Pamphlet No. 22

May 1927

STATE OF IDAHO
H. C. Baldridge, Governor

BUREAU OF MINES AND GEOLOGY
Francis A. Thomson, Secretary.

THE GEOLOGY AND ORE DEPOSITS OF THE SOUTH MOUNTAIN MINING DISTRICT, OWYHEE COUNTY, IDAHO.

By

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THE GEOLOGY AND ORE DEPOSITS OF THE SOUTH MOUNTAIN MINING DISTRICT, OWYHEE COUNTY, IDAHO.

by

Robert E. Sorenson

INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

This report is the result of a survey of the South Mountain Mining District, Owyhee County, Idaho. The isolation of the region has been a great handicap in its development, but many mining engineers have reported favorably on the district in the past. The revival of interest in the base metals, inspired by higher prices and the desire of operating companies to extend the life of their operations, has led to a period of prospecting and development throughout the country. This interest has been felt at South Mountain, and reports that these ore deposits were of the rare, lead-silver contact metamorphic type, added scientific interest to the district. The writer was assigned to the problem by the State Bureau of Mines and Geology for the purpose of attempting to determine the economic possibilities of the district and of adding to the information regarding the mineral resources of the state.

It was thought highly desirable that the survey cover, in a cursory way, an area somewhat larger than that enclosed within the boundaries of the mining district proper and, in detail, an area containing the representative and more important ore deposits of the district. The reconnaissance survey was made to obtain some idea of the geologic conditions surrounding the most highly mineralized area (Pl. I). The selected smaller area has been mapped, in detail, both topographically and geologically, in order to give specific information concerning the geology and the ore occurrences (Pls. IIA and IIB).

FIELD WORK

The field work was begun on July 28, 1926, and completed on September 9, 1926. A base map for the reconnaissance survey was prepared from township plats obtained from the United States General Land Office. A week was spent in the preparation of the base map and the actual sketch mapping of the large area. A period of about nine days was spent in the measurment of a base line, the establishment of triangulation points, and the development of the large-scale topographic map. The writer had a field assistant to help with topographic work. The horizontal control was based on the location of the United States Location Monument No. 1 of the South Mountain Mining District, the claim corners located therefrom, and section corners plotted on the Mineral Monument plat. The vertical control was based on an assumed elevation of 8,025 feet above sea level for the Summit of South Mountain, the Monument Peak. This figure and others near it have been obtained by various engineers with aneroid barometers. The writer was unable to check the elevation so the assumed one must suffice.

Some of the geology was mapped by stadia-planetable methods, but most of it by pacing traverse from section corners, claim corners, and established points. Imperfect exposures added much difficulty to accurate mapping, and much had to be inferred from scanty outcrops. An unusually thick covering of soil, general throughout the area, obscured the surface expression of the geology.

HISTORY

The first references in geologic literature to the South Mountain Mining District are found in Raymond's reports of 1872, 1873, and 1875. The most complete early description is given by Mr. Eilers in the Raymond report of 1873. W. P. Jennings, of the United States Geological Survey, summarizes the early history of the district in his unpublished manuscript, History of Mining in Idaho. The account is so comprehensive that a knowledge of the history of the district can best be obtained by quotation from this manuscript (11).*

> "Mr. A. Eilers made an examination of the mines at South Mountain in 1872. He describes the district as situated in a distinct range much lower than the Owyhee Mountain, about 25 miles south of Silver City. A number of small veins carrying gold were discovered on South Mountain in 1868, but were too poor to work. In the fall of1871 veins carrying argentiferous lead ores were discovered in a deep canyon southwest of the crest of the range. Granite prevails throughout the range, but along the southwestern slope on both sides of the canyon, a belt of white limestone with thin strata of mica slate outcrops, constituting the ore-bearing formation.
>
> "The principal mines developed were the Golconda, Cottonwood, Bay state, and Grant. The Golconda, near the head of the canyon, has a vein of quartz and calc spar 8 feet in width, carrying carbonate and galena. The walls are crystalline limestone. The ore is stated to average 34 per cent lead and $40 to $60 per ton in silver--the galena assayed separately is higher in both lead and silver.
>
> "The Bay State mine, located lower down the canyon, shows a body of three feet of pure galena--a sample taken by Mr. Eilers of galena and gray carbonate assayed 0.35 oz. gold, 172.5 oz. silver, and 61 per cent lead.
>
> "The Grant mine, near the mouth of the canyon, has an incline 100 feet deep, exposing a vein 3 to 7 feet wide, carrying iron-stained carbonate, with galena. A sample of solid gray carbonate assayed .04 oz. gold, 277.4 oz. silver, and 32 per cent lead.
>
> "The Cottonwood is an iron mine carrying a little carbonate of lead, and should be of value as a flux in smelting the ores of the camp. An incline of 63 feet deep opens a vein of soft iron ore 10 feet thick. A town, called Bullion City, was laid out and a road built to old Camp Three Forks, 6 miles distant, connecting with the military road to Camp McDermott, making the distance of the mines from the Central Pacific at Winnemucker, 128 miles.[1]

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[1] Mineral Resources, Raymond, 1872, pp. 193-197.

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* Numerical notations of this type refer to the corresponding entry in the bibliography which follows this section.

"In the fall of 1874, San Francisco parties bought up the more important mines and incorporated as the South Mountain Consolidated Mining Company. The Company opened up the Colconda, Bay State, Yreka, and other mines. The Bay State has proved to be the richest mine in the camp. It is opened by an incline 135 feet deep with levels on the vein for over 200 feet. The Yreka shows an even larger body of good smelting ore, but it carries less silver.

"The company built a smelting furnace, which made one or two short campaigns during the fall; but smelting had to be stopped for the winter, owing to the insufficient supply of charcoal that had been provided.

"The failure of the Bank of California seriously crippled the South Mountain Consolidated Mining and Smelting Company, and with the company, the whole camp went down. The causes of this collapse at South Mountain are discussed by Doctor Raymond, who shows that the fault lay with the management and not from any failure of the mines. The mine owners could not ship their ore, and with the collapse of the company, the district was deserted.[2] Strahorn states that the smelting operations at South Mountain produced about $150,000 in bullion.[3]"

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[2] Op. cit., 1875, pp. 227-230.

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[3] Resources of Idaho Territory, p. 35.

The South Mountain district remained practically idle during the period from 1875 to 1906. In 1906 some work was done on the Standard group of claims, and the South Mountain Company's mines were operated under option by the Bagdad-Chase Gold Mining Company in 1907. Operations were soon stopped, however, and the bond was forfeited because of the financial depression. Very little work, other than annual assessment work on unpatented claims, has been done in the period from 1907 to 1926. A bond and option on the property of the South Mountain Mining Company is held now by Utah and eastern capital. Repair work on the camp buildings was started in August, 1926. "The name of the new corporation is the Uida Consolidated Mines Company. Mr. Daniel J. Shields of Johnstown, Pennsylvania, is president. Attorney Samuel A. King of Salt Lake City is treasurer. W. F. Hayden, Salt Lake City Engineer, will be in charge of the active work."*

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* W. F. Hayden, Vice-President of Uida Consolidated Mines Co. Excerpt from letter of January 27, 1927, sent to the writer.

ACKNOWLEDGMENTS

The writer is greatly indebted to the ranchers in the South Mountain region, and to residents of Jordan Valley, Oregon, for the many courtesies extended. Dr. W. W. Jones of Jordan Valley, was most generous in providing information. Mr. G. A. Sonneman of Spokane, Washington, Mr. M. G. Sacrider of Mountain Home, Idaho, and Mr. W. F. Hayden, mining engineer of Salt Lake City, Utah, deserve especial thanks for reports, photographs, and maps loaned to the writer. Figures "A", "C", and "D" of Plate IV were reproduced from negatives provided by Mr. Hayden. Mr. Curtis C. Jones of Jordan Valley, Oregon, and Mr. Leonard Koonce of Fairfield, Idaho, gave efficient aid during the preparation of the topographic map. The writer expresses his appreciation to Dr. Francis B. Laney, Professor of Geology, University of Idaho, and to Professor Virgil R. D. Kirkham for valuable advice and counsel during the preparation of this report. To Dr. Laney the writer is indebted for a critical reading of the manuscript. Thanks are due to J. Vernon Otter for careful drafting of the maps.

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G E O G R A P H Y

LOCATION AND EXTENT OF AREA

The South Mountain Mining District is situated about twenty miles south, and slightly west, of Silver City, within four townships (T. 7, S., R. 4 W; T. 7, S., R. 5 W; T. 8, S., R. 4 W; T. 8, S., R. 5 W; Ranges West of Boise Meridian, Idaho) in west-central Owyhee County, in the southwestern part of Idaho. The district proper is contained in an area about two miles square, but possible extensions may increase the area considerably. The 42° 45' parallel of latitude traverses the approximate center of the mining district, and the 116° 52' meridian west longitude passes slightly east of South Mountain. The location of the area as regards state boundaries is shown by the insert index map (Pl. I).

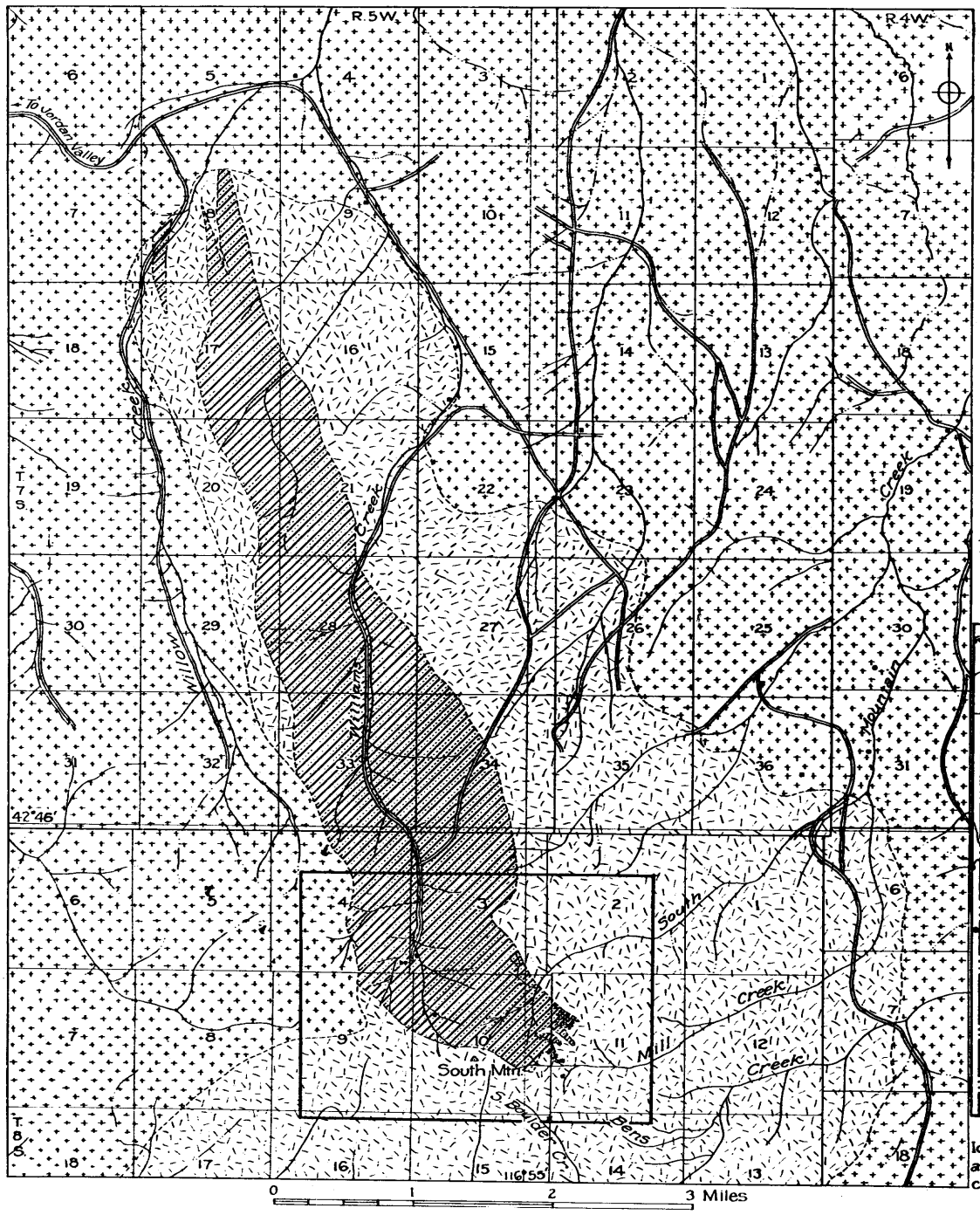
TRANSPORTATION

The greatest handicap to a more intensive development of the South Mountain Mining District in the past has been its isolation from main lines of travel. Economical and profitable operation of the mines in this district hinges, to a great extent, upon the cost of transportation from the mines to the railroad shipping point. The most feasible railroad shipping point for the South Mountain region is Homedale, Idaho, a station on a branch line of the Oregon Short Line Railroad, which connects with the main line at Nyssa, Oregon. The distance by automobile road from South Mountain, via Jordan Valley, Oregon, to Homedale is about eighty-two miles. The road is easily traveled during the dry summer months; but parts of it would have to be repaired, rebuilt, and hard surfaced in order to accomodate heavy traffic. The grades from South Mountain to Homedale, the direction in which the heaviest haulage must take place, are, in most instances, less than 5 per cent. Some few short pitches of greater grade, which could be avoided by rebuilding and rerouting, occur between South Mountain and Jordan Valley. The highway from Jordan Valley to Homedale gradually climbs the drainage divide between the Jordan Creek Valley and the head of Succor Creek. It descends Succor Creek Canyon by easy grades, rises gently for a short distance, levels out for a distance, and then descends into Homedale. After proper construction, the road could be traveled throughout the greater part of the year, although extremes of snowfall during the winter months might cause trouble and delay. At the present time charges for outgoing freight from Jordan Valley to Homedale during the summer months, on small consignments, average about one dollar per 100 pounds. Cheaper rates are provided for larger shipments.

Jordan Valley is situated about 22 miles by auto road from South Mountain. The stage from Caldwell, Idaho, a station on the main railroad line, delivers mail daily to the Jordan Valley post office. Jordan Valley is connected with Nampa, Idaho, by telephone, and telephone lines from Jordan Valley run a distance of six or seven miles toward south Mountain.

POWER

The Flint Mining District, approximately thirteen miles north and northeast of South Mountain, is equipped with electric power lines by the Idaho Power Company from the Swan Falls Plant on Snake River. This line



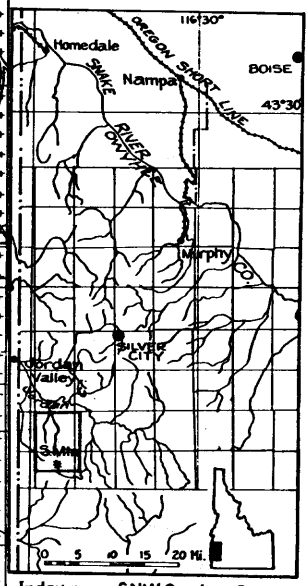
LEGEND

BASALT
(Fine grained and porphyritic flows)

GRANODIORITE
(Including areas of other rocks too small to represent on this scale)

METAMORPHOSED SEDIMENTARY ROCKS
(Interbedded schist, quartzite, and limestone. Including areas of other rocks to small to represent on this scale)

AREA INCLOSED BY HEAVY BLACK LINE IS MAPPED IN DETAIL ON PLATES IIA AND IIB.



Index map of N.W. Owyhee County, Idaho. Showing area covered by Plate I, and (by insert) the portion of Idaho covered by this index map.

Base from U. S. township plats.
Drafted by J. Vernon Otter.

Geology by Robert E. Sorenson.
Surveyed in 1926.

RECONNAISSANCE GEOLOGIC MAP OF A PART OF THE SOUTH MOUNTAIN REGION, OWYHEE COUNTY, IDAHO

-7-A

could easily be extended, if the size of operations should justify it. Such power would be indispensable to the mining and milling, as the cost of either coal or wood fuel is prohibitive.

WATER SUPPLY

Williams Creek (Pl. I) has often been termed "never-failing". The water supply is almost constant, because the creek is fed continuously by numerous springs and spring-fed tributaries. Some of the springs have their source within about 200 feet vertically of the Summit of South Mountain, and others occur along the creek at lower elevations. At Bullion City, one of the best millsites in the mineralized area, Nutter Creek connects with Williams Creek, giving a supply of water sufficient for the needs of a large mill. Other springs and tributary streams feed Williams Creek below this point. South Mountain Creek, on the east side of the divide between it and Williams Creek, should supply the necessary water for that part of the ore deposit. All the springs and streams supply clean potable water.

CLIMATE AND VEGETATION

No definite weather reports were available to the writer, so most of the weather information was obtained from residents or other people acquainted with the region. Piper and Laney give accurate figures of precipitation in the Silver City region which may apply quite well to the South Mountain region. They say, "The Silver City region has a mean annual precipitation of 23.14 inches, of which only 1.95 inches falls during the summer months of July, August, and September. Usually only these three months are without snow, and the annual snowfall is 129 inches." (15:p.9) The summer days are dry, warm, and sunny, and the nights are clear and cool--all typical of the Western Mountains region. The abundant snowfall is the objectionable winter feature as the winter temperatures are not reported as severe.

The vegetation in the region is not abundant. Sagebrush, bunch grass, buffalo grass, and other hardy grasses are the typical small plant types. Buck brush, mountain mahogany, and quaking asp are distributed sparsely in the higher altitudes. Red fir, largely second growth, grows on north facing slopes, in protected gullies, and other places where the accumulation of snow is greatest. Much of this second growth is of sufficient size to serve as mine timbers, but a large part of it--that on government land--is protected by law. On some of the patented claims, there is enough second growth red fir to serve immediate mining needs.

