DEPARTMENT OF THE INTERIOR
Hubert Work, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

Bulletin 774

THE COPPER DEPOSITS NEAR SALMON, IDAHO

BY

CLYDE P. ROSS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

CONTENTS

	Page
Introduction	1
Scope of the report	1
Location of the deposits	1
Means of access	2
Acknowledgments	2
Historical sketch	2
Topography	4
Stratigraphy and petrology	5
Metamorphic rocks	5
Paleozoic rocks	8
Granitic rocks	9
Tertiary lava	9
"Lake beds"	10
Quaternary deposits	11
Structure	11
The copper deposits	15
General character	15
Structural relations	16
Ore shoots	20
Hypogene mineralization	22
Oxidation and enrichment	25
Age and genesis	26
Outcrops	27
Operating conditions and future of copper mining	29
Mines and prospects	30
Dishman prospect	31
Tormey mine	32
Pope-Shenon mine	34
Porterfield prospect	37
Harmony mine	37
Prospects on McDevitt Creek	41
Prospects on Hayden Creek	42
Silverton prospect	43
Index	44

ILLUSTRATIONS

		Page
PLATE I.	Geologic sketch map of parts of the Eureka and McDevitt mining districts, Lemhi County, Idaho	8
II.	*A*, Perreau Creek near the Tormey mine, Salmon River Mountains; *B*, Salmon River Mountains near Baldy Mountain	14
III.	*A*, Precipitous contact between metamorphic rock and Tertiary lava on Withington Creek below the Harmony mine; *B*, North end of Lemhi Range	15
IV.	Plan and vertical section of Pope-Shenon mine	36
V.	Sketch map showing relations of lodes on property of Harmony Mines Co	38
FIGURE 1.	Index map of Idaho showing location of the area covered	3
2.	Sketch map of part of Lemhí County, showing the locations of known copper deposits	15
3.	Diagram showing strikes of copper deposits in Lemhi County	17
4.	Diagram showing strikes of ore deposits other than copper deposits in Lemhi County	18
5.	Geologic sketch map of Greenhorn tunnel, Tormey mine	33
6.	Geologic sketch map of Rattlesnake tunnel, Tormey mine	34
7.	Block diagram showing relation of ore shoot in Harmony mine to Contention and Leapyear lodes	39

THE COPPER DEPOSITS NEAR SALMON, IDAHO

By Clyde P. Ross

INTRODUCTION

SCOPE OF THE REPORT

This report is the result of field work during 12 days in August and September, 1923. The investigation was made in cooperation with the Idaho Bureau of Mines and Geology. The copper deposits described lie in an area of about 350 square miles in the southern part of the Eureka mining district and the western part of the McDevitt district. They are described in some detail, and an outline of the general geology of the area is given. The geologic map (Pl. I) was prepared by sketching on copies of township plats of the General Land Office and is accurate only in a broad way, not in detail. The work was occasioned by the advances made in the development of the copper deposits since Umpleby[1] made his report on the ore deposits of Lemhi County. When he visited the region little work had yet been done on any of the copper deposits. Since then small amounts of ore have been shipped from several of them, and at the time of visit in 1923 there was more activity in the copper mines than in any of the other mines in the county, with the exception of the work being done at the old Yellow Jacket gold mine preliminary to reopening it.

LOCATION OF THE DEPOSITS

The area mapped geologically on Plate I comprises T. 21 N., Rs. 21, 22, and 23 E.; T. 20 N., Rs. 21, 22, and 23 E.; T. 19 N., R. 23 E.; T. 18 N., R. 23 E.; and parts of some of the contiguous townships and includes all the copper deposits at which work has been done in recent years. The area lies on both sides of Salmon River in the central part of Lemhi County, near the middle of the east boundary of Idaho, as is shown in Figure 1. In addition to these Umpleby[2] described the copper deposits in the Copper King mine, to the northwest, the Copper Queen mine, to the east, and others of less impor-

[1] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, 1913.
[2] Idem, pp. 120–121, 155.

tance. No work is reported to be in progress at any of these mines, and they were not visited during the present investigation.

