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PRELIMINARY REPORT ON THE GOLD HILL MINING DISTRICT, BOULDER COUNTY, COLO.[1]

by

E. N. GODDARD[2]

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ILLUSTRATIONS

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[1]Published by permission of the Director, Geological Survey, United States Department of the Interior, of the Colorado State Geological Survey Board, and of the Colorado Metal Mining Fund.

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Introduction

The Gold Hill mining district, as covered in this report, includes the greater part of the Boulder County telluride belt. It has long been noted for its variety of telluride minerals and in recent years has produced more than 65 percent of the gold and silver mined in the county. The mines, though small, have produced some very rich gold-telluride and free-gold ore. The largest, the Slide mine, has made a gross production of between one and two million dollars in gold and silver.

The area covered in this report comprises about 12 square miles in the central part of Boulder County, from 3 to 8 miles northwest of Boulder and about 30 miles (airline) northwest of Denver. It includes the camps of Sunshine and Salina as well as the greater part of the Sugar Loaf district. Gold Hill is the chief town and has a permanent population of about 100 people. Other settlements comprising a few houses each are Rowena and Glendale on Lefthand Creek, Sunshine in the eastern part of the district and Summerville, Salina, Crisman, and Wallstreet in the central and southern parts.

The district ranges in altitude from 5,900 to 8,400 feet. The town of Gold Hill is connected with Boulder, the nearest railway shipping point, by 12 miles of fair automobile road, and nearly all the mines are readily accessible by automobile.

The areal geology and petrography of the area was studied in 1906 and 1907 by R. D. Crawford,[3] whose map was incorporated in Worcester's report on the Ward region,[4] but no detailed work was done on the structural features nor on the ore deposits. In the fall of 1931, T. S. Lovering,

[3]Crawford, R. D., Geology and petrography of the Sugar Loaf district, Boulder County, Colorado: Univ. of Colo. Studies, vol. VI, no. 2, 1909.

[4]Worcester, P. G., The geology of the Ward region, Boulder County, Colorado: Colo. Geol. Surv. Bull. 21, 1920.

assisted by L. B. Graff and Bert Stegeman, traced the system of strong northwest-trending faults known as breccia reefs[5] through the Gold Hill region. During the summers of 1934 and 1935 Lovering and the writer visited several of the more important mines in the district and mapped some of them in detail. In the summer of 1937, an excellent topographic map of the district on a scale of 1/12,000 was prepared by S. G. Lunde of the topographic branch of the U. S. Geological Survey and, with this map as a base, the writer mapped the geology in detail and studied the ore deposits during the field seasons of 1937, 1938, and 1939. Stanley Jerome and Lawrence Warner ably assisted in this work. A few areas in the southern part of the district have not yet been mapped but most of the veins in those areas have been traced. The geology of the area which includes the Logan and Yellow Pine mines and vicinity was mapped in 1932 by Lovering during his work in the Nederland district, but, as this area belongs more properly to the Gold Hill district, he has kindly contributed that part of his Nederland map to the Gold Hill geologic map. The geology of Poorman Hill was mapped by Lovering and the writer in 1936.

The writer wishes to express his appreciation to the mining men of the district and of Boulder for their valuable assistance and wholehearted cooperation and to his colleagues of the U. S. Geological Survey for much helpful advice; and to Chas. W. Henderson, of the Colorado Scientific Society for editing and critical reading of the manuscript.

History[6] and Production

In the fall of 1858, a party of fifteen or twenty prospectors under Captain Thomas Aikens camped near the mouth of Boulder Canyon. In January 1859, a few members

[5] Lovering, T. S., Preliminary map showing the relation of ore deposits to geologic structure in Boulder County, Colorado: Colo. Sci. Soc. Proc., vol. 13, no. 3, pp. 77-88, 1932.

[6] Fossett, Frank, Colorado—Gold and Silver Mining Region, Denver Daily Tribune Printing House, 1876.
Henderson, Chas. W., Mining in Colorado; U. S. Geol. Survey Prof. Paper 138, pp. 8, 38, 1926.
Montgomery, Mabel G.—A Story of Gold Hill, Colorado, May, 1930. (A privately published booklet that can be purchased from Mrs. Montgomery in Boulder, Colorado.)

of this group started prospecting, and on the sixteenth, discovered gold in Gold Run Creek at the present site of Gold Hill. News of this discovery was carried back immediately to the valley camp and spread rapidly. Between three and five thousand people flocked to the district during the first few seasons. In the first summer, it is reported that $100,000 worth of gold was washed from Gold Run.

During the summer of 1859 a search was made for veins and the first claim was located by J. D. Scott in the vicinity of the Cold Spring mine. The same year, David Horsfal discovered the Horsfal lode (Fifty Nine claim). The first settlement of Gold Hill was on the flat-topped ridge one-half mile east of the present town, but in the fall of 1860 this settlement was wiped out by a forest fire. Although a few cabins were rebuilt, most of the new town grew on the present site; the 1890 Census gave it a population of 425.