INDUSTRY

The people of the region are largely occupied in the raising of sheep, cattle, and horses. The upland valleys, and grassy slopes of South Mountain are particularly well adapted to summer grazing. Hay for winter feed is grown in the fertile irrigated parts of creek valleys, and there the stock is wintered. Some of the South Mountain summer grazing land is leased to ranchers of the Snake River plains, who winter their stock on their home ranches.

PHYSIOGRAPHY

South Mountain was called a continuation of the Owyhee Range by Lindgren (13:p. 188), and an isolated uplift by Bell (5). The South Mountain uplift well deserves the term "range". It is practically as high as the Owyhee Range which seems to parallel it about 20 miles north, and it is separated from the Owyhee Range by the basalt covered basin-like depression occupied by the Boulder Creek-Jordan Creek Valley. In all particulars, the South Mountain uplift bears no direct connection to the Owyhee Range. Although the highest summits of the South Mountain Range tend to follow the strike of the metamorphosed sediments, the longest axis of the range strikes in a northwest-southeast direction and parallels the Owyhee Range.

South Mountain Peak, the summit of the South Mountain Range, reaches an elevation of about 8025 feet. Associated peaks are Laura Peak, 7973 feet; Stanley Peak, 7970 feet; Coxcomb Peak, 7850 feet; Jim's Peak, 7817 feet; and North Peak, 7800+ feet. Summits of less relief and less elevation outline the axis of the range for 15 miles in a northwest-southeast direction. The width of the range is about 10 miles. To the northeast the uplift slopes gradually downward to the dissected basalt covered upland plain which is traversed by the Jordan Creek-Boulder Creek Valley. The elevation of Boulder Creek valley north of South Mountain Peak is about 4500 feet. The elevation of Jordan Valley, Oregon, is 4200 feet. The regional relief, therefore, is about 3800 feet. On the east, south and southwest, the uplift slopes downward more abruptly to the lava covered plateau which is drained by the Owyhee River.

In all directions away from the South Mountain uplift, the basalt appears to tilt slightly, although any particular flow cannot be followed for a great distance, due to imperfect outcrops. The depression, in which Jordan Creek and Boulder Creek outline the approximate center, is undoubtedly a structural depression which may be caused by a gentle downfold or by systems of block faults resulting in a graben structure. No evidence of block faulting, however, was noted by the writer.

The South Mountain region is drained by tributaries of the Owyhee River which heads in southwestern Owyhee County, flows westward across the Oregon-Idaho line, then turns northward to connect with the Snake River. The south slopes of the range are drained by Juniper Creek, a tributary of Soldier Creek, which has other tributaries that head on the south slopes; Buck Creek, which drains into Deep Creek, and thence into the South Fork of the Owyhee River; and the South Fork of Boulder Creek, which heads south of Boulder Ridge, flows southeastward for a mile and a half, eastward for three miles, then turns abruptly to the north for about seven miles where it empties into Boulder Creek. About four miles northwest of this point Boulder Creek unites with Jordan Creek and, under the latter name, flows westward through Jordan Valley, Oregon, to the Owyhee River. The north slopes of the South Mountain range are drained by Williams, Mill, South Mountain, and Willow creeks, and other small tributaries of Boulder and Jordan creeks. Williams Creek, which heads about 200 feet vertically and 500 feet horizontally from South Mountain is a permanent stream from its source to its end during all seasons.

The topographic features of the South Mountain region are very similar to those of the Silver City region. Streams with steep gradients, and hills with steep slopes are the rule, but summits are rounded rather than sharply pointed. (Pl. IIB and "A" Pl. IV) Mill, South Mountain, Williams, Nutter, and Vessels creeks, head in ampitheatre-like basins which owe their origin to mountain glaciation. These streams are now reworking the glacial debris. Cirques are developed only on the north side of the range.

The physiographic history of the South Mountain region is rather easily readable. After the intrusion of the granodiorite it was denuded by erosion with consequent development of old age topography. During Miocene (?) time the basalt was poured out over this topographically mature surface of granodiorite and metamorphosed sediments. At some time since the outpouring of the basalt, the region was uplifted and again subjected to active stream erosion. The present topography is the result of glaciation and stream erosion, the latter being the most important agent.

G E O L O G Y

STRATIGRAPHY

Metamorphosed Sediments

The stratified rocks of the South Mountain region may be classed as metamorphosed sediments. The present altered condition is largely due to dynamic metamorphism, but the contact effects of the granodiorite intrusion are dominant locally and these effects are not entirely absent at any place. The rocks composing the metamorphosed sedimentary series are dominantly garnetiferous-quartz-mica schist, fine-grained quartzite, and marble. There are many departures from these normal types. Discussion of the normal phase and the departures from the normal phase are to be found under the separate headings, schist, quartzite, and marble. A detailed section of the sedimentary series can not be obtained in the district because of imperfect exposures, but a generalized section follows:

(Youngest member at the top, oldest at the bottom.)

		Thickness of exposures
"ES"	Quartzite, and calcarious quartzite, locally containing schist and marble lenses.	1200+ feet
"DL"	Marble, largely banded blue and white, containing siliceous layers	100 - 180 feet
"DS"	(Graphitic-quartz-mica schist) (Schist)	560 - 580 feet
"CL"	White marble and banded blue and white marble. . .	80 - 120 feet
"CS"	Schist and quartzite	150 - 220 feet
"BI"	Banded blue and white marble, locally white marble	130 feet
"BS"	Schist and quartzite	150 - 230 feet
"AI"	White marble, locally containing white siliceous material and banded blue and white marble.	350 - 500 feet
"AS"	Schist and quartzite . .(bottom unexposed)	850+feet
	Total.	3570 to 4010 feet

The relationships between the members of this metamorphosed sedimentary series are shown in the cross-sections (Pl. III) Each member appears to rest conformably on the underlying member in all parts of the area, although breaks in sedimentation probably have occurred. There is an abrupt change from limestone to quartzite in some places. Reference to the generalized stratigraphic section might suggest the conditions of sedimentation under which the rocks were laid down. The sedimentary rock section indicates a number of fluctuations between conditions of comparatively deep water deposition and shallow water deposition. Evidence suggests an alternately rising and sinking sea bottom as the place of deposition. In the four upper members of the sedimentary series, there appears to be a gradual normal transition from deeper-water conditions to shallow-water conditions and back to deeper-water conditions again.

The surface exposure of the metamorphosed sedimentary series outlines an area about seven miles long, varying in width from a minimum of a few feet to a maximum of 7500 feet. The minimum width of exposure may be found on the north end of the belt and the maximum width may be found about one and one-half miles north of Bullion City (Pl. I). The belt of metamorphosed sediments strikes approximately N. 5° to 10° W., and outcrops, with variable width, continuously from N.E. 1/4, Sec. 8; T. 7, S., R. 5, W., southeastward to Bullion City. There the belt turns sharply toward the east on a strike of about N. 120° E. for a mile. The large exposure of the metamorphosed sediments appears to be entirely surrounded by the intrusive granodiorite

although definite contacts on the west are partly obscured by the overlying basalt.

Small outliers or inclusions of the sediments are found irregularly distributed throughout the granodiorite area. These small pendant bodies are too small to map, but observations show that neighboring inclusions are oriented so that the schistosity is approximately parallel.

Lindgren (13:Pl. VIII, P. 76) maps the South Mountain sediments as possibly carboniferous and correlates them with the Seven Devils series. The nearest exposure to South Mountain is at Huntington, Oregon, about 115 miles north. It is assumed that the only means of correlation used by Lindgren was some similarity in the character of the sediments as he does not use fossils as a basis.

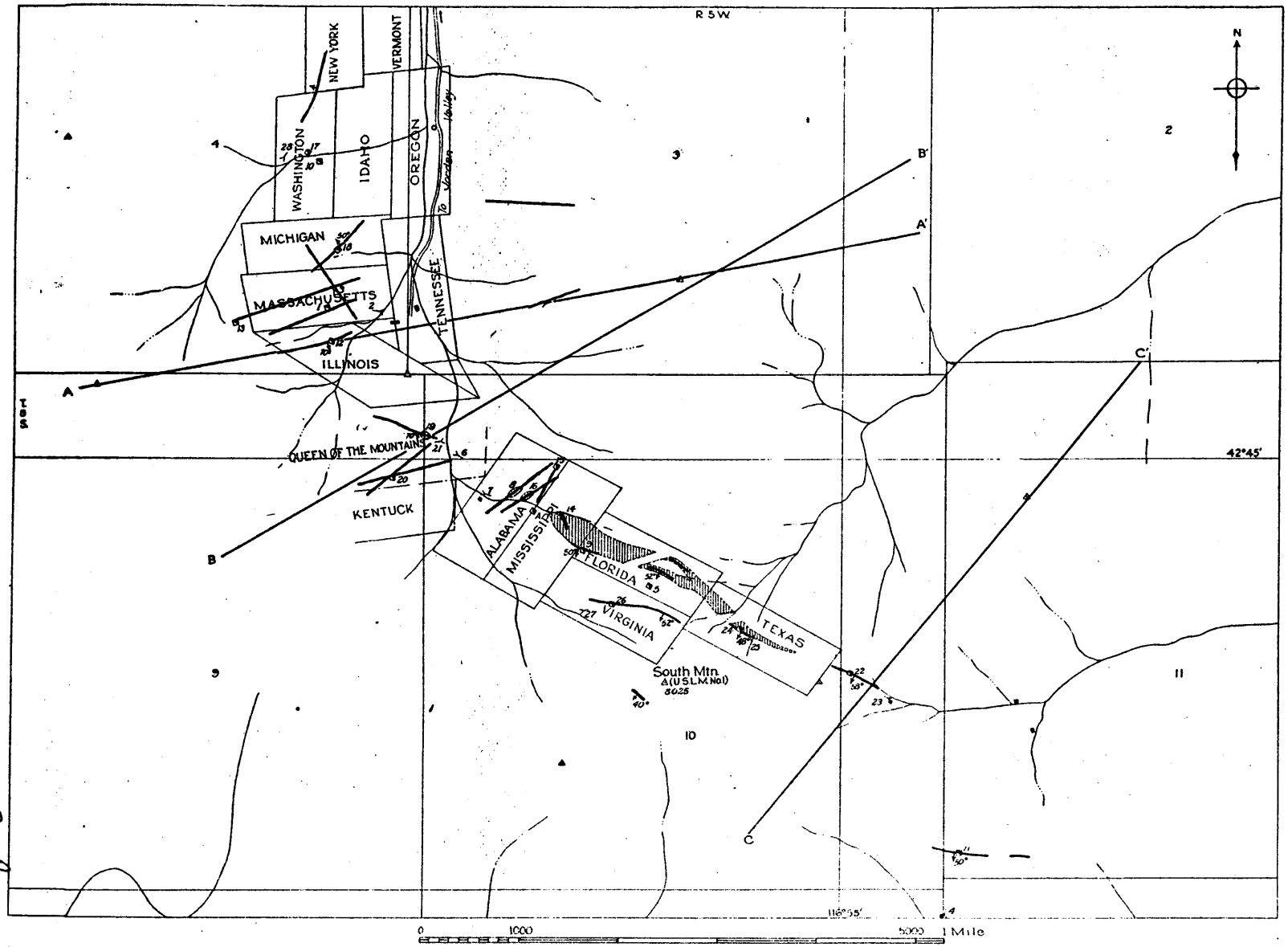
Piper and Laney describe graphitic and biotite schists which occur in small scattered blocks in the granodiorite of the Flint District. They say, "It is probable that the sediments of the Flint District are an extension of the South Mountain series and to be correlated with them. These rocks show unquestionably the effects of intrusion by granitic magma and of contact metamorphism; they are, therefore, undoubtedly older than the intrusive." (15:pp. 13, 14)

The writer's search for fossils, which might establish the age of the sediments, was futile. In a study of the ore deposits, the age of these sediments need be known only relatively. Ample evidence exists that the metamorphosed sediments are older than the granodiorite intrusive and the basalt extrusive.

Schist:

Rocks which might be classed under the general heading of schist are rather freely distributed in the geologic column. They occur interbedded with massive fine-grained quartzite and with completely recrystallized limestone. Schist lenses are common to the other metamorphosed sediments. The granodiorite contains schist inclusions which are commonly oriented with the planes of schistosity lying in one general direction in a particular locality. In the granodiorite, on either side of the sedimentary belt, the schistosity of the small schist pendants generally parallels the schistosity in the neighboring well-defined belt of sediments. Visible effects of intense dynamic metamorphism are best shown in the schist. In highly contorted parts of the district the less competent or micaceous layers have moved by flowage, which has resulted in a thickening of these layers at the crests of the minor folds. The quartzose layers are often fractured because of a greater power of resistance (Pl. IV, B).

In the hand specimen, the rock varies greatly in composition. Great lack of uniformity is certainly to be expected in rocks which have been derived from sediments that were deposited under fluctuating conditions. The normal phase of the schist is rich in quartz and micas, and commonly shows a knotty surface due to an uneven distribution of dark reddish-brown garnets. Cleavage surfaces of the rock are somewhat wavy due to pressure effects. The departures from the normal phase are many--quartz-biotite schist, quartz-muscovite schist, quartz-graphite schist, quartz-hornblende schist, all containing variable amounts of garnet, being especially important. Many combinations and gradations of the different kinds of schist are common.



LEGEND

Hedenbergite-ilvaite Contact Rock
(Contains some irregular replacement deposits of sulphides)

Black Lines Indicate Mineralization
(Arrow and degree gives direction and amount of dip)

Shaft
Tunnel
Open cut
Mine Workings

LIST OF MINE WORKINGS

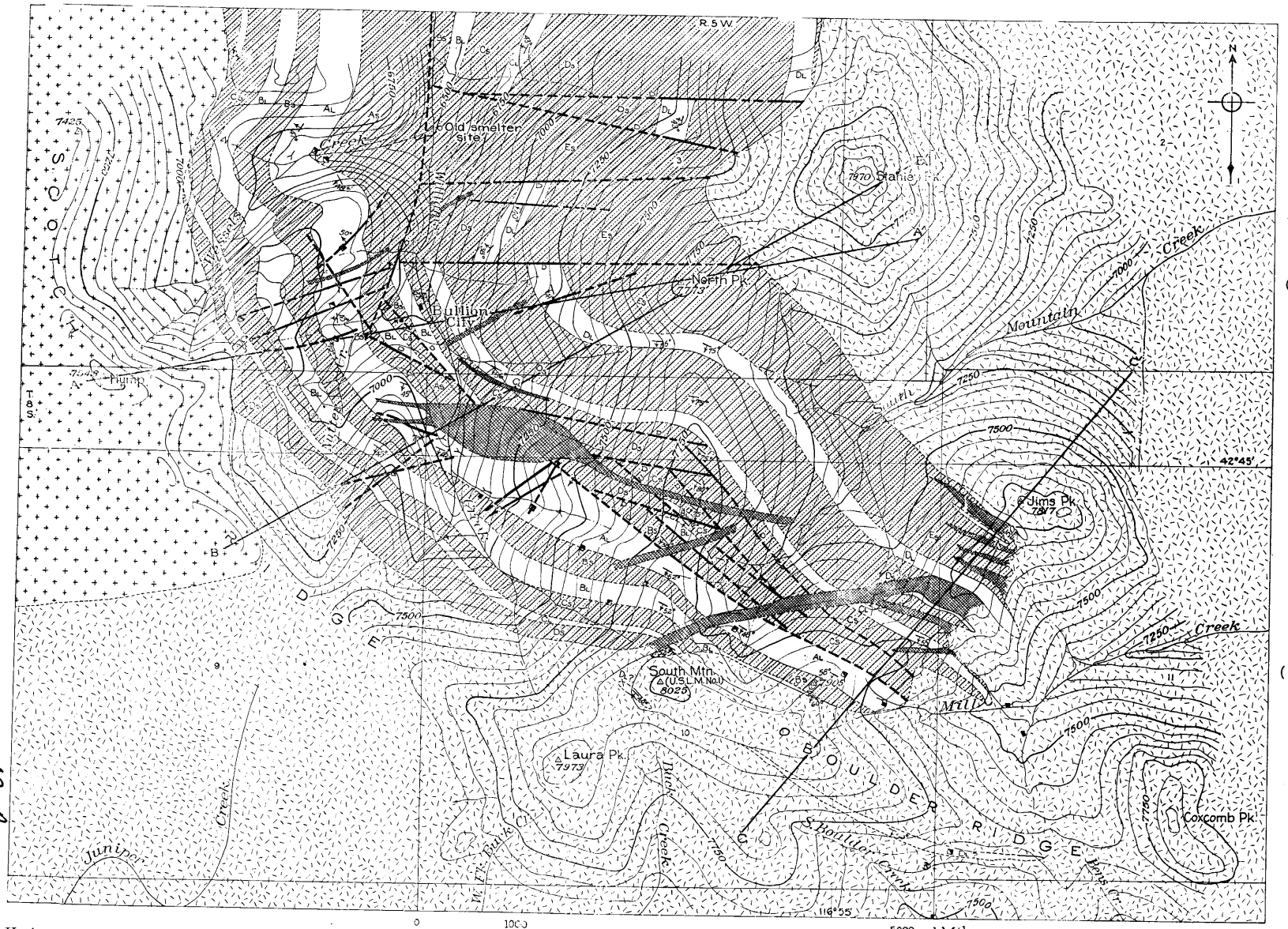
A. Avenue shaft
1. Bay State shaft.
2. Bay State tunnel.
3. Bay State upper tunnel.
4. Boulder tunnel
5. Fanny Hunt shaft.
6. Golconda new tunnel.
7. Golconda old tunnel.
8. Golconda stope.
9. Gopher shaft.
10. Grant incline.
11. Humbug shaft
12. Illinois shaft
13. Independence shaft
14. Laxey tunnel.
15. Little Rhoda shaft
16. Mahogany open cut.
17. Mexican shaft
18. Michigan shaft.
19. Queen of the Mountains open cut.
20. Queen of the Mountains shaft.
21. Queen of the Mountains tunnel.
22. Standard shaft.
23. Standard tunnel.
24. Texas shaft.
25. Texas tunnel.
26. Virginia shaft.
27. Virginia tunnel.
28. Washington tunnel.