MEANS OF ACCESS

Salmon, which according to the 1920 census has a population of 1,311, is the county seat and largest town in Lemhi County, and the principal distributing point for the region. It is the terminus of the Gilmore & Pittsburgh Railroad, which connects with the Oregon Short Line at Armstead, Mont., 100 miles from Salmon. This railroad crosses the Continental Divide through Bannock Pass, northeast of Leadore, and has a branch extending south from Leadore to Gilmore. A train is operated from Armstead to Leadore every other day except Sunday, returning to Armstead on the alternate days, and a train makes a trip to Salmon at least once a week to carry freight and stock. There is passenger service between Leadore and Salmon daily except Sunday by means of a gasoline-propelled car with a trailer. An automobile stage alternates with the train between Leadore and Armstead. Automobile roads connect Salmon with Gilmore, Challis, Stanley, Hailey, and Mackay, and a wagon road runs to Leesburg. Salmon can be reached by automobile stage from Mackay, which is at the end of a branch of the Oregon Short Line.

ACKNOWLEDGMENTS

The work was greatly facilitated by the hearty cooperation and assistance of those in charge of the copper mines and other mining men in Salmon. William Snow, P. J. Shenon, and a number of others gave their time and knowledge freely. The efficient assistance of A. L. Anderson, of the University of Idaho, did much to hasten the progress of the field work.

HISTORICAL SKETCH

The presence of copper in the rocks of this part of Idaho has long been known. The Mormons who settled in Lemhi Valley in 1854[3] are reported to have prospected the copper deposits on Hayden Creek and perhaps also on McDevitts Creek. The Mormon settlement was abandoned in 1857[4] on account of trouble with the Indians. In 1866[5] the discovery of gold placers attracted other white men, and Salmon was founded. Little attention was paid to the copper deposits for some time after this. The Mormons found some copper ore about 1856, and other deposits appear to have been located in the late seventies and early eighties, but little copper mining was attempted until after 1911. The total production of copper ore from proper-

[3] Bancroft, H. H., History of Washington, Idaho, and Montana, 1845–1889, pp. 402, 403, 1890.
[4] Idem, p. 534, footnote.
[5] Idem, pp. 554–556, footnote.

ties in Lemhi County through 1922 is less than 25,000 tons, and a large part of this has been shipped in the last few years from the Eureka and McDevitt districts. At the present time three small copper

