend west and N. 50° W. and that the major ferberite fissures trend either east or N. 75° to 80° E. Both figures indicate the presence of minor mineralized fissures that box the compass.

FIG. 7—ILLUSTRATIVE OF THE TREND OF THE TUNGSTEN VEINS IN THE MAGNOLIA MINING DISTRICT. LENGTH OF LINE INDICATES RELATIVE IMPORTANCE OF VEINS.

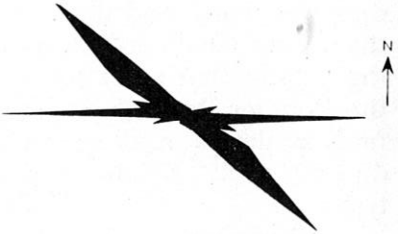

FIG. 8—ILLUSTRATIVE OF THE TREND OF THE TELLURIDE VEINS IN THE MAGNOLIA MINING DISTRICT. LENGTH OF LINE INDICATES RELATIVE IMPORTANCE OF VEINS.

A study of the paragenesis of the ores reveal the telluride mineralization to be later than the persistent silicified and hematite-impregnated breccia fault zones previously discussed, and the major part of the tungsten mineralization to have occurred after the deposition of the tellurides.

## ORE DEPOSITS

### *Mineralogy and paragenesis*

The gold telluride fissure zones contain several telluride minerals, chalcedonic quartz, disseminated pyrite, and small amounts of native gold, sphalerite, marcasite, fluorite, and calcite. Sylvanite is the main ore mineral and usually is accompanied by one or more of the following tellurides: calaverite, hessite, petzite, coloradoite, altaite. The various tellurides are in blades that average about 1.5 to 2.5 mm in length and 0.5 mm in width and in many places are so abundant that they resemble single large prismatic crystals. The fissure zones commonly consist of several narrow seams of telluride minerals; seldom does the ore occur in a single seam. The seams generally are one-sixteenth to half an inch wide, although some several inches wide are found.

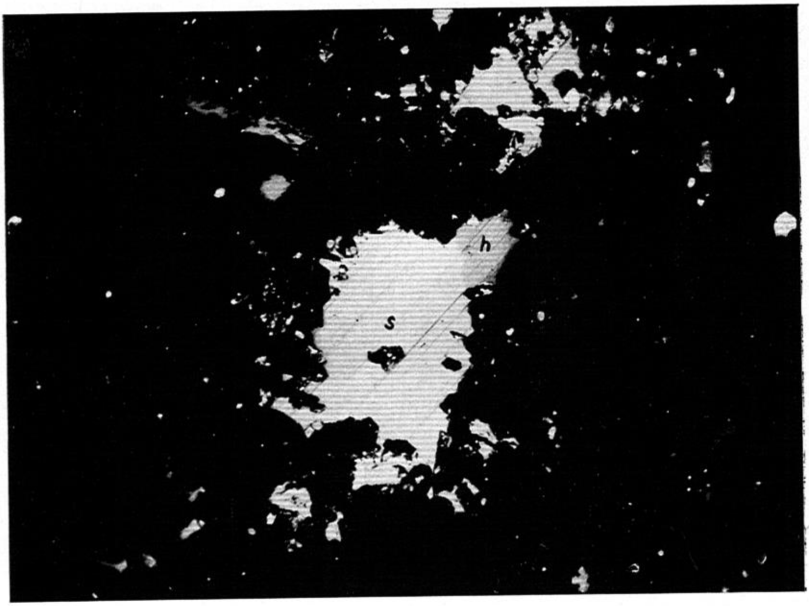

Figure 9. Photomicrograph of telluride ore from Eclipse mine. Hessite (h) replaces sylvanite (s). Black areas are quartz. x 68.

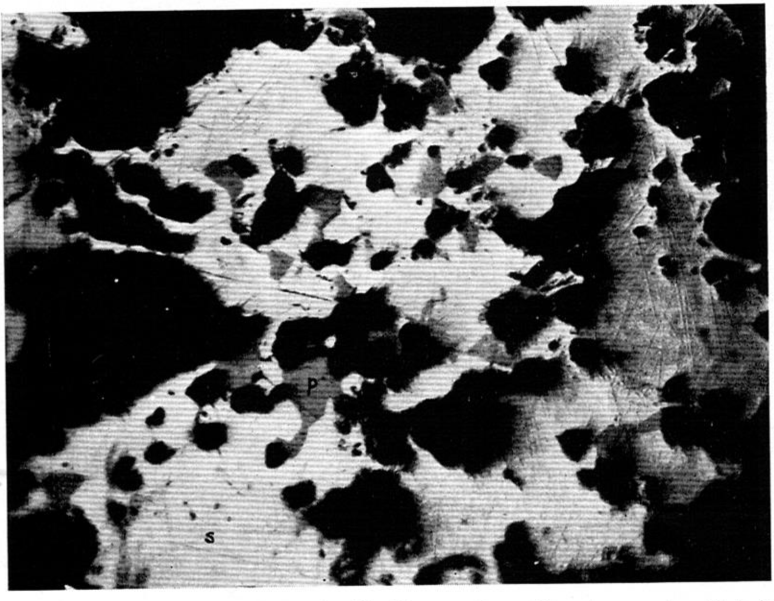

Figure 10. Photomicrograph of telluride ore from Keystone mine. Petzite (p) replaces sylvanite (s). Black areas are quartz. x 127.