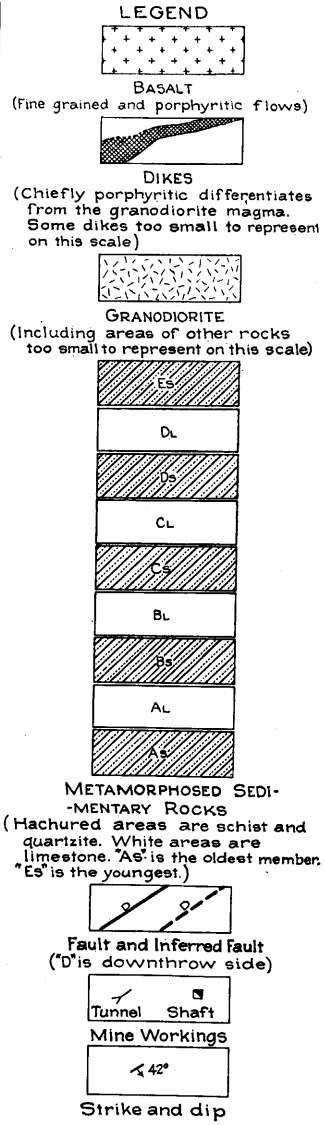
Control and claim corners from mine surveys.
Drafted by J. Vernon Otter.

Geology by Robert E. Sorenson.
Surveyed in 1926.

MAP SHOWING MINING CLAIMS, MINE WORKINGS, CONTACT ROCK, AND LINES OF MINERALIZATION, SOUTH MOUNTAIN MINING DISTRICT, [illegible]CHEE COUNTY, IDAHO

-12-A





Horizontal control based upon mine surveys and stadia traverse. Elevations based upon assumed elevation of 8,025 feet for South Mountain (See text).
Topography by Robert E. Sorenson.
Drafted by J. Vernon Otter.

0 1000 5000 1 Mile
Scale
Contour interval 50 feet Datum is mean sea level

Geology by Robert E. Sorenson.
Surveyed in 1926.

TOPOGRAHPIC AND GEOLOGIC MAP OF THE SOUTH MOUNTAIN MINING DISTRICT, OWYHEE COUNTY, IDAHO

-12-B

The normal phase of schist in thin section is seen to be composed of about 75 per cent quartz, 1 to 5 per cent garnet, and the remainder divided between muscovite (white mica) and biotite (black mica). The mineral particles composing the rock are all oriented with their long axis in one direction, thus giving the schistosity to the rock. Quartz grains are in part slightly elongated in the direction of rock cleavage. This elongation produces grains of lenticular cross-section measuring from 0.10 to 3.0 mm. in length, and 0.05 to 1.0 mm. in width. The average size of equidimensional quartz grains is about 0.25 mm. in diameter. In the main, the quartz is completely recrystallized, resulting in an interlocking mosaic. The quartz always shows wavy extinction, due to the intense pressure which altered the original sediment, and the grains are commonly much fractured. Quartz contains inclusions of apatite, muscovite, biotite, garnet, zircon, and magnetite. Laths of biotite and muscovite micas penetrate edges of quartz grains but normally lie parallel between quartz-rich layers of the rock. Garnets vary in size from 0.1 to 5.0 mm. in diameter with an average diameter of about 0.5 mm. The general character as shown in the hand specimens and the mineral composition as shown in the thin sections give the rock the name "garnetiferous-quartz-mica-schist".

In thin section, it may be seen that many of the schist members are rich in biotite, with very little muscovite; or rich in muscovite nearly to the exclusion of biotite. Quartz is present in small amount in some specimens and in much larger amount in others. A large increase in the amount of quartz makes the rock a true quartzite.

An important phase of the schist not discussed thus far is the graphitic schist. In thin section it is seen to be composed of quartz, for the most part, with minor amounts of biotite, muscovite, and garnet. Graphite makes up a maximum of perhaps 15 per cent of the rock in some specimens. It occurs rather evenly distributed through the rock. The rock might well be called a "garnetiferous-graphitic-quartz schist".

One narrow schist member is dark green to black in color, due to the presence of a large amount of hornblende. As in the other schist rocks, quartz is the dominant mineral. A small amount of biotite and muscovite may be seen in all thin sections, but hornblende makes up about 40 per cent of the rock. A few garnets are scattered through it. The composition, and the parallelism of the constituents suggests the name "quartz-hornblende schist." At its first outcrop north of South Mountain, this quartz-hornblende schist is intruded along its cleavage and occasionally in fractures across the cleavage by aplite stringers. The resulting rock might be termed an injection gneiss. The aplite is extremely fine-grained, but the high power lense resolves the mineral particles, so that tentatively they were identified as orthoclase, microcline, albite, and quartz. Secondary micas are present in small amount as alteration products of the feldspars.

Some phases of the schist show the results of contact metamorphic action. Small amounts of titanite, diopside, and actinolite--all distinctly younger than the quartz, mica, and other constituents of the rock--are present in some sections. The common relation, where diopside is developed, is partially replaced quartz grains in a matrix of younger diopside. Blades of actinolite, not commonly oriented along the lines of rock cleavage, branch out into the various rock constituents. Evidence of contact

metamorphism in the schist is slight when compared with the extensive changes in the limestone and calcareous quartzite. It is highly probable that the development of diopside and actinolite is the result of contact action on the calcareous matter which was present in the rock before the granitic intrusion. Biotite, along its cleavage, commonly shows alteration to chlorite. The result is an interfingering of the two minerals. The highly indurated character of the rock with the development of the quartz mosaic appears to be due, at least in part, to the action of solutions whose source was the granodiorite magma.

Weathering processes acting upon the schists, develop a yellowish rusty outcrop due to alteration of biotite, magnetite, and hornblende. In the main, this rusty surface appearance increases with an increase in biotite content of the rock.

Quartzite:

Quartzite of various types frequently occurs interbedded with the schists. A general idea of its prevalence may be obtained by reference to the geologic column (section on stratigraphy). Some fairly pure quartzite occurs interlaminated with micaceous layers in the schist. In some instances, fairly pure quartzite passes imperceptibly into quartz-mica-schist. True quartzite also grades into graphitic quartzite, and the latter into graphitic quartz-schist. No sharp line can be drawn between quartzites on the one hand and quartz-schists on the other. Almost every thin section of quartzite shows a small amount of mica or graphite. Quartzite and marble show intimate relations also. One comparatively important phase of the quartzite might well be classed as a calcareous quartzite, and locally, large limestone lenses are contained in it. ("BS" schist and quartzite in Geologic column and Pl. IIB). The areal distribution of quartzite is about the same as that of the schist since both occur interbedded and often interlaminated. Distinct bedding lines are developed in the quartzite, which, after weathering processes have effected it, show well-defined parallel bedding lines because of unequal weathering of different beds. Quartzite, with some schistosity, has this schistosity developed parallel with the lamination in the schists.

In the hand specimen, the rock varies much in general character, due to the varying amounts of the impurities--lime, mica, and graphite. The most common or normal phase of the quartzite might be classed as fine-grained. The color of the rock generally is light gray when fresh and yellowish gray when weathered. The common facies of the rock are : (1) a graphitic-calcareous quartzite, (2) micaceous quartzite, (3) calcareous quartzite, and (4) a phase resulting from extremes of contact metamorphism, with a development of large amounts of a greenish ferromagnesian mineral. Each of the phases combines with other phases to produce a multitude of rock types.

The normal phase of quartzite in thin section is seen to be composed largely of quartz with minor amounts of biotite, muscovite, and garnet. Accessory minerals are apatite, zircon, magnetite, and rutile. The texture is finely granular in the main, but departure to a coarser grained rock is not uncommon. Where biotite or muscovite are present, they are oriented with their long axis in one direction, giving a slight schistose character which is not very evident in the hand specimen. As noted in the description

of the hand specimen, in thin section there appears to be a gradation from true quartzite on the one hand to a quartz-mica schist on the other hand. The quartz grains average 0.25 mm. in diameter but vary widely from this average size. Inclusions of apatite, zircon, magnetite, rutile, and small dusty specks are common. Wavy extinction of the quartz is one criterion of the severe dynamic metamorphism which the rock has undergone. Water rounded quartz grains now are indicated by shadowy outlines. Quartz has been added to the central rounded nucleus and now the quartz grains have mutually interfering boundaries giving an interlocking mosaic. The quartz which has been added to the rounded nucleus has the same optical orientation as the central portion and represents a recrystallization of the rock due to the intense dynamic and contact metamorphism. Small stringers and fracture fillings of fine grained and drusy quartz cut through the rock and occasionally form a matrix for the large quartz grains in the rock. The micas, though quite commonly present, are not of much importance quantitatively. Less than one per cent of micas is the rule. They commonly penetrate the edges of the recrystallized quartz. Garnet is of minor importance as a constituent of the rock. The normal rock might well be classed as a quartzite.

The graphitic phase of the quartzite is much like the normal phase in general character but with an addition of varying amounts of graphite. The graphite probably represents a recrystallization of carbonaceous impurities in the original sediment. Bands of quartzite containing graphite definitely indicate the bedding planes in the sediment.

The micaceous phase of the quartzite is similar to the normal phase except that the micas are present in amount up to about 10 per cent. From this high-mica quartzite there is commonly an imperceptible gradation to the quartz-mica schist. Garnet, generally in small amount, is a constituent of the rock.

The calcareous phase is one of the most important of the quartzitic rocks. The rock, where only slightly acted on by contact-metamorphic agents, is a quartzite containing alternating bands of impurities, largely calcareous matter. The impurity bands are composed of fine to coarse grained calcite with some grains measuring as much as half an inch in diameter; fine grained white mica, probably sericite, biotite, which in part has altered to chlorite, and some graphite. Extremely fine-grained quartz is often a part of the impurity bands. The conditions of sedimentation under which this rock was laid down must have been extremely variable. Limestone lenses, varying in thickness from a few inches to as much as fifty feet, are present interbedded with the calcareous quartzite. The best examples are shown on Plate IIB just south of Jims Peak.

Evidences of contact metamorphic action in the normal phase of quartzite are not prominent, but much of the extreme induration is undoubtedly due to the action of solutions and gases which emanated from the intrusive granodiorite magma. The quartz stringers might also be referred to this source. In many instances a small amount of albite and potassic feldspars, of later generation than the quartzite grains, are found in the quartzite near its contact with the granodiorite. Magnetite, of later generation than the primary quartzite grains, is sometimes found near contacts. Needle-like quartz grains and sericite, with pyrite and pyrrhotite accompanying them, are common developments near igneous contacts.

One specimen of this quartzite containing pyrite and pyrrhotite was brought to the writer's attention by the owner of the prospect. It was reported to have come from Swazey gulch, about three miles northwest of Bullion City, and to have assayed about $12 per ton in gold. The writer did not examine the prospect, and the assay was not checked.

Weathering processes acting upon the normal phase of quartzite develop a slight iron stain due to oxidation of the biotite and magnetite. The coloration, which is poorly developed, is generally faint yellowish gray. The weathered rock, when pure, is light gray in color. Disintegration of the rock results in a residual fine-grained sandy material. In the graphitic quartzite contact metamorphism has probably produced a large part of the induration and the recrystallization of both quartz and graphite. Much the same results, as in the contact metamorphism of the normal quartzite, have also been noted in the graphitic quartzite. Weathering processes produce about the same results as they do on the normal phase. The micaceous quartzite exhibits about the same contact metamorphic alterations as the normal phase. The biotite is commonly altered to chlorite along the cleavage. This alteration to chlorite is probably a result of the action of the heated solutions and gases from the magmatic source. Near the surface the micaceous phase is generally quite highly colored with iron oxide.

The calcareous phase of the quartzite is the one exhibiting the most evidence of contact metamorphic action. The contact metamorphic mineral most commonly present is diopside, which generally occurs in thin beds interbedded with almost pure quartzite. The long axis of these pyroxene grains is not definitely oriented with the rock cleavage, and bedding lines in the rock can be easily seen in hand specimens because of the alternation of pyroxene-rich beds with quartz-rich beds. The diopside is light grayish-green in color and varies in size from microscopic grains to grains as large as one inch by three-eights of an inch in cross-section. In thin section the diopside is almost colorless. It commonly incloses and replaces rounded quartz grains, indicating its later generation. Residual calcite also occurs as inclusion in the diopside grains. Garnet, actinolite, rutile, clinozoisite, sericite, albite, orthoclase, and hornblende are minor constituents which are also due to contact-metamorphism. Chlorite is a common alteration of some of the sparcely distributed biotite laths. On exposure to the weather, the rock assumes a banded appearance. The diopside rich layers are colored yellowish by iron oxide, and the quartz-rich layers, which stand out in slight relief, are generally gray in color. The source of many of the elements, which are now a part of the contact metamorphic minerals, can be assigned to the calcareous impurity bands in the original calcareous quartzite. The action of the emanations from the granodiorite magma has been to develop the new and more complex minerals.

Limestone:

Limestone is probably the most important of the metamorphosed sediments from an economic viewpoint, because it is the host rock for the ore deposits. Practically all of the important ore bodies occur as veins and replacements in limestone. Limestone makes up 660 to 930 feet of the total 3570 to 4010 foot section of the metamorphosed sediments (see geologic column and Pl. III), and outcrops practically continuously from a

point near the head of Mill Creek to the most northerly exposure of the metamorphosed sediments in the area, a distance of about seven miles in all. Small oriented bodies of limestone are found as inclusions in the granodiorite, but most of these inclusions are too small to map. One large included bed, south of Boulder Ridge, outcrops for a distance of about 3300 feet (Pl. IIB). Similar lenses in the schist and quartzite are a common occurrence. Small schist and quartzite lenses, also, are found sparingly in the limestone. For the most part, the limestones are white or light gray in color and contain bluish bands of varying thickness. The bluish color is largely due to the presence of graphite. Quite commonly fine grained quartz is associated with graphite in the bluish layers. These quartzose-graphitic layers probably represent changes in sedimentation. Along the strike of any of the limestones the color varies greatly within the small area studied. In color the limestone varies from white to blue, and in some places these colors occur in alternating bands. This feature is one to be expected under changing conditions of deposition. A similar gradation is common vertically in many of the beds.

All the limestone in the area has been changed by metamorphism, and where the alterations have been least severe, the rock has been recrystallized. Small crystals are common in this instance. Part of this recrystallization, which is so general, must be referred to alteration as a result of dynamic metamorphism during the period in which the sediments were highly folded. Most of the altered character of the original sediment is probably a result of extensive recrystallization accompanying the intrusion of the granodiorite. In the areas least affected the individual grains of the limestone are not easily seen with the naked eye, but in the more affected areas--for example, in the vicinity of the Queen of the Mountains and Alabama claims--calcite crystals up to 2 inches in diameter are common. No definite line can be drawn which will separate the marbles produced by dynamic metamorphism from those caused by contact action. The fine to coarse crystalline rock is the normal phase and is discussed in the following paragraph. Comon facies, in the most part, referable to contact action are: (1) hedenbergite-ilvaite contact rock, (2) diopside contact rock, (3) tremolite contact rock, (4) garnet-diopside contact rock.

The normal phase of the limestone is fine-grained in texture and massive in structure. The color is white to bluish depending on the amount of impurities present. Locally, as stated above, the limestone is made up of alternating white and bluish bands, and layers of fine grained quartz are commonly interbanded with the lime-rich layers. Weathering of the banded siliceous limestone causes the quartz-rich bands to stand out in relief, because of their greater resistance to the processes of weathering.

The rock is holocrystalline, and the texture varies from fine to coarse. The pure white limestone is composed chiefly of calcite with some quartz. The calcite grains vary in size from 0.1 mm. to one cm. in diameter in the average rock specimen, but the coarse grained marble, present in the Queen of the Mountains and Golconda workings, contains calcite crystals as large as two inches in diameter. The large part of the rock is composed of grains averaging one mm. in diameter. Much of the calcite shows well developed twinning bands.

The bluish limestone differs from the white only in the amount of impurities present. The bluish color is due to the presence of varying amounts of graphite unevenly distributed through the rock in small specks and dentritic forms which occur generally between calcite grains, or as inclusions in the mineral. The banded blue and white limestone is merely a variation of the white rock and the bluish rock, but the banded limestone generally contains more quartz than the white or blue types. The quartz occurs almost invariably with the graphite in the bluish bands. Commonly the quartz is fine grained in texture and forms an interlocking mosaic as a result of recrystallization. The former rounded nature of the grains, now almost obscured by recrystallization, is occasionally seen as shadowy rounded outlines. Qualitative chemical tests, in some instances, show the presence of a small proportion of magnesium. The amount of magnesium appears to be variable, and in some specimens the amount is so small that qualitative tests indicate only a trace. From the evidence stated the rock might be called a recrystallized limestone or marble.