After 1860, mining in the district rapidly declined, but suddenly became active again in 1872 with the discovery of gold-telluride ores at the Red Cloud mine. Other telluride veins were soon found and very rich ore was mined from many properties. Ore having a value of $61,000 was produced from the Red Cloud vein from August 1 to December 31, 1872,[7] and in the same year the Cold Spring vein adjacent to the Red Cloud was opened. In 1874 the American and Interocean telluride veins at Sunshine were discovered; the Slide claim near Gold Hill was located in 1875 and the Emancipation claim in 1877.

Mining in the district was stimulated in 1898 by the completion of a railroad from Boulder to Ward, passing just three miles west of Gold Hill. An earlier railroad extending as far as Sunset was washed out by the flood of 1894.

During the early part of the twentieth century there was a gradual decline of activity in the district, lasting until the fall of 1933, when the sudden rise in the price of gold caused a great increase in activity. As a result, the gross production of the district (including the Sugar Loaf district) jumped from $79,368 in 1933 to $450,995 in 1934, and to

[7]Thompson, L., Mines of Boulder County, Mining Rev., vol. 1, no. 5, p. 8, Jan. 1873.

$816,929 in 1939.[8] During 1934 the Ingram, Slide, Klondyke, Interocean, Emancipation, Wood Mountain, Poorman, Grand Republic, and many other mines were reopened and actively worked, and the production continued to increase during the next five years.

Few figures are available on the production of the Gold Hill district in the early days. Fossett[9] in 1879 stated that "the district has probably produced half a million (dollars) altogether." The total production of gold, silver, copper and lead, in terms of recovered metals, in Boulder County through 1939 has amounted to $30,008,589.[10] As careful an analysis as can be made of the relative production of the several mining districts of Boulder County seems to indicate that the Gold Hill district (including the Sugar Loaf district) has contributed somewhat more than one-third of the county's production, or between $10,000,000 and $12,000,000. The production figures of the Gold Hill district and of the Sugar Loaf district[11] from 1904 to 1939 are given in the following tables:

[8]Data furnished by Chas. W. Henderson, U. S. Bureau of Mines, Denver, Colo.

[9]Fossett, Frank, Colorado, its gold and silver mines: C. B. Crawford, printer, New York, p. 273, 1879.

[10]Henderson, Chas. W., Mining in Colorado: U. S. Geol. Survey Prof. Paper 138, p. 106, 1926.

——————, Gold, silver, copper, lead, and zinc [mining] in Colorado: Minerals Year Book, U. S. Bureau of Mines, 1935-1940. These figures of the gross production of gold, silver, copper, and lead for the county do not include $20,000,000 gross output of tungsten. (C. W. H.)

[11]At least 90 percent of the production of the Sugar Loaf district has come from the area included in this report.

Year	Ore sold or treated	Gold (lode and placer)		Silver (lode and placer)		Copper		Lead		Total value
	Short tons	Fine ounces	Value	Fine ounces	Value	Pounds	Value	Pounds	Value	
1904	5,207	9,273.20	$191,677	14,538	$8,324	1,800	$225	-------	-------	$200,226
1905	4,120	5,647.71	116,748	44,157	26,670	-------	-------	-------	-------	143,418
1906	2,351	3,238.94	66,955	11,873	7,955	-------	-------	47,491	$2,707	77,617
1907	1,040	2,312.02	47,794	4,909	3,240	-------	-------	4,076	216	51,250
1908	5,218	2,858.67	59,094	12,247	6,491	-------	-------	84,000	3,528	69,113
1909	1,438	2,621.92	54,200	12,932	6,725	514	67	11.199	482	61,474
1910	7,180	2,886.24	59,664	10,676	5,765	1,662	211	47,334	2,083	67,723
1911	10,501	3,837.35	79,325	24,435	12,951	4,118	515	126,247	5,681	98,472
1912	6,540	2,850.85	58,932	18,762	11,539	2,441	403	56,889	2,560	73,434
1913	2,011	1,414.06	29,231	7,828	4,728	1,316	204	42,368	1,864	36,027
1914	1,822	1,258.96	26,025	4,379	2,422	-------	-------	6,240	243	28,690
1915	3,008	2,117.62	43,775	5,173	2,623	554	97	27,723	1,303	47,798
1916	2,163	777.58	16,074	3,467	2,281	1,793	441	5,348	369	19,165
1917	4,239	1,025.89	21,207	5,318	4,382	608	166	7,790	670	26,425
1918	6,967	1,160.71	23,994	4,114	4,114	1,429	353	1,000	71	28,532
1919	1,526	371.71	7,684	20,500	22,960	1,479	275	2,359	125	31,044
1920	216	347.72	7,188	9,278	10,113	1,098	202	12,113	969	18,472
1921	341	518.82	10,725	1,748	1,748	-------	-------	8.379	377	12,850
1922	311	410.17	8,479	5,517	5,517	-------	-------	3,733	205	14,201
1923	56	81.61	1,687	1,639	1,344	-------	-------	515	36	3,067
1924	12	27.28	564	36	24	-------	-------	-------	-------	588
1925	262	406.25	8.398	654	454	-------	-------	-------	-------	8,852
1926	115	405.00	8,372	963	601	-------	-------	850	68	9,041
1927	152	243.52	5,034	552	313	1,031	135	2,048	129	5,611
1928	283	380.57	7,867	4,251	2,487	187	27	3,758	218	10,599
1929	1,134	430.44	8,898	2,270	1,210	-------	-------	904	57	10,165
1930	228	126.02	2,605	748	288	-------	-------	-------	-------	2,893
1931	591	365.28	7,551	1,131	328	-------	-------	-------	-------	7,879
1932	1.267	681.46	14,087	1,195	337	-------	-------	-------	-------	14.424
1933	3,704	992.30	25,363	1,908	668	4,000	256	12.460	461	26,748
1934	24.657	6,370.93	222,664	17,458	11,286	17,200	1,376	60,100	2,224	237,550
1935	34,005	6,680.00	233,800	12,224	8,786	11,300	938	8,900	356	243,880
1936	47,075	10,737.60	375.816	35,508	27,501	30,130	2.772	78,600	3,616	409,705
1937	25,750	8,410.80	294,378	21,810	16,870	41,300	4.997	68,800	4.059	320,304
1938	55,926	11,787.00	412,545	31,779	20,544	78,800	7.722	153,500	7,061	447,872
1939	72,494	17,783.00	622,405	29,663	20,135	154,200	16,037	72,000	3,384	661,961
TOTAL 1904-1939	333,910	110,839.20	$3,180,805	385,640	$263,724	356,960	$37,419	956,724	$45,122	$3,527,070