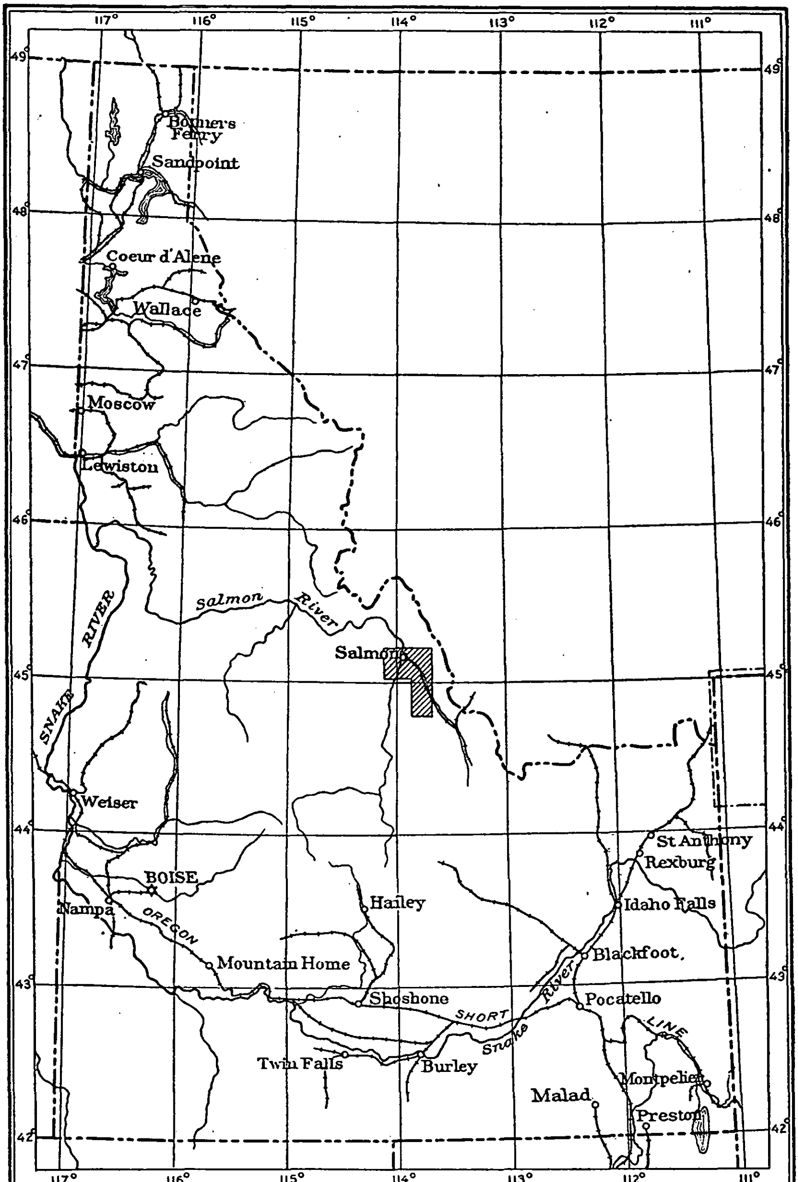


FIGURE 1.—Index map of Idaho showing location of the area covered

mines are in operation, and two of them ship ore regularly. There are several prospects on which work has recently been done, but only one of these was in operation at the time of visit.

TOPOGRAPHY

The area containing the copper deposits lies near the confluence of Salmon and Lemhi rivers, on the east slope of the Salmon River Mountains and in the northern part of the Lemhi Range. On the east side of the valley of Lemhi River rises the imposing bulk of the Beaverhead Mountains. The crests of this range mark the Continental Divide and form the boundary between Idaho and Montana.

The Beaverhead Mountains rise to heights of over 10,000 feet above the sea. Their rugged, rocky crests show, even when viewed from a distance, abundant evidence of the former presence of glaciers. The west side of the massive range is gashed by subparallel canyons spaced on the average about 2 miles apart. The peaks and upper slopes have little soil and support only scanty vegetation. At intermediate altitudes most of the slopes are fairly well covered with pines and other trees and bushes. Farther down trees are less abundant, and on the lower slopes sagebrush constitutes the principal vegetation.

Lemhi River is formed by the confluence of several creeks near Leadore and flows somewhat west of north about 45 miles to its junction with Salmon River at Salmon. The stream has a swift current and flows with many curves between steep banks a few feet high. It is bordered along most of its course by a luxuriant growth of bushes and grasses. Much of the level land on either side is irrigated. The dry terraced slopes of the valley sides are rather scantily covered with sagebrush and a few small cacti and stand out in sharp contrast to the green flats near the river, except in the scattered patches where they have been turned green by means of irrigation. The lower courses of the principal tributary streams are also bordered with irrigated fields.

The major part of the Lemhi Range has a northwest trend, but the portion visited during the present investigation trends nearly north. This portion has a maximum width of about 16 miles and terminates in a rather blunt end about 5 miles south of Salmon, though the foothills extend almost to that town. The crests in this portion reach altitudes of over 9,000 feet, thus rising about 4,000 feet above Lemhi River on the east and even more above Salmon River on the west. Some of the peaks in the southern part of the range are considerably more than 10,000 feet above sea level. Except on the cliffs and the sagebrush-covered lower slopes the northern portion of the range has a fairly continuous forest cover. The peaks and highest ridges carry fewer trees than the intermediate slopes. The cliff-bordered headwater basins of many of the streams are probably in part the work of glaciers.