Hedenbergite-ilvaite contact rock

A contact phase of the marble composed chiefly of hedenbergite and ilvaite, outcrops about 100 feet northeast of the Laxey tunnel on the Mississippi claim and extends uninterruptedly southeastward along the strike of the "AL" limestone to the Texas shaft on South Mountain Creek. From there the outcrop is covered southeastward, but rock on the dump of the Standard shaft about 1200 feet southeast of the Texas shaft contains hedenbergite as an important constituent. In this distance of more than 3000 feet the hedenbergite-ilvaite outcrop varies much in width. Where it is crossed by the east line of the Mississippi claim this contact rock is almost 200 feet wide (Pls. IIA and IIB, and "C" Pl. IV). Near the Texas shaft the hedenbergite-ilvaite rock is about twenty-five feet thick. The main body of this material follows along near the hanging wall of the "AL" limestone, but branches out irregularly, replacing the latter, and, in some instances, including large bodies of the normal rock. The replacement is very irregular as is characteristic of contact deposits. Another body of this phase of the contact rock is found along the hanging wall of the "BL" limestone on the Virginia claim. The thickness of this deposit is generally less than fifteen feet, but it is exposed irregularly for about 900 feet (Pls. IIA and IIB). In all of the area mapped in detail, the above described deposits of the hedenbergite-ilvaite contact rock are the only ones that were noted.

The rock is typically massive in character and is composed largely of hedenbergite, ilvaite, quartz, and unreplaced recrystallized limestone ("A", "C", and "D" of Pl. V). The color of the rock, when fresh, is a brownish olive green due to the large proportion of hedenbergite. The hedenbergite ($CaO.FeO.2SiO_2$), lime-iron pyroxene, occurs in fine grained massive aggregates and fine to coarse bladed masses. This mineral is described by Shannon (20:p.282) in specimens from South Mountain. The blades are mutually interfering and interlocking in part, and radiating groups of bladed crystals terminate in semicircular outlines. In many instances the bundles and radiating groups of hedenbergite blades terminate in rudely symmetrical, smooth surfaced, fossil-like forms. The blades vary from microscopic size to six inches in length by one-half inch in diameter. Hedenbergite is present in largest amount, but ilvaite is one of the

important rock constituents. Ilvaite ($H_2O.CaO.4FeO.Fe_2O_3.4SiO_2$) occurs in fine grained aggregates to coarse crystalline masses, in most instances, in a matrix of hedenbergite, calcite, or quartz. Ilvaite at South Mountain has been described in detail by Shannon (19:pp.118-125, and 20:pp.334-337). Ilvaite crystals vary in size from microscopic grains to prisms four inches long by one inch in diameter. The best developed crystals occur in crystalline limestone("A" Pl. V). Quartz is present throughout the hedenbergite-ilvaite zone. Garnet is also present but it occurs rather unevenly distributed. One specimen is composed of large masses of ilvaite in a matrix of garnet and quartz ("C" Pl. V) with no hedenbergite visible to the unaided eye. Small cavities in the hedenbergite-ilvaite contact rock are filled with quartz prisms, calcite rhombs, nail head calcite, dog tooth calcite and pyrite. Shannon (20:p.337) includes an analysis of the South Mountain ilvaite in his detailed description of the mineral from this district. A copy of that chemical analysis follows:

Analyses of Ilvaite, Golconda Mine

(W. F. Hillebrand, Analyst)

Silica (SiO_2)	29.16
Alumina (Al_2O_3)	.52
Ferric iron (Fe_2O_3)	20.40
Ferrous iron (FeO)	29.14
Manganese oxide (MnO)	5.51
Lime (CaO)	13.02
Magnesia (MgO)	.15
Soda (Na_2O)	.08
Water (H_2O) below 110° C.	.15
Water (H_2O) above 110° C.	2.64
- Total -	100.77

Following the above analysis, Shannon describes the physical properties of the Idaho ilvaite. He says: "In the Idaho ilvaite, cleavage is present, but not conspicuous, parallel to b(010). The fracture is uneven, hardness 5.75; specific gravity 4.059 (Hillebrand). The luster is vitreous and not submetallic as described from other localities; color, black; streak black with faint brownish tinge. The mineral is rather difficultly fusible before the blowpipe and upon fusion, it intumesces slightly and yields a black magnetic bead. It is readily soluble in hot hydrochloric acid, yielding an amber solution which gelatinizes."

In thin section this contact rock is composed of the following minerals listed in the order of crystallization, oldest first: (1) residual calcite; (2) garnet; (3) ilvaite; (4) hedenbergite and tremolite (?);

(5) quartz, sulfides, and calcite. Some variations of this order were noted.

The residual calcite (calcium carbonate) represents the part of the recrystallized limestone which has not been replaced by the later minerals. The grains of this mineral are intimately intergrown, twinning is common, and the residual calcite is replaced by all of the later minerals. Ilvaite has grown at the expense of the calcite, and in most instances it was noted that the larger ilvaite crystals are formed in the residual calcite ("C" Pl. V). Garnet, commonly showing anomalous double refraction, replaces the calcite of the marble but is in turn replaced by ilvaite and the other younger minerals.

The hand specimen description of hedenbergite holds also in thin section. The hedenbergite blades are, in part, concentric in habit, but bundles of parallel blades are not unusual. The color is only slightly greenish with little or no pleochroism. The cleavage is well pronounced, and there is a tendency for the blades to fracture across the long axis of the prisms. The hedenbergite blades cut through and replace the residual calcite in every instance when the two minerals are associated. In one thin section a small amount of a fibrous mineral was tentatively identified as tremolite. It is quite closely associated with hedenbergite in age.

With the exception of some of the pyrite, sulphides, accompanied by quartz, are a somewhat later development than the hedenbergite. Sulphides, following fractures through this contact rock, commonly replace the residual calcite and metamorphic silicates in an irregular manner, and small sulphide-filled fractures widen out into larger masses of solid sulphides. Pyrite, pyrrohotite, sphalerite, chalcopyrite, and galena are the predominating sulphides.

Small cavities in the hedenbergite-ilvaite contact rock are partly filled by quartz prisms, calcite rhombs, dog tooth spar, and nail head spar.

This iron-rich hedenbergite-ilvaite rock is very easily altered by the action of katamorphic agencies. Near the present surface the rock has altered to an oxidized mass which has been confused with a gossan cropping of an ore body. Limonite, some hematite, and manganese oxides make up the near surface expression which on close examination reveals the branching and concentric bladed hedenbergite. In many places along the strike of this contact rock, oxidized copper minerals occur in association with the iron and manganese oxides. The best example of this type of oxidized material is exposed in the Laxey tunnel, a short drift into the hedenbergite-ilvaite contact rock near its foot wall. Oxidized lead and zinc minerals are also present.

Diopside contact rock

About 1000 feet southeast of the old smelter site in the "DL" limestone there is an exposure of contact rock composed largely of diopside*

*Identified microscopically by Dr. Esper S. Larsen of Harvard University, March, 1927.

with a small amount of graphite. The diopside rock replaces the marbleized limestone irregularly along the hanging wall of the latter and is exposed for about 150 feet in a northeast-southwest direction. The thickness of the contact rock varies considerably, but it widens to as much as 100 feet.

The rock in hand specimen is white in color with a slight bluish tinge due to the presence of graphite. The diopside ($CaO.MgO.2SiO_2$), calcium-magnesium silicate, which replaces the marble, occurs in fine grained and fibrous masses and in coarsely crystalline aggregates. The crystals are prismatic in habit and form long blades. The largest of the blades measured seven inches in length by two inches in cross-section ("B", Pl. V). Small amounts of graphite occur in close association with the diopside.

In thin section the diopside is seen to be replacing the calcite of the marble. Remnants of calcite are included within the blades of diopside, and prisms of the latter penetrate calcite grains. The white color of the diopside and the unusually large crystals are interesting features.

Tremolite contact rock

In many places within the area examined, the limestone is replaced in part by tremolite. Irregularly along the "AL" limestone from Bullion City north for more than two miles, tremolite is an important contact mineral in the limestones. Good specimens of fibrous and bladed tremolite in the marble were obtained from the dump of the Bay State tunnel and from an outcrop of the "AL" limestone, about one mile north of Bullion City.

The tremolite occurs as a filling along minute fractures and former bedding planes in the limestone, and, as an irregular replacement of the calcite grains in all directions from the small fractures. The tremolite is both fibrous and bladed.

Garnet-diopside contact rock

Along the hanging wall of the "AL" limestone near the Texas shaft there is an outcrop of contact rock which is composed largely of garnet and diopside. The outcrop indicates that the contact rock is about fifteen feet thick. In part, this garnet-diopside rock forms the hanging wall for the hedenbergite-ilvaite rock and associated sulphides.

The rock is extremely porous in nature, due to the action of weathering. The garnet and diopside have both been altered to limonite giving a yellowish tinge to the rock. The garnet is a light pink in color, and the diopside is light greenish. The garnet appears to be slightly older than the diopside although the relations might be interpreted as those of contemporaneity. A few grains of sulphides, pyrite, sphalerite, and chalcopyrite, were noted in the specimens examined. The sulphides appear to be younger than the garnet and diopside.

METAMORPHISM

Dynamic Metamorphism

The results of dynamic metamorphism can be seen best in the metamorphosed sediments. The granodiorite shows no parallel arrangement of the mineral particles; in fact, the only evidence of pressure effects is found in a slight wavy extinction in the quartz grains. The metamorphosed sediments, on the contrary, exhibit much evidence of pressure effects. In the schist the mineral particles are all oriented with their long axis in parallel arrangement. Much of the quartz in these rocks is somewhat lenticular in cross section, and the laths of biotite and muscovite are parallel with the long axis in the lenticular quartz grains. This parallel arrangement, or schistosity, is to be expected as an accompaniment of the overturned folding which has affected the metamorphosed sediments (see discussion of structural features and Pl. III, also "B", Pl. IV).

Minor folds in the metamorphosed sediments are commonly present. The less competent beds have thickened and the more competent beds have fractured near the crests of these folds. The minor folding gives rise to highly contorted beds ("B", Pl. IV), and is not well shown in the marble because of a greater tendency toward recrystallization to care for increases of pressure. In the major overturned anticlinal fold the beds have swelled and pinched, due to flowage in the less competent members. Because of this the thickness of any particular beds varies somewhat from place to place. Much of the recrystallization of the sediments no doubt can be assigned to dynamic metamorphism.

Contact Metamorphism

To separate entirely the results of contact metamorphism from those of dynamic metamorphism is impossible, but the former exhibits unquestionable evidence of its prevalence during the intrusion of the granodiorite magma. Much of the evidence of contact action is contained in the descriptions of the metamorphic rocks--schist, quartzite, and limestone--hence a review of the previously mentioned material will serve to cover the subject of contact action.

Contact metamorphism has left little impression in the normal phases of schist and quartzite. Part of the recrystallization of the quartz and other minerals can be referred to this cause. In the calcareous phases of the quartzite, contact metamorphism has produced a number of typical contact minerals, among these are: diopside, actinolite, quartz, albite, potassic feldspars, magnetite, sericite, pyrite, pyrrhotite, graphite, calcite, garnet, rutile, clinozoisite, hornblende, and titanite. The development of many of the metamorphic minerals calls for an addition of iron and magnesia. Most of the other elements which are found in the contact metamorphic minerals probably were present in the rocks as impurities. The development of these minerals is great near contacts with the granodiorite intrusive, although, in some instances, at the contacts themselves very little change has taken place in the calcareous quartzite; but in other instances, contact action is well pronounced as much as 1000 feet laterally from the igneous rock. All evidence points to the assumption that the metamorphosed sediments represent a roof pendant resting upon the intrusive granodiorite. As shown in the geologic structure

sections, Plate III, the sedimentary beds have such an attitude that solutions and gases from the intruding rock would follow upward quite naturally along the bedding planes. Concentration of emanations along particular beds might account for more contact action in those beds perhaps at some horizontal distance from the intrusive contact.

The marble owes much of its crystalline character to recrystallization accompanying the intrusion of the granodiorite. None of the original limestone in the region has been allowed to retain its original character. Recrystallization is everywhere apparent, but, as should be expected, limestone in parts of the district has been marbleized to a much greater degree with the development of extremely large crystals of calcite. The area of most intense contact action is found in the "AL" limestone from the Bay State workings south and southeast to the Standard workings (Pls. IIA and IIB). The development of large calcite crystals is greatest in the vicinity of the Queen of the Mountains tunnel. Southeastward along the Mississippi, Florida, Texas, and Standard claims in the "AL" limestone there is a large body of hedenbergite-ilvaite contact rock. Another small body of this same material crops out on the Virginia claim along the hanging wall of the "BL" limestone. Near the hanging wall of the "AL" limestone on the Texas claim there is a body of garnet-diopside rock. About 1000 feet southeast of the old smelter site in the "DL" limestone there is an exposure of almost pure white diopside. The only other contact minerals associated with it are quartz, calcite, and graphite.

In the production of the hedenbergite-ilvaite rock and the garnet-diopside rock, an addition of silica, iron, and probably some magnesia is necessary. In part, the limestone is somewhat magnesian, but indications are that sufficient magnesia was not present to produce such large bodies of magnesian-rich minerals. The hedenbergite-ilvaite contact rock is in part replaced by sulphide minerals which probably accompanied or followed closely the solutions responsible for the contact metamorphism.

The contact metamorphic minerals identified in the limestones are, in part, the same as those identified in the calcareous quartzite with the addition of hedenbergite, ilvaite, and tremolite.

IGNEOUS ROCKS

Intrusive Rocks

The granitic intrusive of the South Mountain region, like the intrusive of the Silver City region, (15:p.14) is possibly a small outlier of the great Idaho batholith of Cretaceous (?) age. All evidence indicates that the South Mountain intrusive should be correlated with the granitic intrusive of the Silver City region. A granitic intrusive is exposed at Demming on Boulder Creek about midway between South Mountain and Flint. Relatively, the granodiorite is younger than the pendant block of metamorphosed sediments, and in a large measure, the alteration of the sediments is due to the granitic intrusion. The absolute age of the South Mountain granodiorite is not known; it was intruded in pre-Miocene time. Relative age is all that is necessary in a study of the economic aspects of the region. The granitic rock of the region is normally a granodiorite in composition. A departure from the normal rock is the biotite granite of Jim's Peak. Pegmatite, aplite, and dacite porphyry dikes are common differentiates of the granitic intrusive.

Granodiorite:

Granodiorite and closely associated rock types, surrounding the lense-like outcrop of metamorphosed sediments, outcrop over an area about ten miles long and two miles to five miles wide. The narrowest outcrop is in the northwestern part of T. 7, S., R. 5, W., and the widest outcrop is just south of South Mountain (Pl. I). The granodiorite practically surrounds the belt of metamorphosed sediments and contains oriented inclusions of the latter. The relations existing between the metamorphosed sediments and the granodiorite strongly suggest that the sediments are structurally a roof pendant in the small granitic intrusive. The writer has so interpreted the structural relations (Pl. III). Along the southeast end of the outcrop of the metamorphosed sediments the granodiorite intrusive irregularly replaces the schist, quartzite, and limestone, and interfingers with the sediments. The granodiorite grades imperceptibly from the coarse grained granitic mass to the porphyritic phase immediately surrounding the periphery of the metamorphosed sediments, and in the interfingering apophyses the rock takes on a dike-like character. In some instances, the apophyses continue into the sedimentary rocks a long distance, break away from the line of bedding, and strike out at an angle through the sediments. This tendency on the part of the granodiorite has been illustrated on the map (Pl. IIB) by giving the dike symbol to the apophyses.

The granodiorite is commonly jointed and thereby broken into blocks of varying size. The joint planes usually intersect at nearly a right angle, and dip practically vertical. In some instances, sheeting, very similar to that exhibited in the Silver City region (15:p.38), gives a bedded appearance to the rock. This sheeting tendency is not developed everywhere in the area, however.

The highest peaks of the South Mountain Range are rocky peaks of granodiorite. The slopes are covered, in part, by the altered granitic rock giving a deep soil mantle.

In the hand specimen, the normal phase of the granodiorite is granular in texture, light to medium gray in color, and holocrystalline. Biotite, quartz, feldspars, and an indeterminable greenish-black mineral are visible to the unaided eye. The individual grains of the rock average about one-eighth of an inch in diameter, but occasionally large phenocrysts of the feldspars reach an inch or more in cross-section. The megascopic examination of the rock classifies it as a granodiorite.

Under the microscope, the rock is medium granular in texture. The essential minerals in the order of their crystallization are: pyroxene, biotite, hornblende, plagioclase, potassic feldspars, and quartz. Accessory minerals are magnetite, pyrite, apatite, zircon, and garnet. Alteration minerals are white mica, chlorite, uralite, limonite, and kaolin. By microscopic examination a quantitative estimate of the mineral composition is as follows: quartz 15%, orthoclase and microcline 15%, oligoclase 45%, biotite 15%, pyroxene altered to uralite 5%, hornblende 3%, accessory minerals and alteration minerals 3%.

A pyroxene is a common constituent of the rock, but the exact mineral is indeterminable because of alteration. The pyroxene has been completely altered and completely replaced by the pseudomorph, uralite. The pyroxene was one of the first minerals to crystallize following the apatite and magnetite, which are present as inclusions in the younger minerals. Biotite, the most abundant ferromagnesian mineral, occurs in irregularly distributed laths, which have been slightly altered to hornblende along the cleavage and around grain borders. The outlines of the biotite grains show resorbtion by the later crystallizing minerals. Hornblende is present in only small amount in the normal phase of the rock. Prismatic crystals showing replacement outlines are common. Alteration minerals of the hornblende are chlorite and limonite. The dominant feldspar is oligoclase, which occurs as elongate prisms showing euhedral outlines in the main, although mutually interfingering grains of this plagioclase are common. Twinning according to the albite law is common, and a large proportion of the grains show well developed zonal growth. White mica is an alteration product along fractures in the oligoclase. The crystals of orthoclase and microcline have anhedral outlines, due to interference by the minerals already present. In some instances, the potassic feldspar grains reach more than an inch in diameter. White mica and kaolin are alteration products of the orthoclase and microcline. Following the crystallization of the orthoclase and microcline, quartz was deposited as an interspace filling. The quartz grains have anhedral outlines and form an interlocking mosaic. Wavy extinction is only slightly pronounced. The composition of the rock, according to the classification of Iddings (10:pp.357, 358), would classify it as a normal granodiorite.