TABLE 2

Production of metals in the Sugar Loaf district, Boulder County, Colo., 1904-1939

(Compiled by Chas. W. Henderson, Supervising Engineer, Mineral Production and Economics Division, U. S. Bureau of Mines, Denver, Colorado.)

IN TERMS OF RECOVERED METALS.

Year	Ore sold or treated	Gold (lode and placer)		Silver (lode and placer)		Copper		Lead		Total value
	Short tons	Fine ounces	Value	Fine ounces	Value	Pounds	Value	Pounds	Value	
1904	4,971	2,659.41	$54,973	50,787	$29.076	--------	--------	--------	--------	$84,049
1905	3,336	3,930.58	81,253	21,645	13,074	--------	--------	--------	--------	94,327
1906	808	2,982.27	61,649	6,416	4,299	238	$46	--------	--------	65,994
1907	520	1,355.03	28,011	13,734	9,064	--------	--------	--------	--------	37,075
1908	576	1,069.43	22,107	4,291	2,274	18,000	2,376	--------	--------	26,757
1909	6,489	1,611.75	33,318	28.908	15,032	3,908	508	411,677	$17,702	66,560
1910	5,037	1,899.85	39,273	27,856	15,042	1,202	153	3,232	142	54,610
1911	1,668	1,460.97	30.201	13,916	7,375	2,790	349	8,108	365	38,290
1912	814	667.88	13,806	28,880	17,761	3,177	524	13,470	606	32,697
1913	1,434	714.07	14,761	93,535	56,495	11,872	1,840	42,292	1,861	74,957
1914	3,018	1.252.51	25,892	195,902	108,334	12,128	1,613	69,272	2,702	138,541
1915	1,662	1,028.31	21,257	67,229	34,085	28,215	4,938	14,617	687	60,967
1916	15,529	3,446.09	71,237	42,363	27,875	4,118	1,013	23,348	1,611	101,736
1917	3,883	1,512.20	31,260	63,085	51,982	5,850	1,597	34,082	2,931	87,770
1918	946	567.10	11,723	60,219	60,219	10,117	2,499	75,915	5,390	79,831
1919	2,038	1,096.27	22,662	87,892	98,439	7,935	1,476	39,302	2,083	124,660
1920	10,610	976.93	20,195	60,422	65,860	5,016	923	28,225	2,258	89,236
1921	8,624	607.01	12,548	60,492	60,492	302	39	16,468	741	73,820
1922	1,664	976.40	20,184	62,192	62,192	--------	--------	11,709	644	83,020
1923	945	954.00	19,721	9,656	7,918	--------	--------	3,271	229	27,868
1924	2,144	886.52	18,326	6,282	4,209	--------	--------	4,561	365	22,900
1925	219	456.81	9.443	5.485	3.806	--------	--------	5,100	444	13,693
1926	798	383.47	7,927	6 691	4.175	800	112	23,600	1,888	14.102
1927	366	434.07	8,973	642	364	--------	--------	--------	--------	9.337
1928	2,227	576.00	11,907	11.041	6.459	333	48	2,741	159	18.573
1929	3,911	909.74	18.806	3,882	2.069	--------	--------	1,159	73	20,948
1930	193	371.57	7.681	1,356	522	--------	--------	--------	--------	8,203
1931	438	495.41	10,241	324	94	--------	--------	--------	--------	10,335
1932	2,863	1,682.05	34.771	3,057	862	--------	--------	--------	--------	35,633
1933	2.213	1.974.73	50.474	5.846	2,046	--------	--------	2,703	100	52,620
1934	19.247	6,025.24	210,582	4,429	2,863	--------	--------	--------	--------	213,445
1935	37,555	10.057.60	352.016	6.421	4,615	--------	--------	10,100	404	357,035
1936	34.660	9.113.80	318,983	9.264	7,175	1,090	100	6,680	307	326,565
1937	22.208	7,048.20	246,687	6,450	4.989	1,600	194	200	12	251,882
1938	9.066	4.279.60	149,786	2.255	1 458	3,000	294	1,000	46	151,584
1939	9,975	4,367.00	152,845	5,691	3,863	900	94	5,000	235	157,037
TOTAL 1904-1939	222,655	79,829.87	$2,245,479	1,078,536	$796,457	122,591	$20,736	857,832	$43,985	$3,106,657