Salmon River is second only to Snake River among the large streams in Idaho. At Salmon, the altitude of which is 3,940 feet, the combined valleys of Salmon and Lemhi rivers form a broad expanse of country, but a few miles above the town the major stream is confined in a comparatively narrow canyon that has moderately steep walls with small cliffs and numerous talus slopes. The narrow patches of flood plain bordering the swift stream are covered with a tangled growth of small trees and bushes, except where they have been brought under cultivation. Much of the land bordering the river below the mouth of Sevenmile Creek and some of that above this point is cultivated. Most of the tributaries along this part of Salmon River flow in narrow canyons whose walls have an average inclination of more than 30° and are covered with alternate patches of talus and forest. The larger streams have flood plains, especially on their lower courses, but few of these are wide enough to offer much encouragement to farmers. Plate II, *A*, shows a typical stream near the border of the mountains.

The Salmon River Mountains form part of the east border of the great mass of high mountains that occupies the central part of Idaho. The part of the range visited during the present investigation trends nearly north and culminates in Baldy Mountain, which towers about a mile above Salmon near the eastern base of the mountains. Some peaks in other parts of the range are even higher than this. The lower hills of the eastern part of the range support only a scanty vegetation, but a large part of the mountains up to an altitude of about 8,000 feet above the sea is covered with evergreen forest. Above this are bare rocks and talus slopes, with scattered trees and bushes in favorable spots, as can be seen from Plate II, *B*. The valleys in the higher portions of the mountains have been glaciated, but it is unlikely that the ancient glaciers ever covered the sites of the copper prospects in this range examined during this investigation.

STRATIGRAPHY AND PETROLOGY

The broad features of the general geology of Lemhi County have already been worked out by Umpleby.[6] In the present examination only passing attention was given to the stratified formations younger than the metamorphosed sedimentary rocks, which inclose all the copper deposits examined during this investigation, and the information obtained has been supplemented from Umpleby's descriptions.

METAMORPHIC ROCKS

Metamorphosed rocks of sedimentary origin form the major part of the mountain masses near Salmon. The same rocks probably underlie the valleys of Salmon and Lemhi rivers in this vicinity

[6] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, pp. 30-48, 1913.

under the cover of younger strata. In view of the uncertainties regarding their age and stratigraphic relations, correlations with other formations can not be made. For convenience the term "metamorphic rocks" will be used in this report to designate the thick succession of sedimentary rocks which appears to constitute the oldest formation exposed in the area examined. The metamorphism of these rocks is everywhere more striking than that of any of the other formations exposed.

The metamorphic rocks consist in general of quartzitic argillite and micaceous quartzite, with some beds of comparatively pure quartzite. The color of fresh surfaces ranges from dark green to gray and black. All the rocks have undergone metamorphism, with the development of slaty cleavage or schistosity, and partial recrystallization. In many exposures, however, the original bedding can still be discerned on close examination. The rocks are almost everywhere traversed by closely and irregularly spaced joints. As a consequence the outcrops are skirted by talus slopes composed of angular fragments, most of which are less than a foot in largest dimension. Slaty or schistose cleavage is present in many exposures but as a rule is not well developed. Typical schistose structure was observed only in the rocks on Hayden Creek.

There is a monotonous similarity in the general characteristics of the rocks, but close examination reveals variations, and further study of these might result in subdivision into several stratigraphic units. Most of the metamorphic rocks in the Salmon River Mountains from Baldy Mountain southeastward to the border of the range are more nearly black than those in the north end of the Lemhi Range, where the predominant color is dark green. Green rocks were, however, noted on the upper slopes of the canyon of the North Fork of Perreau Creek near its head. Some of the black rocks contain considerable argillaceous material and have distinct slaty cleavage. Interbedded with these are minor amounts of light-gray quartzite, apparently purer than any seen elsewhere in the formation. The dark-gray to black rock on Baldy Mountain splits into thin slabs of larger surface area than those in talus piles in other localities. A number of these slabs show cylindrical masses lighter in color than the containing rock. These masses penetrate from one side to the other of the slab and can not be cracked clean from the rock. Most of them are an inch or more in diameter. The dark-colored rocks in a number of localties in the Salmon River Mountains are ripple marked.