Where exposed to the processes of weathering, the granite is highly altered, giving a surface stained reddish-brown by the iron oxide which has been developed from the ferromagnesian minerals. More complete alteration causes the feldspar to break down, giving a sandy mantle which covers the granodiorite slopes.

A departure from the normal phase of the granodiorite is the development of a porphyritic phase in a peripheral belt near the contact of the granodiorite and the metamorphosed sediments. This porphyritic phase grades imperceptibly into dike rock in many instances. The most evident example of this gradation was found in dikes or apophyses, which intrude the metamorphosed sediments along their strike. This is best shown at the southeast end of the metamorphosed sedimentary belt between Jim's Peak and Boulder Ridge (Pl. IIB). The rock is porphyritic in texture and light in color. Its composition is much the same as the normal granodiorite, and it differs markedly from the granodiorite only in texture. The minerals common as phenocrysts are uralized pyroxene, biotite, and oligoclase or andesine. Potassic feldspars, quartz, and ferromagnesian minerals form a finer grained matrix for the euhedral to subhedral phenocrysts. The rock might well be classed as a dacite porphyry.

On Jim's Peak, Coxcomb Peak, and Stanley Peak, the intrusive is lighter in color than the normal granodiorite. The texture is granitic and the mineral composition, as seen with the unaided eye, is quartz, feldspar, and biotite. In thin section the estimated amounts of the minerals are as follows: orthoclase and microcline 45%, oligoclase 20%,

quartz 25%, biotite 10%. The order of crystallization is biotite, oligoclase, orthoclase and microcline, and quartz. The rock is a typical biotite granite.

Differentiates of the Granodiorite:

Graphic Pegmatite

Graphic pegmatite, an intergrowth of quartz and large crystals of orthoclase and microcline, is a common differentiate of the granodiorite on Jim's Peak and Coxcomb Peak. Quartz is graphically intergrown with orthoclase and microcline, which are present in subhedra as large as six inches in greatest cross section. A small amount of albite and occasionally muscovite are associated with the potassic feldspars and quartz.

Aplite

Small aplite dikes and stringers, differentiates of the granodiorite magma, are closely associated with the graphic pegmatite. The rock is typically fine grained in texture and is composed of orthoclase and microcline about 50%, quartz about 30%, and albite about 20%. Only an occasional grain of muscovite was noted.

Dacite Porphyry

As noted under the discussion of granodiorite, apophyses of the latter interfinger with the metamorphosed sediments. These apophyses are of essentially the same texture and composition as the typical dike rocks which grade laterally in many instances from the apophyses. The intrusion of the dacite porphyry dikes in a large measure probably closely accompanied the intrusion of the granodiorite. Little differentiation of the granodiorite was necessary to produce the dacite dikes in so far as the dikes are of approximately the same composition as the larger intrusive mass. In one instance on Coxcomb Peak, a dacite porphyry dike about 15 feet wide traverses the granodiorite. Most of the dacite porphyry dike outcrops are confined to the areas of metamorphosed sediments, however.

In the hand specimen, the rock is medium to dark gray in color and porphyritic in texture. Phenocrysts of the feldspars, quartz, and occasionally ferromagnesian minerals are discernable to the naked eye.

In thin section, the normal phase of dike rock is porphyritic in texture with large phenocrysts of plagioclase, quartz, hornblende, and occasionally potassic feldspars in a finer grained holocrystalline ground mass. The size of the grains of the ground mass vary from grains resolvable only with the high power lense to grains easily distinguishable with the naked eye. The mineral composition is as follows, in order of abundance: Plagioclase, potassic feldspars, quartz, biotite, hornblende, and pyroxene. A large proportion of the phenocrysts are the plagioclase feldspar, andesine, but phenocrysts of quartz and potassic feldspars are not uncommon. The fine grained matrix for the phenocrysts is composed largely of potassic feldspars, biotite, hornblende, and finer grained quartz. The phenocrysts of quartz and andesine, occasionally potassic feldspars and ferromagnesian minerals, commonly are partly resorbed by the slower

crystallizing matrix. Chlorite, accompanied by iron oxides, is a common alteration product of the ferromagnesian minerals, and white mica and kaolin are alteration products of the feldspars. The rock has the composition and texture of a typical dacite porphyry, hence it is thus named.

One dike exposed on the Michigan and Massachusetts claims is somewhat richer in ferromagnesian minerals than the normal phase of the dike rock. Phenocrysts, predominantly hornblende accompanied by andesine, are the rule in this specimen. The composition is otherwise little changed. Variation in the amounts of the mineral constituents changes the color of the rock and outward appearance, but all of the dikes examined may be classed under the general head of dacite porphyry.

A Peculiar Dike Rock Alteration

In the Boulder tunnel a clay-like substance, probably a dike alteration, follows along the foot wall of a thin limestone body which is a pendant in the granodiorite. (See the description of the Boulder claim under the description of Mines and Prospects). The material has physical properties similar to those of bentonite. It is massive, clay-like, and soft, and the luster is feeble. It adheres to the tongue, and swells to many times its original size when placed in water. The material contains sufficient iron oxide to color it a light chocolate brown. Evidences of possible phenocrysts are visible as whitish specks in the brown mass.

The writer is of the opinion that the product is an alteration of an acidic dike rock. Bentonite has been described as an alteration of acidic lavas, but the writer can find no reference in geologic literature to its possible origin as an alteration product of a dike.

Extrusive Rocks

Extrusive igneous rocks are represented by basalt in the South Mountain region. The basalt flows can be directly correlated with the basalt of the Silver City region which is assigned, with a question, to Miocene time on the basis of recent work by Chaney (7) and Buwalda (12:p.19). This recent work has revised Lindgren's (13:pp.97-99) correlation of the Payette formation which determines the age of the Silver City extrusives.

Basalt:

After the granodiorite was intruded erosion acted upon the sediments and the intrusive to produce a land surface with slight relief. Basalt lava was poured out upon this denuded surface during Miocene (?) time. The age of the extrusive basalt is unquestionably shown to be younger than the granodiorite and metamorphosed sediments by its attitude, especially on the ridge north of the Washington tunnel (Pl. IIB). Figures "A" and "D" of Plate IV show the superimposed character of the basalt.

The thickness of the basalt was not determined in more than one part of the area. On Scotch Ridge the writer observed a thickness of more than 600 feet. Northwest of the detail area, small canyons about 1000 feet in depth have their walls entirely in basalt. The elongate area, in which the metamorphosed sediments and granodiorite are exposed, is completely surrounded by the basalt flow.

Unlike the basalt which forms the basal portion of the flows in the Silver City region (15:p.21), the lower portions of the basalt which is exposed in the vicinity of South Mountain is chiefly fine grained in texture and probably the result of quiet flows. No definite figure on the number of separate flows was obtained by the writer, but indications are that they are not few in number.

In the hand specimen, the normal phase of the basalt is fine grained in texture and dark in color. Individual mineral particles are not recognizable. The basalt is not an unusual type and needs little description.

In thin section the rock is fine grained in texture and is composed of the following minerals: labradorite, augite, magnetite, and occasionally olivene. The plagioclase, labradorite, occurs in fine lath-like crystals with terminations controlled by the augite grains. The small labradorite laths penetrate and replace the augite grains which apparently were of an earlier crystallization. Magnetite makes up perhaps two or three per cent of the rock. A small amount of olivene was noted in some slides. Chlorite was occasionally noted as an alteration product of the augite. As a whole the rock is comparatively fresh, however. The rock may be classed as a basalt of usual type.

Weathering processes acting on the basalt produce a mottled surface colored yellowish to reddish brown by iron oxides. A mottled surface effect is due, it seems, to a slight patchy distribution of the minerals which alter to produce the iron oxides.

One phase of the basalt, which is of interest, is a highly vesicular porphyritic type. The only observed outcrop is near the Hump triangulation point on Scotch Ridge. This flow is partly denuded but the exposed thickness is not in excess of 100 feet. The composition is essentially the same as the normal phase, but the rock is highly vesicular. Labradorite phenocrysts occur in a finer grained matrix of labradorite, pyroxene, and magnetite. The large phenocrysts possibly are intratelluric, that is, they may have formed in large part before this flow was extruded. After extrusion, the matrix cooled quickly, and enveloped the larger phenocrysts. The vesicular character of the rock is so well pronounced that it approaches a scoria. The most descriptive term for this flow rock is perhaps "vesicular porphyritic basalt."

STRUCTURAL FEATURES

Pendant Metamorphosed Sediments

An interesting structural feature in the South Mountain region is a lenticular-outlined roof pendant of metamorphosed sediments in the intrusive granodiorite. The areal extent of the sediments is shown on Plate I. The included block is surrounded peripherally by granodiorite at the surface, with the exception of a distance of about two miles on the southern part of the west side, and about one-fourth of a mile on the north end. In both of these instances, the younger superimposed basalt is in contact with the sediments. That this body of metamorphosed sediments is a roof pendant in the granodiorite intrusive, is indicated by

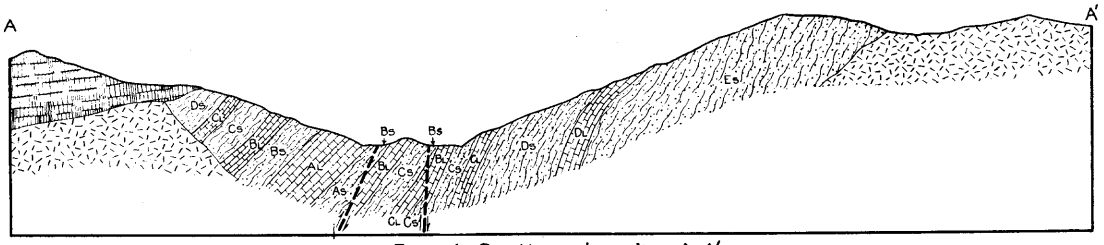


Figure 1 - Section along line A-A'

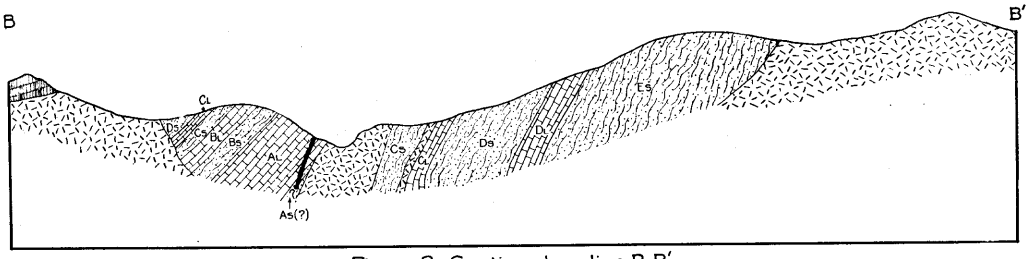


Figure 2 - Section along line B-B'

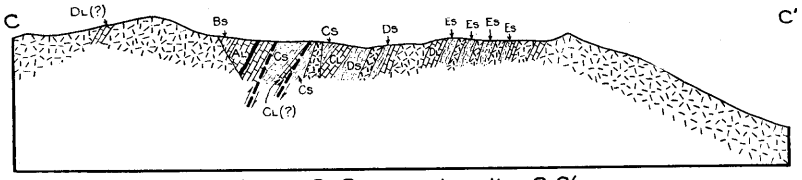
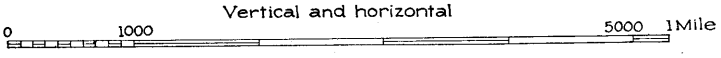


Figure 3 - Section along line C-C'

Scale
Vertical and horizontal

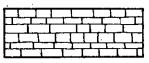


LEGEND

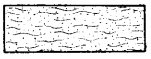
BASALT
(Fine grained and porphyritic flows)

BLACK LINES INDICATE MINERALIZATION

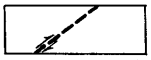
GRANODIORITE
(Includes differentiates from the granodiorite magma)



RECRYSTALLIZED LIMESTONE
("AL" oldest - "DL" youngest. Interbedded with schist and quartzite. "As" schist and quartzite is older than "AL" limestone etc.)



SCHIST AND QUARTZITE
("As" is oldest metamorphosed sediment exposed)



FAULT
(Dip approximate)

-28-A

GEOLOGIC STRUCTURE SECTIONS ALONG DESIGNATED LINES ON PLATES IIA AND IIB

innumerable isolated inclusions of the sediments in the granodiorite. Most of these are too small to represent on the scale of the maps, but two inclusions of the "DL" (?) limestone are shown on Plate IIB south of South Mountain and Boulder Ridge. Small bodies were noted unevenly distributed in many places in the granodiorite. Limestone, schist, and quartzite pendant bodies are rather prevalent in the vicinity of Coxcomb Peak. In the main, such inclusions are oriented with the schistosity practically parallel with that of the main body of metamorphosed sediments.

Another indication that the sediments occupy the position of a roof pendant is the large number of apophyses of granodiorite which are intruded into the metamorphosed sediments. The best examples may be found at the southeast end of the pendant body where the apophyses, in part, follow along the strike of the bedding in the sediments (Pl. IIB).

An interesting feature at this end of the sediments is that the limestone members have withstood the replacing action of the intrusion to a greater degree than have the quartzite and schist. As a consequence, the limestone members penetrate further into the granodiorite mass than do the other members. The presence of isolated remnants of "DL" (?) limestone south of Boulder Ridge is further evidence of the resistance, on the part of the marble, to replacement by the intrusive body. In most of these instances, the limestone is not highly silicified.

Folding

Prior to the intrusion of the granodiorite, the South Mountain group of sediments was highly folded and contorted. The only major folded structure still preserved in the sediments is an overturned anticlinal fold whose axis strikes north-south to N. 10° W. in a northerly direction from Bullion City, but east of Bullion City the axis strikes about northwest-southeast. The fold is overturned from west to east with its axial plane dipping 50° to 70° to the west and southwest. The fold pitches slightly toward the north. The development of this fold demands a crustal shortening in a direction approximately at right angles to the strike of the axial plane, with the greatest movement from west to east. Small minor folds with their axes approximately at right angles to the axis of the major fold give rise to some curvature of outcrops, especially along the strike of the sediments between Wessels Creek and Nutter Creek (Pl. IIB). On the limbs of the major fold are developed a multitude of minor folds.

Fracturing

It is indeed regretable that so little information concerning fracturing was obtained in this survey of the South Mountain district. The fracture sets in the belt of metamorphosed sediments were not extremely difficult to locate, but only little information regarding faulting in the granodiorite areas was obtained. The reason for this lack of information is that the granodiorite is covered by a thick mantle of soil everywhere, with the exception of a few widely separated places. It is probable that the complex fault systems mapped and analyzed by Piper and Laney in the Silver City region (15:pp.37-51) have their representatives in the granodiorite and basalt at South Mountain. The fracture systems

noted in the metamorphosed sediments appear to be older than the granodiorite intrusive. Faults are rather easily located because of displacement of the beds and the resulting offset, or, a break in the normal sequence; but the minor fracture sets of little displacement are difficult to locate because of the deep soil covering.

The fractures may be divided into those formed in the sediments before the intrusion of the granodiorite, hereafter called fractures in the metamorphosed sediments; fractures in the granodiorite; and fractures in the basalt.

Fractures in the Metamorphosed Sediments:

As an accompaniment of the overturned folding occurred the commonly associated overthrust faulting. These faults are overthrust from west to east and from southwest to northeast. The largest overthrusts, having several hundred feet of vertical displacement, strike and dip approximately with the axial plane of the overturned anticline. The dip, which was impossible to determine accurately, is 50° to 70°, probably nearer the higher figure. The largest of these, two in number, are, respectively: the Williams Creek overthrust, which strikes north and south and follows Williams Creek canyon for more than a mile north of Bullion City; and the Golconda overthrust, which strikes approximately northwest and southeast and follows along near the foot wall of the "AL" limestone a great part of the distance. Another, but small, overthrust nearly parallels the Golconda overthrust to the north. It follows along the strike of the "CS" schist and quartzite from the ridge north of South Mountain to the contact of the metamorphosed sediments and the granodiorite near the head of Mill Creek, and dips southwest at an angle of about 55° to 65°.

After the overthrusting, apparently a readjustment of forces took place with the development of a set of fractures which strikes N. 70° to 90° W. The best examples of this set are the east-west vertical dipping fractures east and north of Bullion City on the down thrown side of the Williams Creek overthrust, and the east-west faults between the "AL" limestone and North Peak on the north side of the Golconda fault. All of these fractures show considerable displacement vertically. The attitude of the beds on the two sides of the fault plane might result from either vertical or horizontal movement parallel with the strike. The field relationships, however, seem to indicate that the movement was chiefly vertical.

Associated with this set of east-west fractures there is a set of steeply dipping or vertical fractures which strike N. 40° to 50° W. This set in combination with the east-west set, has developed fault blocks best shown on and near the ridge between South Mountain and North Peak. In some instances, the vertical component has been great. No measure of the movement could be obtained at the surface and no mine workings expose the fractures. The rocks included between east-west fractures northeast of Bullion City must have moved as fault blocks with a large vertical component. Dikes probably following along former fractures in part parallel the east-west set of fractures.