General Geology

General relations.—The Gold Hill mining district lies in the northern part of a 100-square mile batholith of Boulder Creek granite (see fig. 1). At the northern edge and within the western part of the district, schists of the Idaho Springs formation wrap around this batholith and inter-

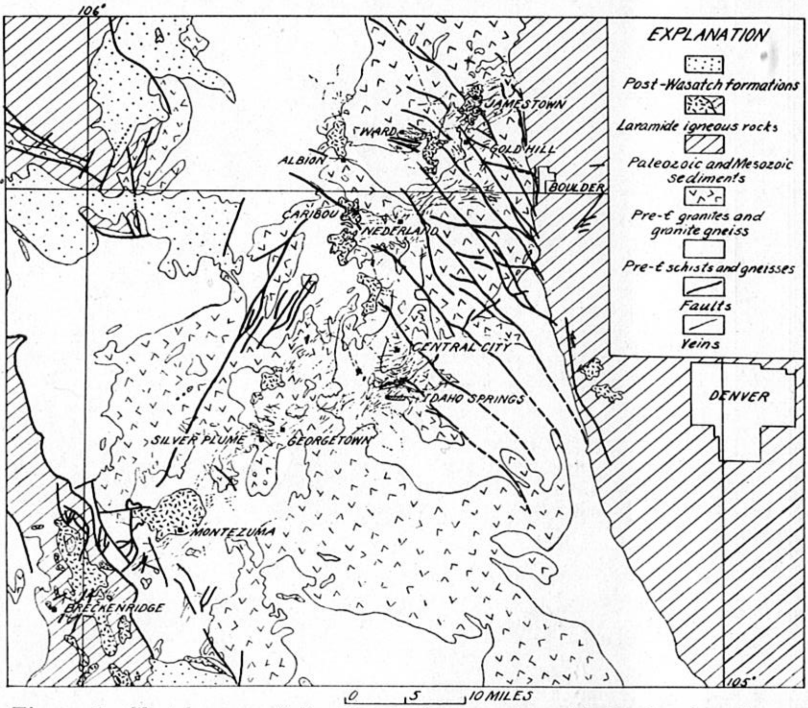

Figure 1. Sketch map of the Front Range mineral belt showing the regional geologic setting of the Gold Hill district.

finger with the granite as shown in figure 2. One and a half to 2½ miles east of the district, the Pennsylvanian "red beds" of the Fountain formation lie unconformably on the granite and dip about 35° to the east. The pre-Cambrian rocks have been cut by a series of Laramide porphyry dikes that range in composition from diabase to alaskite.

Pre-Cambrian rocks.—The earliest rocks in the district are the strongly foliated biotite and quartz-biotite schists of the Idaho Springs formation, which are strongly metamorphosed rocks of sedimentary origin. These schists are more or less impregnated throughout with thin seams of granitic and pegmatitic material, which locally is abundant enough to change the schists to "injection gneiss." The foliation of the schist is mostly steep in dip and trends nearly north in the western part of the district, but east-northeast along the north border of the granite.

The Boulder Creek granite ranges from a very coarse-grained pink and black mottled biotite granite near Bighorn Mountain east of Gold Hill to a medium-grained quartz monzonite gneiss at the borders of the batholith. The flow lines throughout the granite seem to indicate that the source magma rose from beneath the vicinity of Bighorn Mountain just east of Gold Hill and spread out fan-wise to the south. The foliation or gneissic structure in the granite trends north to northeast and dips steeply west throughout most of the district, except in the northern part where it strikes east-northeast and dips steeply south. This foliation in the granite has had an important influence on later geologic structure—such as the trend of pegmatite dikes and the strike of many of the faults and veins.

Dikes of gneissic granite aplite, related to the Boulder Creek granite, are prominent in the southwestern corner of the area but are found sparingly elsewhere. In the central part of the district near Crisman there are three irregular dikelike bodies of dark greenish gray hornblende diorite; in other places very small dikes of this diorite are distributed sparingly. The diorite is also thought to be related genetically to the Boulder Creek granite.