The rock in the Lemhi Range from the Harmony mine north is predominantly dark green, although some beds are nearly black, and others are light colored and somewhat more siliceous than the average. At and south of the Harmony mine the rock seems on the whole less distinctly green than that farther north. The bedding in the rock near this mine is thicker and more easily visible than that in most other localities. Some of the rock near the head of Spring Creek, in the Salmon River Mountains, is similar in this respect. The bedding in the rocks of the north end of the Lemhi Range is in general indistinct but in most exposures can be discerned on close examination. The bedding in rocks along McDevitt Creek is also indistinct in general, but in places clearly defined and ripple-marked beds are exposed.

The rock at the Nellie group, on Hayden Creek, differs from any of the metamorphic rock seen elsewhere. It is a rather soft gray schist, more highly metamorphosed than any other observed, composed essentially of quartz, sericite, chlorite, and a little calcite. This is the only one of the varieties of metamorphic rock examined in which calcite was detected.

All the specimens of metamorphic rock examined microscopically are of similar type, except that just mentioned and those which have been altered in connection with the formation of the mineral deposits. The most abundant constituent is quartz, which in a number of specimens shows the moderately well rounded outlines of the original clastic grains. Most of the rocks show evidence of crushing, and in many the quartz is in a mosaic of interlocking grains with the original texture obscured. In the thin sections examined the quartz grains range from 0.08 to 0.78 millimeters in maximum dimension. The other constituents are nearly all micaceous minerals—sericite, muscovite, chlorite, and dark-green biotite. The long dimension of the largest flakes is less than 1 millimeter. Fine-grained magnetite occurs in some specimens, but all those in which it is a prominent constituent came from the proximity of mineral deposits. Some specimens contain epidote.

These rocks were evidently laid down as moderately fine grained siliceous sediments containing varying amounts of argillaceous material, deposited under shallow marine water. The minerals present might have been developed entirely by rearrangement of the chemical constituents of the original rock, but it seems likely that some material has been introduced from outside sources during the metamorphism. Intense pressure, indicated by the development of schistosity, operated only locally. The metamorphism resembles in a general way that of lithologically similar rocks in the Coeur d'Alene and Pend Oreille districts and elsewhere in northern Idaho. It is thought that the metamorphism of the rocks near Salmon, like that in the two districts mentioned,[7] has been greatly influenced if not

[7] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: U. S. Geol Survey Prof. Paper 62, pp. 15, 74–75, 1908. Sampson, Edward, and Gillson, J. L. Geology and ore deposits of the Pend Oreille district, Idaho (in preparation).

principally effected by the intrusion of the granitic rocks of the batholith of central Idaho and its offshoots.

The metamorphosed sedimentary rocks of Lemhi County have been tentatively correlated on lithologic grounds with the Belt series, which is widespread in northern Idaho and Montana, and have therefore been considered to be of Algonkian age.[8] The thickness of the rocks that crop out in the small area examined is probably of the order of thousands of feet, and it appears from Umpleby's descriptions that a much greater thickness of metamorphic rocks is present in the surrounding region. There is some variation in the character of the rocks here described, and Umpleby's descriptions indicate that in the Beaverhead Mountains the variations are more marked and sharply defined. There may therefore be considerable range in age in the metamorphic sedimentary rocks of Lemhi County, but those seen during the present investigation are sufficiently similar throughout to warrant the assumption, in the absence of definite evidence to the contrary, that all are of about the same geologic age.

PALEOZOIC ROCKS

The rocks near the upper end of Lemhi River appear to be younger than the metamorphic rocks just described. In his report on Lemhi County Umpleby[9] states that rocks of Cambrian, Ordovician, Silurian (?), Devonian, and Mississippian age are present, but in a later report[10] he tentatively assigns the rock he previously considered of Cambrian age to the Ordovician. This rock is a quartzite in which no fossils have been found, and its age can therefore be surmised only on stratigraphic grounds. The data on the stratigraphy of the Paleozoic rocks along the valley of Lemhi River as determined by Umpleby are summarized in the table below, with the modification noted. Umpleby considered that all the formations he assigned to the Paleozoic were conformable with one another but that there was probably an unconformity at the top of the metamorphic rocks. This conclusion is in accord with the facts so far determined.