The tungsten fissures contain ferberite, chalcedonic quartz, pyrite, sphalerite, and a small amount of alunite. The ferberite is found in very small blades that average about 0.22 mm long by 0.10 mm wide. At a few places the fissures contain a single seam, but commonly they have several that are a quarter of an inch to 3 inches wide.

The telluride-native gold sequence of mineralization is probably as follows:

| | | |
|---|---|---|
| 1. | sylvanite | $(Au\ Ag)\ Te_2$ |
| 2. | calaverite | $(Au\ Ag)\ Te_2$ |
| 3. | petzite | $(Au\ Ag)_2Te$ |
| 4. | hessite | $Ag_2\ Te$ |
| 5. | coloradoite | $Hg\ Te$ |
| | altaite | $Pb\ Te$ |
| 6. | native gold | $Au$ |

### *Types and distribution*

All the ore deposits in the Magnolia district are fissure fillings. Most of the gold telluride veins strike west of northwest. Northeastward-trending veins are uncommon and are relatively unimportant. Many of the veins do not exceed several hundred feet in length. Few attain 1,000 feet, but the longest known mineralized fissure, that of the Kekionga, is at least 6,000 feet. The veins range in width from a mere slip to several feet. They dip steeply both north and south with an average of 60° to 70° and are mineralized portions of both normal and reverse faults that have had a strong horizontal component of movement. Aside from a small amount of telluride mineralization within the Copeland fault, all the gold deposits lie in the northwestern part of the district and are close to one or another of the breccia fault zones.

All the tungsten veins occur within, or but a comparatively short distance from, one or another of the westward-trending breccia fault zones. Most of the tungsten veins trend eastward or east-northeastward, dip steeply northward and southward, and are mineralized portions of both normal and reverse faults. Some of the veins probably are not much longer than several hundred feet and are only 1 or 2 inches wide. Longer ones are a foot or more wide. They follow pre-mineral faults along which displacement was chiefly in a horizontal direction. Throughout the district the north wall moved westward in reference to the south wall. With the exception of the ferberite mineralization within the Copeland fault, all the tungsten veins lie within the northwestern part of the district.

Only the strong westward- and northwestward-trending breccia faults were influenced by the early barren stage of mineralization. These faults served as passageways for the ascending solutions that silicified the zones. With continued stresses new westward- and northwestward-trending systems of fissures were formed. The writer believes that a change in the direction of stresses then formed comparatively narrow fissures within the eastward-trending silicified fault zones and also formed new short eastward- and east-northeastward-trending fissures. The breccia faults were tightly silicified and almost closed at the end of the period of barren mineralization, and the solutions that continued to rise found conditions favorable for deposition only where channels had been reopened within the silicified faults or where fissures had been formed nearby. In the newly formed openings, tellurides, and then the major part of the ferberite, were deposited.

### *Vertical range of ore deposition*

The greatest proved vertical range of gold ore in an ore shoot is about 400 feet, but the vertical range of ore deposition is much greater. The gold ore of the Bessie and other veins of the Acme mine is at an altitude of approximately 6,200 feet; similar ore occurs in the Kekionga vein at an altitude of about 7,800 feet—thus deposition through a vertical range of 1,600 feet.

The greatest proved vertical range of tungsten ore in an ore shoot is less than 100 feet, although the vertical interval of tungsten deposition is many times this figure. Ferberite in the Dove vein is at an altitude of 6,400 feet, and that of the Kekionga is about 7,650 feet. A minimum vertical range of 1,250 feet for ferberite deposition is shown in the district.

### *Enrichment*

Partial oxidation extends to a depth of at least 200 feet beneath the surface. Although secondary enrichment of the telluride ores—by leaching of tellurium and probably of some silver—was of importance in the oxidized zone, supergene deposition of gold was not recognized in any of the deposits visited. The writer was shown numerous specimens of "rusty" gold in porous quartz which were collected during the early days of the camp. Much of the rich ore then mined was said to have been "rusty" gold found at or close to grass roots. Oxidation has had no visible effect on the tungsten deposits.

### *Relation of ore to depth*

Since the lower portions of all ore shoots were inaccessible, the writer did not have the opportunity to study possible mineralogical changes at or close to the bottom of any ore shoot. The greatest accessible depth below the surface was but slightly greater than 200 feet (Keystone mine). The various tellurides and their gangues do not change within this short distance. There are no distinct mineralogical differences in the fissure fillings of gold veins within the Magnolia district. "Rusty" gold was reported to a depth of about 140 feet below the surface.