Silver Plume granite, the youngest of the pre-Cambrian granites, forms two persistent eastward-dipping dikes in the northern and central part of the district, and three smaller dikes near Wallstreet, in the southwestern part. These dikes are thought to have come from a stock of Silver Plume granite in the Jamestown district, north of Gold Hill. The Silver Plume granite is a medium-grained biotite granite, characterized by abundant, roughly parallel, lath-shaped phenocrysts of microcline.

Pegmatite dikes are abundant throughout the district but most of them are less than 50 feet wide and are too small to be shown on the map (fig. 2). Most of the dikes are parallel to the gneissic structure of the Boulder Creek granite, striking northeast and dipping steeply to the northwest. A few dip flatly in various directions. In a few places there are rather large irregular masses of pegmatite connected with dikes, notably on top of Bighorn Mountain, and in the southern and western parts of the district. Some of the pegmatites are related to the Boulder Creek granite and others are related definitely to the Silver Plume granite. The two types are so similar that many dikes cannot be identified definitely with either granite. As will be shown later, the pegmatite dikes have apparently had a marked effect on the distribution of vein fissures and of ore deposits in the district.

Laramide (late Cretaceous—early Tertiary) igneous rocks.—The Laramide igneous rocks, the so-called "porphyries" of the Front Range mineral belt, were intruded in the interval during which the Laramide or Rocky Mountain geologic revolution was in progress—a broad time interval that marked the end of one era and the beginning of another. The Laramide rocks are less abundant in the Gold Hill district than in most of the other districts of the Front Range mineral belt. Porphyry stocks, which are common in most of the other districts of the region, are entirely absent at Gold Hill, and porphyry dikes are few. The types of porphyry dikes are listed below in the order of their age,[12] beginning with the oldest:

1. diabase ("Iron dike")
2. intermediate quartz monzonite porphyry
3. alaskite porphyry
4. bostonite porphyry
5. biotite monzonite and latite porphyries and biotite latite intrusion breccia.

[12]The age relations of these rocks and their relations to the ores throughout the Front Range are discussed by: Lovering, T. S., and Goddard, E. N., Laramide igneous sequence and differentiation in the Front Range, Colorado, Bull. G. S. A., vol. 49, pp. 35-68, 1938.

The diabase is a dense, greenish black rock that has a brown iron-stained appearance on the weathered surface. It forms a strongly persistent dike, called the "Iron dike," which strikes about N. 25° W. along the western border of the district and extends brokenly for nearly thirty miles from south of Magnolia to west of Estes Park. In the Gold Hill district this dike is 30 to 50 feet wide and dips steeply to the east. It appears to be related remotely to the ore deposits of the district.

The intermediate quartz monzonite porphyry, called mica-dacite by Crawford[13] is characterized by abundant hexagonal plates of biotite, less abundant white feldspar phenocrysts, and a few rounded quartz phenocrysts in a gray microcrystalline groundmass of quartz and feldspar. It forms a system of northwest-trending dikes in the eastern part of the district and occurs as sills in the sedimentary rocks farther to the east.

The alaskite porphyry, called rhyolite by Crawford, is a white, dense, almost porcelainic rock. In composition and character this rock is very close to a rhyolite but elsewhere in the Front Range it has been called alaskite porphyry by Ball[14] and the name is retained here for the sake of uniformity of type names. Small phenocrysts of quartz, feldspar (sanidine and oligoclase), and biotite are scattered very sparingly through a microcrystalline groundmass of quartz and orthoclase. The percentage of biotite is so small that the rock is more aptly called alaskite porphyry than granite porphyry. Irregular dikes of this rock form a system that trends N. 75° W. across the central part of the district, and one cuts the Iron dike just west of Gold Hill. Alaskite dikes are found in places also along both the Hoosier and Maxwell breccia reefs and a northwest-trending system follows a branch of the Maxwell reef in the eastern part of the district.

The bostonite porphyry was called trachyte by Crawford, but as it is a soda trachyte the name bostonite seems

[13]Crawford, R. D., op. cit.

[14]Spurr, J. E., Garrey, G. H., and Ball, S. H., Economic Geology of the Georgetown quadrangle, Colo., U. S. Geol. Surv. Prof. Paper 63, pp. 77 and 78, 1908.

more appropriate. It is readily distinguished by its lavender to purplish gray color, against which the pinkish white phenocrysts of orthoclase stand out prominently. The microcrystalline groundmass is made up of anorthoclase, orthoclase and quartz. This rock forms a few dikes of easterly and northerly trends in the northern part of the district.

The biotite monzonite, or latite porphyry, is a dense, dark-gray rock made up of small phenocrysts of biotite, hornblende, and plagioclase in a microcrystalline groundmass of plagioclase and orthoclase. In some places the groundmass is partly glassy. In the northwestern part of the district this porphyry forms small dikes that trend northeasterly. One of them lies between the Red Cloud and Cold Spring veins. Small dikes are also found just south of Wallstreet; and in the Logan and Yellow Pine mines at the southern edge of the district. Along some of the veins in these two mines and along the Twin vein in the northern part of the district thin seams of biotite latite intrusion breccia are exposed; it has a gray gouge-like appearance and is crowded with small granite and pegmatite fragments. Minute biotite phenocrysts are visible in places. The groundmass is made up of microcrystalline laths of feldspar and glass. The close association of these biotite monzonite and latite dikes with telluride ore has led Lovering[15] and the writer to believe that there is a close genetic relationship between the dikes and ore.