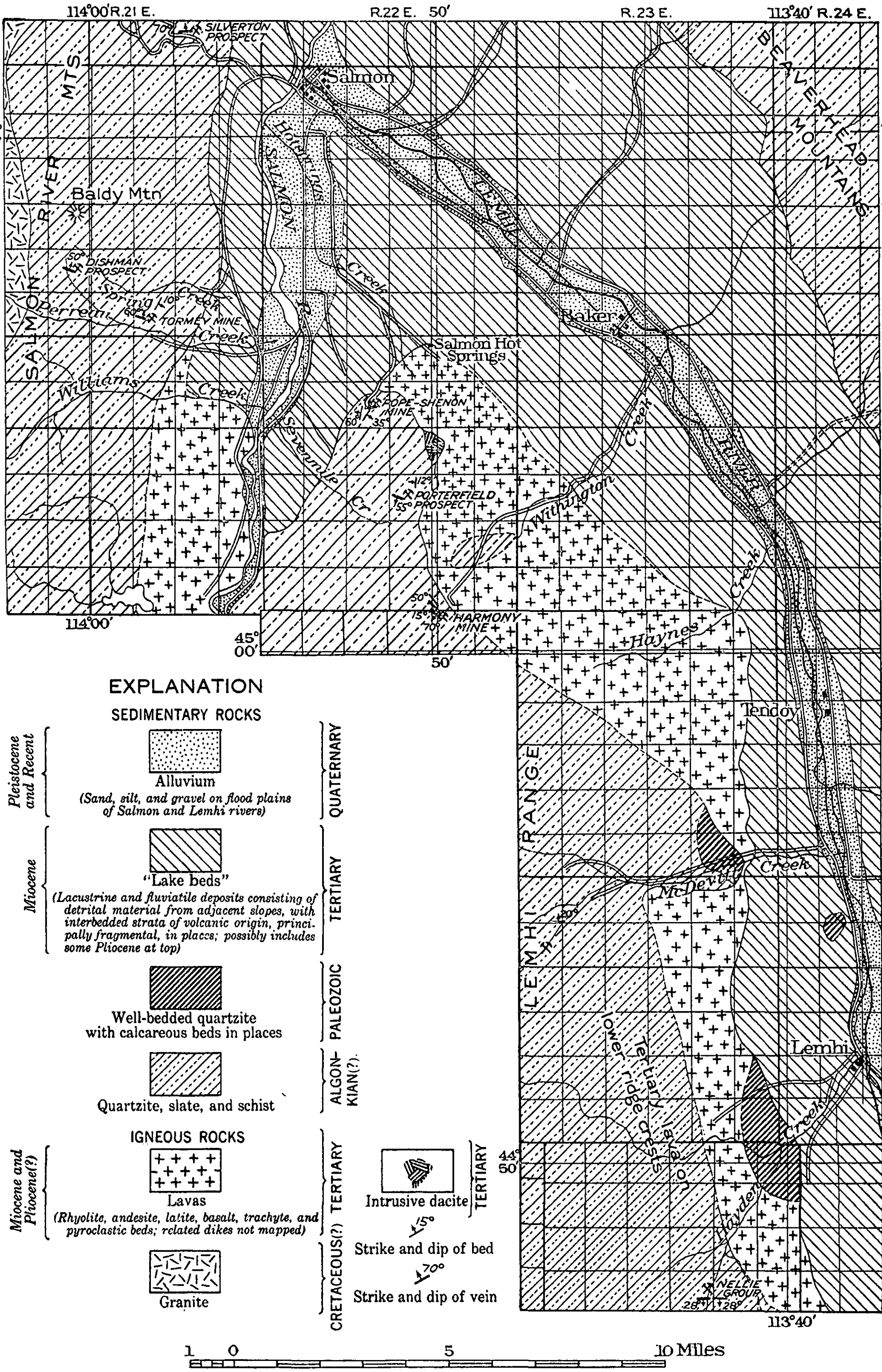
Paleozoic rocks near Lemhi River

Age	Rock	Thickness (feet)
Mississippian	Massive blue limestone; fossiliferous	300+
Devonian	Blue and light-gray dolomitic limestone with numerous beds of slate and some of quartzite; fossiliferous.	2,000+
Silurian (?)	Light-gray dolomitic limestone; scantily fossiliferous	200±
Ordovician	Massive blue dolomitic limestone; Richmond fossils	500±
Lower Ordovician (?)	White fine-grained quartzite; nonfossiliferous	2,000+

[8] Umpleby, J. B., op. cit. (Bull. 528), pp. 30-32.

[9] Idem, pp. 32-35.

[10] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 25, 1917.



GEOLOGIC SKETCH MAP OF PARTS OF THE EUREKA AND McDEVITT MINING DISTRICTS, LEMHI COUNTY, IDAHO

33094—25. (Face p. 8.)

In the area covered in the present examination only three small masses of strata that may be correlated with any of the rocks mentioned in the above table are known. They lie near the mouths of McDevitt and Hayden creeks and on the west side of Lemhi River between these two creeks. Much of the rock in these areas is a light-colored, well-bedded quartzite and is probably to be correlated with the lowest formation in the above table. The beds near Hayden Creek appear to be largely limestone.

GRANITIC ROCKS

On Umpleby's map of Lemhi County[11] is shown a roughly circular area of about 300 square miles a few miles northwest of Salmon. This area is underlain by a granite mass, concealed in the center by metamorphic rocks that crop out over an area of about 90 square miles. The east border of the granite is included in the area mapped in Plate I of the present report, on which the boundary is taken from Umpleby's map. The granite[12] is a light-gray medium-grained rock, with some tendency to porphyritic texture. Microscopic examination shows that there is considerable variation in composition. Orthoclase or microcline, quartz, and biotite are generally present. The accessory minerals zircon, apatite, and magnetite, are found in most specimens, and sodic varieties of plagioclase occur in many. On Little Eightmile Creek and in the Texas and Spring Mountain districts near the upper end of Lemhi River are small areas of quartz diorite that is probably closely connected genetically to the granite.