A number of nearly vertical fractures of little or no displacement are found chiefly on the west and southwest side of the Williams Creek and Golconda overthrusts respectively. Most of the fractures strike north 67° to 75° east. Dikes commonly followed this set of fractures and in many instances this set was followed by sulphide mineralizing solutions.

Other sets of minor fractures, chiefly dipping steeply, strike north 35° to 55° east. These, in part, carry sulphide minerals associated with quartz and calcite gangue. The amount of movement along the fracture plane in these sets is slight.

Fractures in the Granodiorite:

Fracture sets noted in the granodiorite appear to have little displacement. They are so numerous that mapping them was not advisable. Most pronounced sets strike N. 15° to 50° W., and N. 45° to 70° E. The dip is generally steep. Two other sets which are developed locally strike N. 70° to 90° E., and N. 0° to 10° W. These joints are usually steep dipping. In one locality in the area, about three miles north of Bullion City, an outcrop of the granodiorite exhibits a set of gently dipping joints which gives the rock a pseudo-bedded character. This sheeting strikes about N. 20° E. and dips westward at an angle of 30° to 40°. In the Silver City region prominent sets of sheeting planes strike northeastward and dip 30° to 60° southeast (15:p.38).

Aplite, pegmatite, and dacite dikes commonly follow the steeply dipping fractures in the granodiorite. The best examples are found on Coxcomb Peak and Jim's Peak. The presence of these dikes, which are differentiates of the granodiorite magma, indicates that fracturing of the granodiorite took place after the rock had cooled sufficiently to become a comparatively rigid mass.

Fractures in the Basalt:

Fracture sets in the basalt are not well defined for any great distance, and in the main they are joints along which no appreciable movement has taken place. Joints in the basalt on Scotch Ridge in part are included in three sets: one set striking north and south; another set east and west; and another N. 55° E. All dip at steep angles. Locally in the basalt columnar jointing is well developed. The columns vary from a few inches to many feet in diameter.

ORE DEPOSITS

GENERAL CHARACTER

The mineral deposits of the South Mountain district consist chiefly of lead, zinc, silver, and copper with an appreciable amount of gold. A large amount of iron sulphide and arsenopyrite are associated with the ore minerals. In the early seventies, operators removed much of the near surface oxidized ore, and in most instances they reached the primary sulphide ores in little depth. The association of sulphide minerals forms an ore which was considered highly complex and extremely difficult to treat by methods of the time. The method of treating the oxidized ores, that

is by direct smelting, would not work satisfactorily with the complex sulphide ores. The medium high grade carbonates were removed in large part, and the sulphides were left for possible future treatment. Although the primary ores are composite in character and contain a large proportion of iron sulphides, they should not be extremely difficult to treat with present methods of differential flotation. The minerals are rather closely associated but minute intergrowths are an exception.

CLASSIFICATION OF THE DEPOSITS

The ores may be placed in two main classes--typical contact metamorphic replacement deposits, and characteristic vein-replacements. Exceptions to these two main types are gold bearing quartz veins, which are probably of little economic importance in the district. They are present in small fractures in the metamorphosed sediments, and the largest veins of this type parallel the bedding in the sediments. Smaller ones traverse the sediments along minor fractures. The outcrops are colored yellowish-brown by iron oxide. Little of the material was examined in very great detail, but that which was examined contained no metallic minerals. These deposits commonly contain from a trace to about one-tenth of an ounce in gold.

Contact-metamorphic-replacement Deposits

The contact-metamorphic replacements have been only slightly exposed by mine workings, hence, very little is known concerning their size. Sulphide deposits of contact metamorphic type appear to be confined to the region east of Williams Creek. On the dump of the Old Golconda tunnel is some hedenbergite-ilvaite contact rock containing irregular replacements of sulphides, chiefly chalcopyrite and sphalerite. Small pits expose the oxidized contact rock southeast to the Standard shaft. In many of the pits, oxidized copper minerals fill fractures in the hedenbergite-ilvaite rock and color the material rather completely. In the vicinity of Coxcomb Peak, small pendant bodies of schist, quartzite, and limestone are replaced in part by garnet and quartz, with some chalcopyrite and associated gold and silver. However, with these exceptions, the deposits of strictly contact-metamorphic-replacement type appear to be confined largely to the "AL" and "BL" limestones southeast of Williams Creek. The metallic minerals in the order of their deposition are (1) pyrite, (2) arsenopyrite, (3) sphalerite and chalcopyrite, and (4) galena. Chalcopyrite and sphalerite are the ore minerals present in largest amount. Galena is only a minor constituent. No tetrahedrite was identified in these ores, excepting in the deposit exposed in the Texas shaft (see description of mining properties). The sulphides replace the hedenbergite-ilvaite rock irregularly in many of the specimens examined, and the material on the dump of the Old Golconda tunnel indicates that the sulphides are present in the contact rock in masses of varying size. Quartz and some calcite accompanied the deposition of the sulphides. This relation is indicated in the thin sections. The gangue minerals of the contact-metamorphic deposits are described under hedenbergite-ilvaite contact rock, in the discussion of limestone. In the hedenbergite-ilvaite rock, near the hanging wall of the "AL" and "BL" limestones, there are

deposits of the metallic minerals which strike and dip with the limestone, and are probably confined in part to definite fractures or planes along which mineralization proceeded with less resistance than would be expected in massive hedenbergite-ilvaite rock. These deposits are closely related to the contact rock, and probably represent concentration along lines of easy passage for the solutions which deposited the same sequence of sulphides in irregular replacements of the hedenbergite-ilvaite rock.

Vein-replacement Deposits

Mineral deposits, following definite premineral openings, are commonly associated with the sets of nearly vertical fractures which are best developed west of the Williams Creek overthrust and southwest of the Golconda overthrust. Most of these fractures strike N. 67° to 75° E., others strike N. 35° to 55° E. (see section on structure). This last set contains sulphide mineralization on the Alabama claim. The most important deposits of vein-replacement type are confined, in large part, to areas within the "AL" and "BL" limestones. Replacement of the limestone along fractures by the vein matter was not difficult. Small deposits are present in the schist and quartzite in contact with the above mentioned limestones, but these deposits are poorly defined. The vein matter, following fissures, replaced the country rock irregularly a short distance to either side of the main fractures. Vein matter traverses minute openings, chiefly joint planes and bedding planes, in all directions away from the main body. The walls of the veins are generally poorly defined, because of this irregular replacement.

The veins are three to eight feet wide in the main, although they occasionally pinch down to mere stringers. The deposits are distinctly richer in galena and sphalerite, and leaner in chalcopyrite, than are the deposits of contact-metamorphic-replacement type. In fact, these vein deposits are important chiefly for the lead, and silver with associated zinc. As seen in the polished surface under the microscope, the minerals, in the order of their paragenesis, are (1) remnant calcite, (2) pyrite, (3) arsenopyrite, (4) pyrrhotite, (5) sphalerite and chalcopyrite, (6) galena and tetrahedrite. Calcite and quartz accompanied the mineralization practically throughout, and some quartz followed the deposition of the galena and tetrahedrite. The silver content of the ore is probably assignable to the tetrahedrite which is present as minute specks in the galena.

Emmons (8:p.31), in a recent paper entitled Relations of Metalliferous Lode Systems to Igneous Intrusives, proposed a classification of deposits with respect to certain conditions of their environment. His fifth group in this classification fits the observed conditions at South Mountain. This group of deposits "Endobatholithic, in and near roof pendants of large batholiths. The invading rocks predominate and form the frame of the area containing the deposits." (8:p.32).

MINERALOGY OF THE ORES

The primary sulphide minerals of the deposits are few in number and comparatively simple in composition. Oxidized ore minerals are more complex in character, and more species are present. The gangue minerals are

chiefly of contact metamorphic type. The writer collected many good specimens of primary sulphide ore, largely from mine dumps, but only a few good specimens of oxidized ore were collected, since most of the near surface material, containing the best representatives of the oxidized minerals, was removed in early operations in the district. Some of these minerals, not found by the writer, were identified by Shannon in specimens of the oxidized ores that were obtained by various museums during the early period of mining operations. These descriptions, as well as those of many of the contact metamorphic minerals, are contained in Shannon's "Minerals of Idaho" (20). This source has been freely drawn upon by the writer.

Ore Minerals

Anglesite. - Anglesite, lead sulphate ($PbSO_4$) is a common oxidation product of galena at South Mountain. It is developed along the cubical cleavage of coarse-grained galena and around masses of this mineral. Further alterations of the anglesite produces cerusite, which is commonly in association. Anglesite was identified in practically all of the galena bearing deposits in the district. It is generally gray in color, but it may be stained with iron oxides. Shannon (20:pp.445,446) describes anglesite from the South Mountain district. He notes that in one instance linarite and bindheimite coat the anglesite.

Arsenopyrite. - Iron sulpharsenide, arsenopyrite (FeAsS) is a common constituent of most of the primary ores in the district. The mineral, although one of the first sulphides to form, retains its euhedral outline. It forms beautiful intergrowths with the younger minerals, especially chalcopyrite and sphalerite.

Azurite. - Basic copper carbonate ($3CuO.2CO_2.H_2O$), azurite, associated with malachite, is a common oxidation product of copper bearing material. The azurite in the Laxey tunnel on the Mississippi claim is a beautiful azure in color. It is present as incrustations, stains, and well developed crystals irregularly distributed in the oxidized hedenbergite-ilvaite contact rock. Oxidized lead and zinc minerals are associated with it. Some azurite is present in most of the oxidized exposures of vein matter in the district.

Bindheimite. - A hydrous lead antimonate, bindheimite, was identified in a specimen of oxidized lead ore from the Golconda stope. The material is present as a yellowish, dusty alteration product of galena, and is associated with red minium. The bindheimite was derived from primary ore in which galena, with associated tetrahedrite, is an important constituent. Shannon (20:p.436) describes bindheimite from South Mountain.

Bornite. - Bornite, copper iron sulphide ($2Cu_2S.CuS.FeS$), is found in small amount as a supergene alteration product of chalcopyrite in the ore from the Texas shaft. The mineral is not of importance as an ore of copper here.

Calamine. - Basic zinc silicate ($H_2O.2ZnO.SiO_2$), calamine was identified by Shannon (20:p.340) in a specimen of oxidized ore from the Laxey mine.

He says that the calamine occurs as "drusy crusts of minute crystals and drusy surfaced globular masses lining cavities in compact limonite."

Caledonite. - Caledonite, a basic sulphate of lead and copper ($4PbO.2CuO.3SO_3.3H_2O$), was identified tentatively by Shannon (20:p.433) in a specimen of oxidized lead ore from the Laxey mine. He describes the mineral as pale green in color, forming minute waxy globules. It is associated with linarite and cerusite.

Cerusite. - Lead carbonate ($PbCO_3$), cerusite, is the commonest alteration product of the galena in the oxidized zone of lead bearing deposits. It was identified in the ores of the Bay State group, the Golconda stope, the Queen of the Mountains, the Laxey tunnel, and in other small openings in the district. Massive white to gray cerusite is the dominant type, but well developed prismatic crystals, associated with smithsonite, were collected from the oxidized ores from the Bay State shaft.

Chalcocite. - Cuprous sulphide (Cu_2S), chalcocite, or more commonly known as copper glance, occurs in small amount as a supergene alteration of chalcopyrite in specimens from the Texas shaft. It is of no importance as a copper ore, but a thin zone in the deposit has been slightly enriched by this mineral.

Chalcopyrite. - Chalcopyrite ($CuS.FeS$), copper iron sulphide, is one of the important ore minerals of the South Mountain district. It is associated closely with sphalerite and less closely with other sulphides. Chalcopyrite is present in largest proportion in contact metamorphic deposits east of Williams Creek in the "AL" limestone.

Chrysocolla. - Hydrous copper silicate ($CuO.SiO_2.2H_2O$), chrysocolla, is a common near-surface alteration product of copper bearing vein matter in many of the properties. It would in no sense be classed as an important ore of copper at South Mountain. On the Florida claim, chrysocolla of bluish green color replaces hedenbergite. This relation is found in oxidized material exposed in small prospect holes on practically all the claims of the Golconda group. The dump material of the Golconda old tunnel shows a small amount of chrysocolla.

Copper (native). - Native copper was noted in a polished surface of oxidized vein matter found on the dump of the old Golconda tunnel. The metal occurs in fine specks, and small dendritic masses in iron stained oxidized material.

Covellite. - Cupric sulphide (CuS), covellite, is present in small amount as a supergene alteration of chalcopyrite in specimens from the Texas shaft.

Galena. - Lead glance (PbS), galena, is probably the most important mineral in the South Mountain deposits. It is present as medium to coarse granular masses associated with pyrite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and tetrahedrite. The galena is best developed in the vein replacement deposits on the west side of Williams Creek. Tetrahedrite, which is often present in minute specks within the galena, probably bears much of the silver of the ore.

Gold. - Gold has not been identified either megascopically or microscopically in the ores of South Mountain, but assays generally show the presence of appreciable amounts of this metal.

Hematite. - Red iron oxide (Fe_2O_3), hematite, is a relatively common oxidized iron mineral in the district, although limonite is present in largest amount. Hematite is one of the oxidation products of the iron sulphides in the deposits and generally occurs as a reddish earthy oxidation product.

Limonite. - Limonite, hydrated iron oxide ($2Fe_2O_3.3H_2O$), is the most common iron-bearing oxidation product of the district. Limonite, in large amount, is present as a near-surface alteration of the hedenbergite-ilvaite contact rock. The contact rock outcrop is oxidized, in part, from the west side line of the Mississippi claim southeastward to the Standard tunnel. The outcrop resembles a gossan of an ore body, but the limonite, in greater part, was derived from hedenbergite which alters easily. Limonite occurs in the oxidized zone of the vein-replacement deposits as an oxidation product of the iron sulphides.

Linarite. - Basic sulphate of lead and copper, linarite ($PbO.CuO.SO_3.H_2O$), is described by Shannon (20:p.457) in specimens from the Monkey mine and Laxey mine. It occurs as stains and crusts of minute blue crystals. The writer did not find this mineral.

Malachite. - The green basic copper carbonate, malachite ($2CuO.CO_2.H_2O$), like azurite, is a common oxidation product of primary ores containing chalcopyrite. The malachite is present as earthy to finely crystalline masses and incrustations in oxidized material which usually contains considerable azurite. Much of this copper carbonate was found in the Laxey tunnel and Texas shaft.

Manganese. - A black manganese mineral is present in small amount in association with limonite and talc as an alteration product of the hedenbergite-ilvaite contact rock. The mineral species was not determined, due to the character of the material, which is present as a very compact thin black coating, or thin dusty coating, on the contact rock near the surface. It is probably chiefly an alteration product of the ilvaite which contains 5.51 per cent of manganese oxide, according to an analysis by W. F. Hillebrand (20:p.337).

Minium. - Minium (Pb_3O_4 or $2PbO_2$), the vivid red lead oxide, was identified by the writer in a specimen of oxidized lead ore from the Golconda stope. The mineral is an oxidation product of galena, and occurs as a dusty, bright red coating on galena and associated oxidation products of galena, among which are anglesite, cerusite, and bindheimite.

Pyrite. - Iron disulphide (FeS_2), pyrite, is a common metallic mineral in the deposits of South Mountain. It is one of the oldest of the sulphides, and is therefore generally found as isolated, corroded grains in the younger sulphides.

Pyrrhotite. - Pyrrhotite (Fe_7S_8 to FeS), the magnetic iron sulphide, is a common constituent of practically all of the sulphide deposits. It

replaces pyrite and arsenopyrite, both older minerals, and is replaced by, or included in the younger sulphides.

Silver. - Silver was not identified in the native state, nor were definite silver minerals identified from the deposits. Silver is one of the most important metals of the ores; the massive sulphide ore, on an average, probably containing 20 ounces of silver per ton. It is highly probable that much of the silver is associated with tetrahedrite, a common silver-bearer in the western part of the United States.

Sphalerite. - Zinc blende (ZnS), one of the important ore minerals, is present in most of the sulphide specimens examined. The mineral is almost black in color, and would be called "black jack" in common terminology. The sphalerite grains are, in the main, relatively large in size, and should not be difficult to separate from the other constituents of the vein matter. Few very intimate intergrowths with galena were noted, but there is a tendency for the sphalerite and chalcopyrite to be closely associated. In some of the material examined, fine specks and minute stringers of the latter are oriented along definite lines in the sphalerite.

Smithsonite. - Zinc carbonate ($ZnCO_3$), smithsonite, is a prevalent constituent in the oxidized portions of the mineral deposits as an alteration product of sphalerite. Thin botryoidal crusts, of grayish-green to brownish smithsonite, line cavities in the oxidized ore found on the Bay State tunnel dump. Well-developed prismatic crystals of cerusite are attached to these botryoidal crusts of smithsonite.

Tetrahedrite. - Tetrahedrite (essentially $4Cu_2S.Sb_2S_3$), copper sulphantimonide, or gray copper, is present, in close association with galena, as small specks and grains in the latter, and, to a less degree, with other sulphide minerals in the deposits. Tetrahedrite in the South Mountain deposits probably contains a large proportion of the silver in the ore. This mineral, in Idaho, usually contains some silver, and is mined chiefly for its silver content.

Gangue Minerals

The non-metallic gangue minerals have been described in some detail in the sections on metamorphosed sediments, and the section on metamorphism. The most important gangue minerals are quartz (SiO_2), and calcite ($CaCO_3$). These minerals are associated with the sulphides in all of the deposits described. The more typical contact metamorphic minerals, described elsewhere in this paper, are important as gangue minerals chiefly in the contact zone in the "AL" limestone southeast of Williams Creek.