All the porphyry dikes dip steeply and, with the exception of the Iron dike, range in width from a few feet to thirty feet. Seams of intrusion breccia are only a few inches wide. Few of the dikes can be traced continuously for more than a mile and many are only short segments of systems that extend one and one-half to two miles.

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[15]Lovering, T. S., and Goddard, E. N., op. cit., pp. 64-65, 1938.

Structure

General features

The dominant structural features of the Gold Hill district are the strong persistent Laramide faults or breccia reefs, which are known locally as "dikes." Their marked influence on the distribution of ore deposits in the district has long been recognized by local mining men. The distribution of some of these breccia reefs has been controlled by pre-Cambrian shear zones, which are relatively inconspicuous but none the less are important in the structural picture. In places, as on the Richmond fault zone, a pre-Cambrian shear zone has been followed by a breccia reef which in turn has been followed by a vein fissure. Vein fissures of northeast trend are younger than the breccia reefs. They are abundant throughout most of the district but, compared with the breccia reefs, are relatively small and discontinuous.

Pre-Cambrian shear zones

The pre-Cambrian shear zones are not prominent and are chiefly made up of sheared but rather fresh looking granite which resembles a strongly foliated gneiss. Commonly these zones have a faint greenish coloration caused by a chloritic alteration of the biotite, and in places they contain thin stringers of epidote. The strongly gneissic appearance of these shear zones is due to an abundance of small discontinuous shear planes which are an inch or less in length and a small fraction of an inch apart. It seems likely that this shearing took place soon after the consolidation of the Boulder Creek granite, for some pegmatite dikes have been involved in the shearing, whereas others of the same general character penetrate the shear zone undeformed.

The largest of these shear zones, near the southern border of the district, trends about N. 80° W. and has been followed in part by the Poorman dike (see fig.2). It dips steeply to the north, ranges in width from 100 to 200 feet and branches and reunites in several places. Displacements of pegmatite dikes and the positions of grooves on the shear plane indicate that the south wall moved down to the west at about 20° and the amount of displacement has probably been about 100 feet. Other smaller and less continuous pre-Cambrian shear zones, from 5 to 20 feet wide, trend northeastward and dip steeply through the central and northwestern parts of the district and have been followed in part by such productive veins as the Slide, Cash, Richmond, and Grand View. Along the last two veins, small breccia reefs were formed before the vein fissures. Along all these prominent veins the evidence of the pre-Cambrian shear zone has been largely obliterated by later mineralization and the writer found it impossible to tell the direction or amount of pre-Cambrian movement.

Breccia reefs

General character.—The breccia reef faults occur throughout the northern part of the Front Range but are best developed in the Gold Hill district, where they were first recognized. They appear to have had a very important influence on the regional distribution of ore in many parts of the Front Range mineral belt.[16] These faults have long been called "dikes" by local mining men because of their prominent outcrops in many places. Lovering[17] originally called them "breccia dikes" but, at the suggestion of D. F. Hewett, of the U. S. Geological Survey, the name has been changed to "breccia reefs' 'in order to avoid any confusion with dikes of igneous rock.[18] The term "reef" seems very appropriate as it has long been used by English mining men to describe large veins or faults having prominent outcrops.

These breccia-reef faults show considerable variation in character from narrow, strongly sheared fault zones to wide zones of slight shear and from negligible to very great degrees of silicification. Some, like the Hoosier reef, are

[16]Lovering, T. S., and Goddard, E. N., Geologic map of the Front Range mineral belt (explanatory text): Colo. Sci. Soc. Proc., vol. 14, no. 1, pp. 3-48, 1938.

[17]Lovering, T. S., op. cit., Colo. Sci. Soc. Proc., vol. 13, no. 3, pp. 79-88, 1932.

[18]Lovering, T. S., and Goddard, E. N., op. cit., 1938.

commonly marked by large veins of bull quartz from 5 to 30 feet wide and others, like the Blue reef, the Bull o' the Woods reef, and parts of the Poorman reef, contain from 3 to 15 feet of nearly barren horn-quartz. All the breccia-reef faults, however, are characterized by small amounts of hematite which is finely disseminated throughout the fault zone and imparts to it a reddish or purplish coloration. In most places, this coloration serves to identify the breccia reef, but locally it is absent and the fault zone has a greenish appearance owing to the chloritic alteration of the dark minerals of the rock. Where the fault zone has been mineralized by solutions of the ore-forming period, the hematite apparently has been changed to pyrite and the outcrops show the yellowish brown color of weathered pyritic veins.