Neither ferberite nor its mineral associates change in variety or relative amounts with depth attained in the district.

### *Localization of ore*

Gold and tungsten ores are localized in shoots and pockets and show a marked lack of persistence. They have no visible limits other than those indicated by the assay. For the development of an ore shoot solutions must have gained access to a region of unfilled openings. Concentration of ore in the Magnolia district took place in and close to openings in the veins that were dependent upon structural factors—such as junctions of fissures and irregularities of the fissures coupled with the pre-mineral movement. The chemical composition of the walls of the fissures had no influence on the localization of ore.

Although ore deposition was common at intersections of fissures, it was by no means always the rule. At some junctions much gouge formed, but at many places the intersections were much more open than any of the individual fissures. Such openings were favored locations for the deposition of ores because here the ore solutions found easiest access toward the surface. Ore shoots in the Acme, Audophone, Ben C. Lowell, and Poorman are examples of shoots that formed at fissure junctions.

If appreciable horizontal movement along a sinuously-trending fault occurred, open spaces formed. Open spaces likewise formed where there were marked changes in the dip of a fault that had dip slip movement. When the left wall of an eastward-trending fissure moved ahead with a large horizontal component, the fissure narrowed or tightened where it swung to the left, i.e., trended northeast, and open spaces were created where it swung to the right, i.e., trended southeast. Where the hanging wall moved down over the footwall, openings occurred where the dip of the fault steepened, and in a reverse fault the open spaces formed where the dip lessened. Ore shoots in the Kekionga and Keystone mines were formed in openings thus created.

Deposition of ore in the shoot in the Ben C. Lowell vein was facilitated by the "Iron Dike" which caused the circulation of the rising solutions to be impeded, and partial stagnation followed that resulted in more complete precipitation of the ore below the dike. The same principle of impermeable barriers serves to explain why the ore was most often confined between the gouge seams of the hanging wall and footwall without entering the adjacent rock. At many places where the vein was more open and gouge seams were absent, ore was deposited as narrow feeder veinlets in the wall rock and locally enriched these portions. The evident inability of the solutions to penetrate gouge is exemplified in the Bessie vein of the Acme mine, where the mineralized portions of the fissure zone end abruptly against the Red Sign fault gouge.

The largest individual gold ore shoot is that on the Keystone vein. The shoot is 150 feet long and as much as 20 feet wide with a 500-foot pitch length. It pitches 55° SE. Usually the ore shoots do not exceed 100 feet in length, 6 to 10 feet in width, and 250 feet in pitch length. Many small pockets range from 10 to 60 feet in strike length, 10 to 30 feet in height, and 5 to 6 feet in width. The general ratio of pitch length to strike length varies from 3:2 to 4:1. All have been bottomed at depths of less than 600 feet from the surface. They generally are lenticular in shape and, with the exception of that in the Ben C. Lowell vein, pitch toward the southeast at an angle that closely approaches 55°. A few of the shoots are flat-lying. The largest of these, that in the Bessie vein in the Acme mine, was 225 feet in strike length, probably 5 to 10 feet in width, and 20 to 25 feet high. Most of the ore shoots cropped out at the surface in rich oxidized parts on which the shafts and adits were driven. Most of the pockets were blind and were discovered during exploration work.

Tungsten deposits are very erratic and are found as pockets in the veins. The largest individual pocket seen by the writer was that on the Ellis vein. Its strike length was 75 feet, width 15 to 20 feet, and height about 40 feet. Most of the pockets, however, are about 40 feet long, 6 to 10 feet wide, and 15 to 20 feet high.

### *Origin of the ore deposits*

It has been stated previously that a belt of stocks occurs in the Front Range from Jamestown southwestward to Breckenridge. Since the mineral and porphyry belts coincide, a genetic relation of the ore deposits to these porphyries has long been inferred.

The lack of persistency of most of the fissures, and therefore of the mineral deposits that fill them, indicates rupture under slight load. The fineness of grain of both ore minerals and gangue is doubtless a direct expression of the rapidity with which saturation was attained and crystallization induced by rapid loss of temperature and pressure close to the surface. Flaser structure and undulose extinction of the quartz grains in parts of the breccia faults are suggestive of deformation at shallow depths. Many other factors point to a comparatively shallow origin of the deposits: common occurrence of vugs, drusey structure of parts of the veins, chalcedonic quartz gangue, presence of marcasite and alunite, and total absence of heavy silicate gangue minerals and large amounts of sulphides. The ores probably formed near the lower part of the epithermal zone. It is probable that the highest parts of the present surface are not more than 3,000 feet below the surface that existed when the ores were formed about basal Eocene time.

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