PARAGENESIS OF THE MINERALS

The paragenesis of the minerals in the deposits of South Mountain appears to be as follows: (1) crystallization of calcite from the limestone, (2) contact metamorphic minerals accompanied in part by pyrite, (3) primary sulphide minerals, (4) secondary supergene sulphide minerals, (5) oxidation products.

The contact metamorphic minerals overlap somewhat in time of deposition and in some instances they appear to be contemporaneous. The most persistent order of crystallization seems to have been: (1) calcite (recrystallization of the calcium carbonate of the limestone), (2) garnet, (3) ilvaite, (4) hedenbergite and tremolite, (5) quartz, calcite, and sulphides. Pyrite appears, in part, to have been deposited with the contact metamorphic silicates, but it also accompanies the slightly younger primary sulphide mineralization.

Primary and hypogene sulphide minerals with quartz and calcite gangue replace the contact metamorphic silicates, and heal fractures in them. The paragenesis of the sulphide minerals appears to be: (1) pyrite and arsenopyrite, (2) pyrrhotite, (3) sphalerite and chalcopyrite, (4) galena and tetrahedrite. Quartz, with a small amount of calcite, seems to have been present throughout the entire period of deposition of the primary sulphides, and in some instances, brecciated sulphides are isolated in younger quartz, forming a typical ice-cake structure.

In a few instances, especially in the Texas shaft, some copper sulphides, bornite, covellite, and chalcocite, are present as supergene alteration products of chalcopyrite. The supergene sulphides form fringes around and fill fractures in the grains of chalcopyrite. The order of formation of the secondary sulphides is not definitely shown, but it appears to be, in part: (1) bornite, (2) covellite, (3) chalcocite.

Oxidized minerals are numerous, but their order of formation is difficult to determine, and of little consequence. They are products of the primary sulphides and were formed in the upper portions of the deposits.

GENESIS OF THE ORE DEPOSITS

The granodiorite mass exposed at South Mountain was intruded into highly folded and fractured sediments, which, as a result, are now found as inclusions or pendant bodies in the intrusive. The intrusion of the magma with its associated liquid and gaseous emanations given off as the magma was cooling, effected much contact metamorphic action in the pendant sediments.

All the evidence collected during the examination of the district indicates to the writer that the contact metamorphism and the sulphide deposition are the result of three closely related waves or stages of emanation from the cooling magma. Umpleby (20:p.65) formulated an hypothesis of two stages of metamorphism to account for the phenomena in the Mackay deposits and he calls these stages, respectively, contact metamorphism at the time of the intrusion, and contact metasomatism subsequent to intrusion. The first stage is well exemplified at South Mountain by the marbleized limestone which is rather uniformly recrystallized throughout the entire outcrop of the roof pendant. This type of marbleization is probably due, according to Umpleby (20:p.65), to vapors which rose somewhat uniformly from the entire upper surface of the intrusion. In the folded beds at South Mountain some concentration of vapors may have taken place along beds most susceptible to their passage, with the result that more extensive recrystallization may have occurred in some localities, as for example, in the vicinity of the Queen of the Mountains claim.

The second series of emanations, probably closely following the first stage or overlapping the first stage in part, appears to have been concentrated along more definite lines. In Umpleby's second stage (20:p.65) the escaping solutions were supplied locally along a nearly vertical fissure, changing marble to garnet-magnetite rock. At South Mountain, in various localities, contact metamorphic silicates were developed during this stage. The solutions accompanying this stage must have been rich in iron and magnesium to have produced the hedenbergite-ilvaite rock.

A third stage of emanations at South Mountain is probably responsible for the sulphide mineral deposits. This period of deposition overlaps somewhat the period during which the hedenbergite-ilvaite rock was produced, since sulphides, especially pyrite, were in part deposited toward the close of the development of the hedenbergite, ilvaite, and associated contact silicates. The sulphide deposits filling fractures in and replacing the contact rock, suggest that a more or less definite stage of emanations followed the production of the hedenbergite-ilvaite rock. Concentration of the sulphide-bearing solutions of this third stage, along definite fractures in marble, probably produced the vein-replacement deposits typified by the veins on the Alabama claim and claims west of Williams Creek.

PERSISTENCE WITH DEPTH

Both the mineral composition and the mode of occurrence of the South Mountain ores, so far as they are capable of interpretation, indicate that the deposits are from deep seated sources and that they will probably extend to great depths. Lack of underground information precludes positive proof for the above statement, and it must therefore be regarded as a surmise rather than an established conclusion.

M I N E S A N D P R O S P E C T S

Because of the caved condition and inaccessibility of the workings of many of the mines and prospects, it was not possible to obtain information for detailed descriptions of all of them. The descriptions given are, therefore, based upon such information as could be obtained from actual observation, supplemented by information of a historical nature.

A series of fifteen patented claims, under option in 1927 to the Uida Consolidated Mines Company (see section on history) include the greatest part of the most highly mineralized section of the district. With the exception of the northern parts of the New York and Vermont claims, and the entire Maine claim, which is the north extension of the New York, the patented claims are outlined on Plate IIA. Many of the unpatented claims in the district have been located or relocated very recently and in most instances the boundaries and owners are not known to the writer. Names used on the old maps, or description with reference to natural objects are used in indicating the position of unpatented claims. The lines of mineralization, claims, mine workings, and hedenbergite-ilvaite contact rock are shown on the map, Plate IIA, which is an overprint on Plate IIB. Points on Plate IIA can therefore be referred to the geology, topography, and other features on Plate IIB by superimposition.

TUNNEL GROUP

The Tunnel Group includes the patented claims north of Wessels Creek. They are the northern parts of the Washington, Idaho, and Oregon claims, and the New York, Vermont, and Maine claims in entirety. Shallow surface openings on the New York and Washington claims expose some oxidized material which outlines a fairly well defined deposit in the "AL" limestone dipping and striking with the latter. The surface exposure of the deposit is about 3 to 5 feet in thickness. The Washington tunnel, which is caved near the portal, was evidently run to tap the deposit exposed on the hill north of the tunnel opening. Sulphide ore on the Washington tunnel dump contains the usual sequence of pyrite, arsenopyrite, pyrrhotite, chalcopyrite and sphalerite, and galena. No tetrahedrite was positively identified in the material. The gangue is quartz and calcite, and the vein matter replaces residual calcite. Heyden (9) obtained the following assay from samples from this dump: Gold 0.32 ounces, silver 9.6 ounces, lead 4 per cent.

BAY STATE GROUP

The Bay State Group of patented claims includes the Illinois, Tennessee, Massachusetts, and Michigan claims, and the parts of the Washington, Idaho, and Oregon claims south of Wessels Creek. A number of small openings are present in this group but all of them are in a caved condition.

The Grant incline on the Washington claim is not open for observation and nothing is known about it except from a description in an old report (17:p.196), which says that the shaft was 100 feet deep and partly in decomposed galena and iron-stained lead carbonate which averaged $60 to $80 per ton in silver.

On the Michigan, an oxidized vein about four feet wide is exposed by a shallow incline shaft. The vein strikes N. 50° E. and dips 50° NW. The shaft is sunk entirely in the "AL" limestone, and it is highly probable that the mineralization along the fissure is in large part confined to this member. Surface wash and soil obscure the outcrop in both directions a short distance away from the shaft.

On the Massachusetts claim, a number of fractures are exposed by shallow workings. Oxidized vein matter is present in many openings but little can be ascertained because of cavings. About three feet of oxidized vein matter, striking N. 70° E. and dipping vertically, is exposed in the upper Bay State tunnel. Its continuity is not well established from the exposures, although shallow cuts on the hill above show different thicknesses of oxidized material. The deposit appears to be chiefly in the "AL" limestone. Near the collar of the Bay State shaft a vein of oxidized material is exposed. The vein strikes N. 67° E. and dips vertically. The width of the deposit ranges from a few inches to three feet. Some irregular replacement of the limestone was noted. The deposit is not easily traceable on the surface, but Bell (5) reports that the ore was worked by vertical shaft to a depth of 75 feet, and later tapped by a tunnel from the creek level. This Bay State tunnel, according to Bell, exposes an ore body, 100 feet long and one to eight feet wide, filled with clean sulphide ore. He sampled the material from this deposit, and found it to assay, lead 10%, silver 18 ounces, gold $3, and zinc 8%.

No other information about this deposit was obtainable by the writer because of the caved condition of the mine workings. The ore on the dump of the Bay State lower tunnel is practically solid sulphide with very little quartz and calcite gangue. The minerals of the ores are pyrite, arsenopyrite, pyrrhotite, chalcopyrite and sphalerite, galena and tetrahedrite.

The shallow Illinois shaft, on the Illinois claim, exposes a vein of oxidized ore in the "AL" limestone. The deposit strikes N. 72° E. and dips 70° south. The writer obtained clean galena which shows some alteration to anglesite and cerusite. On the hill west of the Illinois shaft, in the "BL" limestone, shallow surface workings expose narrow deposits of oxidized ore containing coarsely crystalline galena which has altered to anglesite and cerusite along the cleavage and around borders of grains. No other sulphides were noted in a microscopic examination of the material. A covering of soil obscures the outcrop between the Illinois shaft and the shallow workings in the "BL" limestone. It is probable, however, that the fracture along which the ore is found in the Illinois shaft and in the Shallow surface workings on the hill, is continuous across the intervening "BS" schist and quartzite.

Underground prospecting on the Bay State lower tunnel level in the "AL" limestone might reveal the underground equivalents of the veins as expressed at the surface. Drifts along the strike of the limestone would be necessary in order to obtain this information. The Bay State lower tunnel, which is caved near the portal, should not be difficult to open for underground exploration.

QUEEN OF THE MOUNTAINS AND KENTUCK

The Queen of the Mountains and the Kentuck claims are located between the Bay State group of patented claims on the north, and the Golconda group of patented claims on the southeast. The workings consist of open cuts, shafts, and tunnels. An open cut about 100 feet long, and about 30 feet deep where it ends against the side of the hill, exposes the oxidized portion of the Queen of the Mountains vein. An adit tunnel, some 120 feet long, was driven to intersect the vein exposed in the open cut. There are also other shallow openings which serve to outline the strike of the vein as it crosses the hill.

The Queen of the Mountains vein, that is, the vein exposed in the open cut and the tunnel, strikes approximately N. 75° W. and dips about 70° south. The vein is typical of the vein-replacement type, wherein the vein matter in part replaces the crystalline limestone walls irregularly and occasionally follows along joints and cracks in the wall rock. Oxidized ore containing some unaltered sulphides, is present in the open cut. The last 75 feet of the tunnel is in vein matter, the first 40 feet of which is oxidized ore about three to five feet wide, showing only small amounts of sulphides. The remaining 35 feet is all driven in or along sulphide ore from three to eight feet wide. Much of the sulphide ore found on the tunnel dump came from a small stope in the sulphide portion of the vein. Bell (5:p.4) sampled this dump which assayed 15% lead, 20 ounces silver, $3 gold, and 8% zinc. The ore contains the usual sulphide sequence, that is, pyrite, arsenopyrite, pyrrhotite, chalcopyrite and sphalerite, galena and tetrahedrite accompanied by a gangue of quartz and calcite. The marble in the Queen of the Mountains tunnel exhibits extremely large crystals of

white calcite. This is the best development of coarsely crystalline marble exposed in the district.

Small open cuts along the veins, caved tunnels, and the Queen of the Mountains shaft, reveal two mineralized cross fractures south of the Queen of the Mountains vein. They are practically vertical and strike N. 75° E. and N. 52° E. respectively. In the shaft the N. 52° E. fracture shows oxidized material about five feet thick. The thickness of the other vein is not determinable from the exposure. It is highly probable that both veins are best developed in the recrystallized limestone areas.

GOLCONDA GROUP

This group consists of the following patented claims: Alabama, Mississippi, Florida, Virginia, and Texas. The Texas claim is described separately because it is the best exposed deposit of its type.

The workings on the Alabama claim consist of the Golconda open cut, the Mahogany open cut, the Little Rhoda shaft, and the Golconda old tunnel. The Golconda open cut (the Golconda stope), in the "AL" limestone, defines a vertical vein of oxidized carbonate ore from two to eight feet wide, that strikes N. 49° E. Much of the high grade carbonate ore, smelted in the early operations, is said to have come from this stope. The surface cut exposes the vein for about 50 feet along its strike. A few feet east a small decomposed dacite porphyry dike approximately parallels the vein.

Two fissures, carrying oxidized material, are exposed by the Little Rhoda shaft and shallow cuts near it. One vein strikes N. 50° E. and the other N. 24° E. The latter is stoped out 20 feet below the collar of the shaft for a short distance along the strike. Fallen timbers and general caved condition prevented an examination.

The mahogany open cut about 100 feet east of the Golconda open cut shows an oxidized vein which strikes N. 55° E. and dips vertically. The vein, which widens to as much as five feet, pinches out near the surface at the fact of the cut.

The old Golconda tunnel was driven in the hillside to intersect the Golconda vein. From this level, according to Bell (5:p.4), carbonate ore was stoped to the surface in the Golconda vein. Regarding other work on this level he says, "From the face of this old tunnel at a point on the cross fissure, a shaft was sunk 100 feet deep which is said to carry its full width in the solid sulphide ore, rich in lead from top to bottom, and from a station 100 feet distant on the same ore body, a winze was sunk 60 feet deep on the same class of solid sulphide ore.

"As an evidence of the truth of these statements, there is an ore dump at the mouth of this old tunnel containing approximately 1000 tons, from which the best galena had been previously sorted out, that gave me an average assay of $6.20 gold, 11 3/4 ounces silver, 9 1/2% zinc, and 1% copper."

The old Golconda tunnel is caved near the portal, hence it was impossible for the writer to enter. It is reported, however, that the tunnel face is about 1000 feet southeast from the portal (4:p.147). The dump shows fresh hedenbergite-ilvaite rock, which, according to the surface exposures, might be encountered by the tunnel about 700 feet from the portal. The collar of the Avenue shaft which connects with the old tunnel is near the Alabama-Mississippi side line, about 500 feet N. 70° W. of the tunnel portal. A large body of sulphide ore, which was expected to be found underlying the oxidized surface expression of the hedenbergite-ilvaite rock, was not encountered in the tunnel.

The new Golconda tunnel was started about 500 feet northwest of the old tunnel portal at an elevation 106 feet lower than the elevation of the latter. Reports indicate that the face of the tunnel is about 275 feet southeast from the portal, but the writer could not examine it because of the caved condition.

On the Mississippi and Florida claims a gossan-like outcrop of hedenbergite-ilvaite contact rock is exposed at the surface, beginning about 100 feet west of the Laxey tunnel portal and extending southeast, with some possible interruption to the Standard tunnel at the head of mill creek. This contact rock is developed in the "AL" limestone along the strike of the latter. The outcrop of this material varies in width from a few feet to a maximum of about 200 feet along the east line of the Mississippi claim. Some secondary copper minerals are found at many points.

The Laxey tunnel is driven for 60 feet into an oxidized deposit near the footwall of the contact rock. It exposes oxidized ore throughout its length. A short crosscut, 15 feet long, is driven toward the foot wall in oxidized material, a sample of which assayed $11 gold, 26.4 ounces silver, 1.7% lead, 4.25% copper, and 6.7% zinc according to Hayden (9). The minerals present are of the oxidized type. Malachite, azurite, cerusite, smithsonite, calamine, caledonite, linarite, limonite, and hematite were identified from this deposit.

Other minor openings between the Laxey tunnel and the Texas shaft, mainly near the hanging wall of the contact rock, expose small amounts of material containing oxidized copper minerals, and occasionally, smithsonite and cerusite. Iron oxides are present everywhere along this hedenbergite-ilvaite zone.

On the Virginia claim, near the hanging wall of the "BL" limestone, there is a thin deposit of hedenbergite-ilvaite contact rock, which crops out irregularly for about 900 feet. The Virginia shaft, largely caved, exposes a narrow seam of oxidized material near the hanging wall. Oxidized copper minerals are present in small amount. The caved Virginia tunnel was driven, evidently, to tap the material exposed in the shaft.

TEXAS CLAIM

The Texas, the easternmost claim of the patented Golconda group, is laid out along the strike of the "AL" limestone (Pls. IIA & IIB). In the limestone near its hanging wall there is a deposit of hedenbergite-ilvaite contact rock, which contains some sulphide mineralization. The

deposit, which strikes with the limestone, is opened by an incline shaft which dips at 48° southwest with the limestone. The shaft follows downward along the dip of the mineral deposit to a depth of about 50 feet where short drifts follow the ore body along its strike both northwest and southeast from the shaft. Because of caved ground, the drifts could not be examined, hence their length is not known definitely. The deposit, as exposed in the shaft, averages about five feet thick and is included between rather definite walls, which indicate that the mineralizing solutions followed upward along a defined fracture. Some irregular replacement outward from the fracture was noted. The presence of the sulphide minerals in this fracture in the hedenbergite-ilvaite rock shows that the sulphide mineralization, in part, followed the deposition of the contact minerals. The time interval between the deposition of the contact minerals and the deposition of the sulphides need not be great, in fact, indications are that both were deposited during one general period.

About 150 feet southeast of the Texas shaft, a small tunnel was driven northwest to tap the deposit. The portal was completely caved at the time of this examination.

The mineral deposits exposed in the Texas shaft are similar to those in the hedenbergite-ilvaite contact rock, as seen in the material on the old Golconda dump. Oxidized vein matter is predominant down to about 25 feet below the collar of the shaft, and below this point is a thin zone of secondarily enriched material which grades downward within a few feet to primary sulphide ore.

The oxidized portion of the deposit contains inclusions of practically unaltered crystallized limestone. Iron oxides predominate as oxidation products, although much malachite and azurite are present also. Smithsonite in small amount was identified in the oxidized ores.