General distribution.—The most persistent and prominent of the breccia-reef faults are the Hoosier and Maxwell reefs, which belong to a set that trends N. 25° to 50° W. and dips nearly vertically. They can be traced from the sedimentary rocks southeast of Gold Hill northwestward for distances ranging from 15 to 25 miles. Another set of prominent but less persistent faults trends N. 70° to 80° W. and dips nearly vertical. This set includes the Poorman reef at the south edge of the district and the Blue and Bull o' the Woods reefs in the northeastern part. A third set, which trends N. 60° to 75° W. and dips 30° to 45° NE., includes the Fortune reef in the central part of the district, a related fault to the southeast of the Fortune reef, and an inconspicuous fault near Wallstreet in the southwestern part. The third set may also include some faults of low dip and northwest trend exposed in some of the underground workings.

A fourth set is much less prominent than the others but has nevertheless had an important influence on the distribution of some of the ore deposits. It includes small faults that strike N. 5° to 30° E., dip steeply to the northwest, and are largely obscured by later mineralization. This group includes faults followed by the Richmond and Grand View veins in the central part of the district, and a series of short discontinuous faults in the eastern part.

Maxwell reef.—The Maxwell reef is the strongest and most persistent breccia reef in the northern part of the Front Range. It can be traced for a distance of about 25 miles. Near Jamestown, just north of the Gold Hill district, it is cut out for a short distance by a granodiorite stock. It trends about N. 28° W. through Poorman Hill and through Glendale, dips 75° to 85° E., and forms essentially the eastern border of the Gold Hill district. This breccia reef ranges in width from 50 to 150 feet and is commonly composed of reddish-colored, sheared, and more or less silicified granite. In a few places it contains veins of white "bull" quartz, but such occurrence is not typical.

Little evidence is available as to the direction of movement along the Maxwell reef in the Gold Hill district. Just north of Glendale, in the southeastern corner of the Jamestown district, the schist-granite contact has been moved from 200 to 400 feet northwest on the northeast side of the fault, but there is no evidence as to whether the northeast wall moved up or down. Where the fault cuts the sedimentary rocks near Boulder, the east or hanging wall has moved up for a distance of at least 1,000 feet.

Hoosier reef.—The Hoosier reef, while not so extensive as the Maxwell, is the most important structural feature in the district; it trends about N. 35° W. through the central part and passes across Arkansas Mountain and just east of Gold Hill. It dips from 80° to 85° east. It is 5 to 100 feet wide; in many places it is made up of wide veins of bull quartz which commonly forms wall-like outcrops. The most prominent outcrops of this type are on Hoosier Hill near Summerville where a series of bull quartz veins 5 to 50 feet wide form wall-like outcrops 10 to 20 feet high. In some places, however, this breccia reef is merely a soft shear zone 5 to 10 feet wide, with a reddish or greenish coloration. In the northern part of the district this breccia reef is followed by a discontinuous narrow dike of alaskite porphyry.

The direction and amount of displacement on the Hoosier reef are fairly well established in the northern part of the district. Grooves on the walls seem to indicate that the southwest wall moved southeast and down at about 30°; pegmatite dikes and schist lenses have been displaced 20 to 50 feet in that direction. However, farther south where the fault is much stronger the displacement may have been greater. There is evidence of at least four periods of movement on the Hoosier fault zone but the first was by far the greatest.

Livingston reef.—Another persistent breccia reef of this system is the Livingston reef, which trends N. 40° W. across the northeast slope of Sugar Loaf Mountain, but it is just outside the area covered in this report.

Poorman reef.—The Poorman reef trends about N. 83° W. across the southern part of the district from the Maxwell to the Hoosier reef and dips 68° to 85° N. At its junction with the Maxwell reef, on top of Poorman Hill, there is a complex system of breccia reefs and veins. East of Poorman Hill the Poorman reef swings to a S. 70° E. direction and extends to the edge of the sedimentary rocks at Boulder.

The Poorman reef is a rather complex fault zone from 10 to 150 feet wide. In places it is merely a shear zone, in others it is a partly silicified zone containing disseminated pyrite, and in many places it contains or is made up of 10 to 20 feet of horn-quartz and strongly silicified granite containing disseminated pyrite which forms prominent wall-like outcrops on top of Poorman Hill and on the hill to the east. In places the Poorman reef follows a pre-Cambrian shear zone 100 to 200 feet wide.

Displacement on the Poorman reef has not been large although the fault fissure has been opened by at least two periods of movement. Displacement on two different pegmatite dikes on top of Poorman Hill indicates that the north wall moved west about 35 feet. Grooves on the walls at these points are nearly horizontal. Apparently both movements were in the same direction.

Blue reef and Bull o' the Woods reef.—The Blue reef and the Bull o' the Woods reef are two less persistent breccia reefs with the same trend as the Poorman reef. They are nearly parallel, 400 to 700 feet apart, and trend about N. 70° W. across the east-central part of the district from the Maxwell reef to Sunshine. Just west of Sunshine, both appear to end abruptly against the northeast-trending Richmond breccia reef. These two reefs are almost identical in character. They average about 5 feet in width and are made up of strongly silicified granite and horn-quartz containing dissemminated pyrite. Their breccia reef character has been largely obscured by the solutions that deposited the horn-quartz and pyrite but in a few places there is the reddish coloration typical of breccia reefs. On both reefs the movement has been the same as on the Poorman reef and the north side has moved west nearly horizontally for about 20 feet. This displacement is found on several pegmatite dikes. As on the Poorman reef there have apparently been at least two periods of movement on these reefs.

The Fortune reef and related breccia reefs.—The Fortune reef is one of the least conspicuous of the breccia reefs and yet it is remarkably persistent and has had a strong structural influence on the distribution of ore deposits. In many places its trace on the surface forms depressions rather than prominent outcrops and for this reason there has been considerable controversy among Gold Hill mining men as to its course and extent. This breccia reef has a general strike of N. 70° W. and dips 35° to 45° NE. It can be traced fairly continuously from Cash Gulch, where it probably junctions with the Hoosier reef, southeastward to Sweet Home Gulch where it is crossed by the veins of the Emancipation group. It disappears 1,500 feet southeast of the Emancipation mine and cannot be traced farther, although a more steeply dipping branch extends eastward to the Maxwell reef and steepens gradually in dip to 90° (see fig. 2). However, farther to the southeast, another breccia reef of low dip and similar character to the Fortune picks up northeast of Crisman and can be traced southeastward for about 3,500 feet. This breccia reef apparently does not connect directly with the Fortune reef but it is probably a continuation of the same fault system. This breccia reef is somewhat more irregular than the Fortune reef and strikes N. 10° to 70°W. and dips 10° to 52° NE. From 1,200 to 1,500 feet northeast of this breccia reef there are several veins of low dip, which show some evidences of shearing along the wall of an alaskite dike. These veins also may belong to the Fortune reef group.

The Fortune reef is from 3 to 15 feet wide and is made up commonly of sheared or fractured granite and gouge seams. In a few places the rock is silicified or has a red coloration. Throughout much of its extent the Fortune reef contains disseminated pyrite which is particularly abundant where the reef is crossed by numerous strong veins, such as the Sunshine, Ingram, and Richmond.

Displacement on pegmatite dikes indicates that the Fortune reef is a reverse fault. The hangingwall has moved up to the northwest at a steep angle and the total displacement is probably between 30 and 60 feet. The fault fissure was opened by at least two periods of movement.

In some of the mines, notably the Poorman and the Logan, there are exposed strong gouge-filled fault fissures from 1 to 5 feet wide which strike northwest and dip 20° to 50° NE. These faults, called "flat veins" by the miners, are apparently earlier than the true veins, although they have been reopened several times, and may belong to the breccia-reef period of faulting.

Breccia reefs of northeast trend.—Two rather inconspicuous steeply dipping breccia reefs, from 5 to 20 feet wide, trend northeastward across the central part of the Gold Hill district and have had apparently an important influence in the localization of some of the ore deposits. Both of these breccia reefs follow narrow pre-Cambrian shear zones for part of their extent and both are followed by rather persistent veins. Thus both the pre-Cambrian shear zone and breccia reef character of the faults are largely obscured by later mineralization. However, in places, the sheared chloritized rock of the breccia reef type is exposed in a narrow zone bordering the later veins. Hematite coloration sometimes is found in this zone. Where later mineralizing solutions have penetrated this fault zone the chlorite has been changed to sericite and the hematite to pyrite so that the zone has a yellowish white appearance instead of a dark green or reddish color.

The most extensive of these breccia reefs is followed by the Melvina-Three Brothers-Richmond vein, and so the term "Richmond reef" is suggested for it. This reef strikes about N. 25° E., dips 65° to 80° NW, and extends diagonally from the Hoosier reef near Melvina Hill to the Maxwell reef near Glendale. From the top of Melvina Hill to the vicinity of Sunshine where it meets the Bull o' the Woods reef, the Richmond reef is followed by a later vein, but farther to the northeast it has the typical breccia reef character. Near Sunshine, this reef cuts a dike of Silver Plume granite, and grooves on the walls at this place indicate that the southeast wall moved northeast and down at about 75°. The total displacement was 15 to 20 feet.

The second of these northeast breccia reefs is followed by the Sunshine-Grand View vein and the name "Sunshine reef" is suggested for it. This reef strikes N. 25° E. and dips 68° to 88° NW. It extends from the east slope of Melvina Hill to the Bull o' the Woods reef near Sunshine, and is followed by later veins for more than half its extent. It appears to end abruptly against the Bull o' the Woods reef; just south of this junction it is bordered on either side by zones of slightly sheared granite 125 feet wide. The displacement on this breccia reef could not be determined but it seems probable that it is similar and equal to that on the Richmond reef.

Other breccia reefs.—Another breccia-reef system that seems to have a structural relation to ore deposits is in the southwestern part of the area and extends from the south slope of Wood Mountain southeastward to Logan Mountain (see fig. 2). This reef system is small and inconspicuous and cannot be traced continuously on the surface but it has apparently influenced the distribution of veins and ore on Wood Mountain, and it may join the Hoosier reef at depth. It ranges in strike from N. 85° E. to N. 50° W. and dips