The minerals of secondary enrichment are bornite, covellite and chalcocite, which are products of alteration of chalcopyrite. They are developed in fringes around chalcopyrite and traverse chalcopyrite grains in a dendritic manner, so typical of supergene alterations. These secondary sulphides are not present in large enough amount to be considered important minerals of the ores.

In the polished surface, under the microscope, the primary sulphide material is seen to be composed chiefly of the following minerals in the order of their deposition: remnant calcite, hedenbergite, pyrite, arsenopyrite, chalcopyrite and possibly tetrahedrite, sphalerite, galena and tetrahedrite (?), and quartz. Quartz, with some calcite, seems to have accompanied the complete cycle of mineralization, and some quartz stringers are distinctly younger than any of the sulphides. The deposit is essentially important for its copper, zinc and silver content. Lead is only of minor importance.

Tetrahedrite, a common bearer of silver, probably has most of the silver in the ore associated with it, since no other silver-bearing minerals were noted in the polished surfaces of the ores. Tetrahedrite is closely associated with the chalcopyrite in the sections examined, and only small amounts are present in the sphalerite. The galena, when assayed

separately, shows a high silver content, but so little galena was present in the ores examined that nothing definite can be said from the microscopic study regarding the association of tetrahedrite and galena.

A sample from the Texas shaft by Bell, assayed 8.1 per cent copper, 43.8 ounces silver, and 0.16 ounces gold, according to an assay certificate dated October 17, 1907, by James A. Pack, assayer of Boise, Idaho (5). Zinc averages about 8 1/2 per cent, according to the list of daily samples taken from the collar to the bottom of the shaft.* One selected sample showing steel galena contained 3.25% zinc, 30.75% lead, 6% copper, and 526 ounces of silver (5). Hayden (9) obtained a sample with approximately the same content of silver from the oxidized zone near the hanging wall of the deposit.

The part of the deposit exposed in the Texas shaft is rather uniform in value. Surface cuts and extension of the tunnel along the strike of the deposit might give some idea of the available tonnage from the surface to the tunnel level 50 feet below.

OTHER PROPERTIES

The Standard shaft is located on an unpatented claim which begins at the southeast end of the Texas claim. The Standard shaft, according to Bell (1:p.136), is a 40 foot incline which follows the deposit. A drift 60 feet long also follows the deposit from the bottom of the shaft. The sulphide material on the dump is similar in character to the Texas material. The Standard tunnel was driven from the head of Mill Creek to tap the deposit exposed in the shaft, but the portal of the tunnel is now caved.

In the vicinity of Coxcomb Peak are a number of small bodies of metamorphosed sediments in granodiorite. Some oxidized material, containing copper carbonates and some chalcopyrite, occurs as an irregular replacement of the garnet-quartz contact rock. No assays of this material were made.

South of Boulder Ridge near the head of South Boulder Creek, is a narrow limestone pendant in granodiorite. On the Boulder claim the Humbug incline is said to follow down along the limestone hanging wall for 50 feet. The dump shows some sulphide ore. South of the Humbug shaft, about 650 feet, the Boulder tunnel has been driven 420 feet toward the Humbug shaft to intersect the deposit. The first 340 feet from the portal is in granodiorite, which is somewhat decomposed because of its nearness to the surface. At this point is a small inclusion of limestone 35 feet thick with an 8 foot altered dike for a footwall. The altered equivalent of the dike appears to be composed largely of bentonite (?), a clay-like mineral having high absorptive qualities (see section on differentiates of the granodiorite). The remaining part of the tunnel is driven in granodiorite and no ore is exposed. The Boulder tunnel must be driven more than 100 feet beyond its present face to intersect the deposit exposed in the Humbug shaft.

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* Copy of assay sheet given to the writer by M. G. Sacrider of Mountain Home, Idaho.

About 1300 feet east of Bullion City is a vein replacement deposit in the "DL" limestone. A small open cut exposes a vertical fracture striking N. 70° E. Some oxidized material, confined largely to the "DL" limestone area, fills the fracture and replaces the walls irregularly. The deposit varies from 6 inches wide, near the surface, to 3 feet wide, 20 feet below the surface. The oxidized material was not examined in detail. It appears to be composed largely of iron oxides.

CONCLUSIONS

According to modern theories of ore deposition, pendant bodies in younger intrusives of intermediate composition are favorable places for the development of ore deposits. Limestone areas within the pendant body are considered favorable.

Observations indicate that the metamorphosed sediments at South Mountain form a roof pendant in the younger intrusive granodiorite. Limestone members are numerous and some of them are large in size. The observed conditions are hence favorable for the development of ore deposits. Most of the deposits of vein-replacement type, which have been prospected in the district, contain a medium-grade sulphide ore. The veins are of easily workable width-three to eight feet according to historical accounts, and such observations as were possible at the time of the writer's examination and the deposits have been found continuous along the veins within limestone areas. Continuity has not as yet been established, however, across intervening schist and quartzite members. Apparently there is no valid reason why vein-replacement deposits of a productive type should not be developed.

The contact-metamorphic replacements in the Golconda group of claims have not been opened sufficiently to give an idea of their possible extent. Some small replacement bodies of sulphides must have been encountered by the Golconda old tunnel because the dump contains hedenbergite-ilvaite rock in part replaced by sulphides. Contact deposits are usually irregularly distributed and of variable size, hence nothing can be said regarding the possibility of large replacement bodies of ore being opened up in explorations of the hedenbergite-ilvaite rock.

The most favorable rocks for prospecting are probably the limestone members within the roof pendant of metamorphosed sediments. North of the patented claims very little prospecting has been done in these rocks, although conditions are favorable for the occurrence of ore deposits.

SUMMARY

The South Mountain Mining District is situated in southwestern Owyhee County, Idaho, about twenty miles southwest of Silver City, and eighty-two miles by road from Homedale, Idaho, a railroad shipping point on a branch of the Oregon Short Line. Included within this district are a number of rounded summits, the highest of which is slightly in excess of 8000 feet above sea level. This summit and others of lesser elevation outline the axis of the South Mountain Range in a northwest-southeast direction for fifteen miles. This range is separated from the paralleling Owyhee Range to the north by the basalt-covered structural depression in which Jordan

Creek-Boulder Creek valley follows the approximate center. Tributaries of this stream valley carry the drainage of the north slopes of South Mountain Range, and other tributaries of Owyhee River drain the south slopes. Many small permanent streams head near the summit of the range.

Stratified sedimentary rocks are represented by a group, 3570 to 4010+ feet in thickness, of alternating beds of schist, quartzite, and limestone. Four limestone members and a number of limestone lenses are represented. All of the sediments have been altered by dynamic and contact metamorphism. The limestones have been completely recrystallized, and typical contact-metamorphic minerals have been developed. In the large limestone member, one outcrop of contact rock is more than 3000 feet long and varies in width from a few feet to 200 feet. This rock is composed chiefly of hedenbergite and ilvaite. The relatively large proportion of these minerals is an interesting feature.

Intrusive igneous rocks are represented by a granodiorite mass and the associated dike-rock differentiates; graphic pegmatite, aplite, and dacite porphyry.

Basalt is the only flow rock in the area. In large part it is normal in character, that is, fine grained, but there is an abnormal phase which is highly vesicular and porphyritic in which labradorite forms phenocrysts.

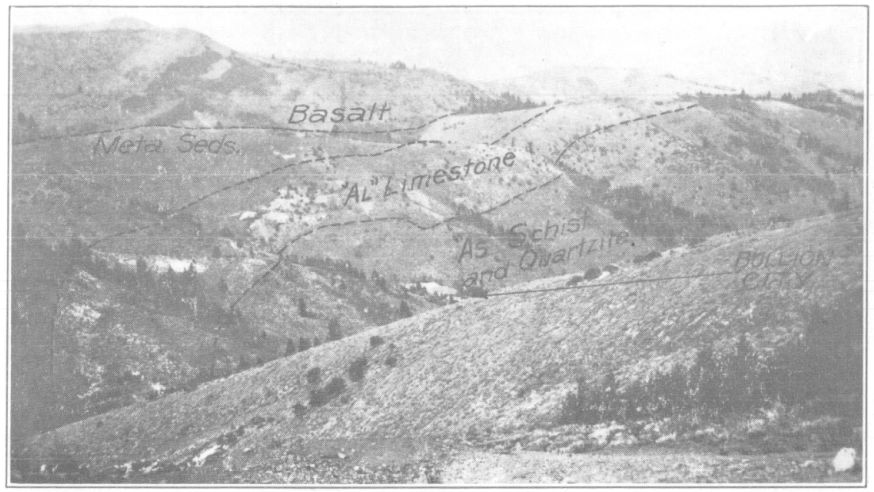
Field evidence indicates that the lense-shaped belt of sediments is a roof pendant in the granodiorite intrusive. Small oriented bodies of the sediments are included in the granitic rock. The metamorphosed sediments have been highly folded with the production of an overturned anticline broken by overthrust faults near the axial plane. The fold strikes about N. 10° W. and is overturned from west to east. A number of sets of steeply dipping fractures, some of them with large displacement, were recognized in the sediments. Combination of two or more sets has produced block-faulting. Sulphide mineralization and dike intrusives have been controlled by some of the fractures. Fractures in the granodiorite and in the basalt are difficult to find because of the deep soil covering.

Three types of ore deposits are present in the region. They are contact metamorphic replacements, vein-replacements, and gold-bearing quartz veins. The vein-replacements contain pyrite, arsenopyrite, chalcopyrite, sphalerite, galena, and tetrahedrite in a gangue of quartz and calcite. The contact-metamorphic replacements have the same sequence plus typical contact-metamorphic minerals. The shallow oxidized portions of the ore deposits were largely mined in early operations in the district and lead, silver, and gold were removed by charcoal smelting.

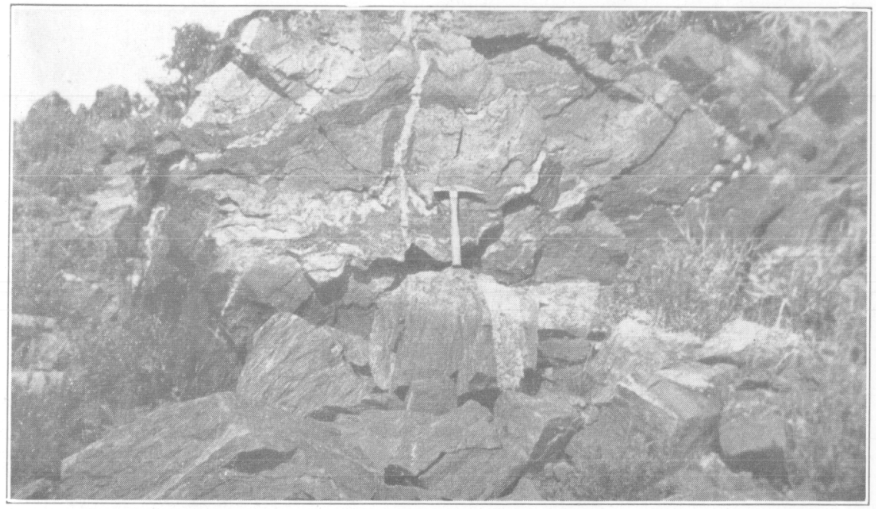
The ore deposits are genetically related to the granodiorite magma and appear to be confined largely to limestone areas in the sediments.

Mining operations in the district have been practically idle since 1875, hence most of the underground openings have caved. Surface observations and historical data was in large part the basis for the description of properties.

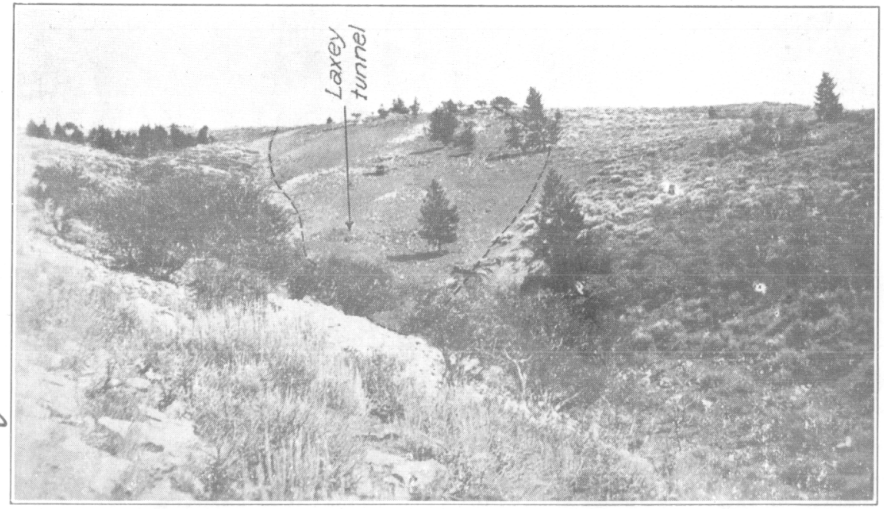
As a whole the possibilities for the development of ore deposits of economic significance in the South Mountain district appear not by any means unfavorable.



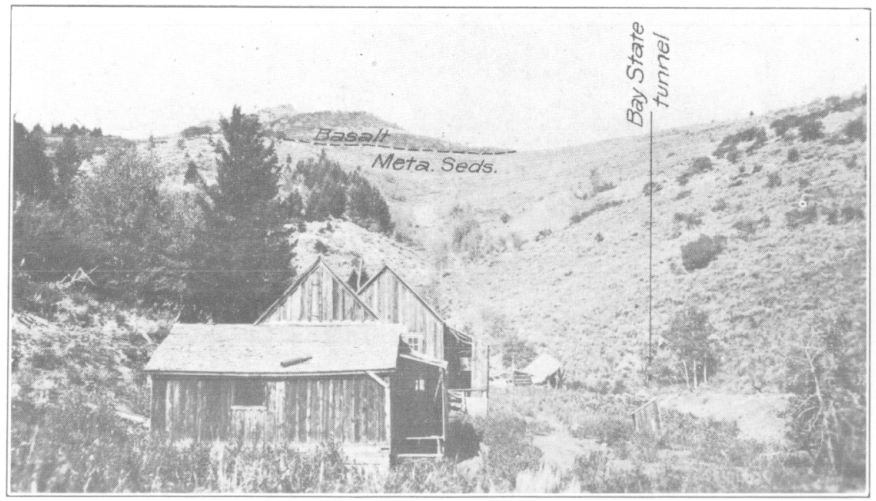
A. Looking northwest along the axis of South Mountain Range. Basalt shown superimposed upon the metamorphosed sediments. Approximate position of contacts outlined by dashed lines. "AL" limestone, the most highly mineralized member of the group of sediments, is outlined approximately. Basalt ridges and peaks in the distance.



B. Outcrop of the "CS" schist and quartzite showing the development of minor folds. Beds swell and pinch due to folding. Photo taken about 500 feet northeast of the Standard shaft.

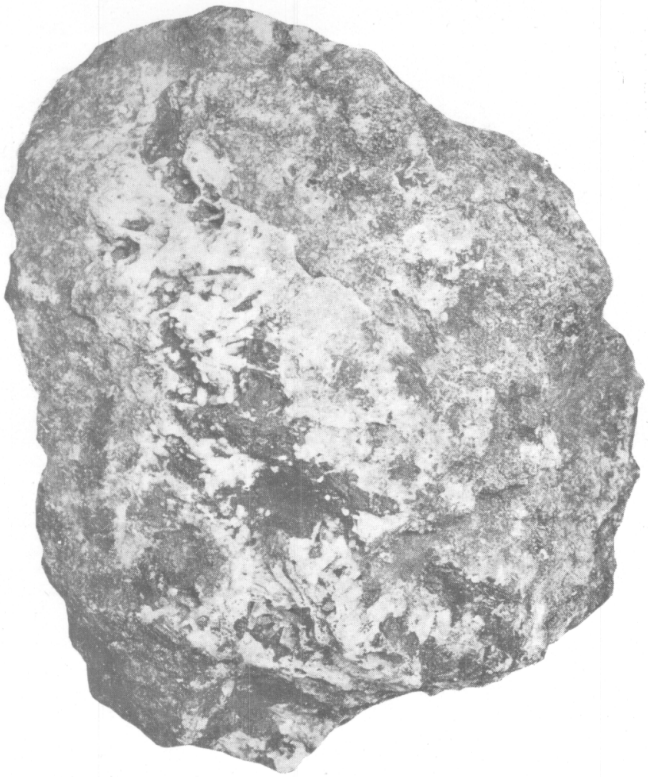


C. Looking east along the strike of the "AL" limestone as it crosses the ridge north of South Mountain. The surface exposure of the hedenbergite-ilvaite contact rock is approximately outlined by dashed lines. The hedenbergite-ilvaite rock, chiefly a replacement of the marble, exhibits a highly oxidized outcrop.



D. Looking west from Bullion City toward Scotch Ridge. Contact of basalt and metamorphosed sediments represented approximately by dashed line. Bay State workings on hillside in right foreground. Bay State lower tunnel and dump are shown.

-31-A



A

GARNET-ILVAITE-QUARTZ CONTACT ROCK
Black areas are ilvaite, medium dark areas are garnet, and white areas are quartz. One half natural size.

B

DIOPSIDE CONTACT ROCK
Diopside crystals and graphite. Four sevenths natural size.

C

HEDENBERGITE-ILVAITE CONTACT ROCK
Ilvaite (black) and hedenbergite (gray black) replacing marble (white.) Four fifths natural size.

D

HEDENBERGITE AND GARNET REPLACING MARBLE ALONG FRACTURES
Eight tenths natural size.

PHOTOGRAPHS OF HAND SPECIMENS OF CONTACT METAMORPHIC ROCK

-37-A