There are in this region numerous dikes,[13] most of which are probably related to the granitic intrusions. The granite and similar rocks are presumably related in age and genesis to the Idaho batholith. This great mass is generally believed to have been intruded at the end of the Cretaceous or the beginning of the Eocene.

TERTIARY LAVA

Volcanic strata of Tertiary age border the Lemhi Range on the east and underlie much of the valley of Salmon River a few miles above Salmon. The boundary between these rocks and the metamorphic rocks that form mountains is actually more irregular than is indicated on Plate I. Many of the ridges on the east flank of the Lemhi Range are partly capped with Tertiary lava, and there may be places where erosion has exposed patches of the older rocks that have not been mapped. The masses of strata in which lava flows greatly predominate over pyroclastic and sedimentary beds have been mapped as Tertiary lava. There is interbedding in places between the lava and

[11] Umpleby, J. B., op. cit. (Bull. 528), pl. 1, 1913.
[12] Idem, p. 42.
[13] Idem, pp. 43-46.

the overlying "lake beds," and the boundaries as mapped are generalized.

Umpleby[14] has shown that rhyolite, andesite, latite, basalt, trachyte, and dacite are present. Rhyolite is probably the most widespread. Pyroclastic beds of various kinds are present in minor amount, and in places, particularly in the northeastern part of the Lemhi Range, sedimentary strata are included in the area mapped as Tertiary lava. The lavas of Lemhi County are believed to date from late Oligocene or early Miocene to about the end of the Pliocene.[15] It seems probable that nearly all those seen during the present investigation were erupted during the early part of this period.

At Salmon Hot Springs, in sec. 3, T. 20 N., R. 22 E., there are warm springs which issue from bleached and altered lava. The water deposits a brown, iron-bearing ooze in the concrete bathing tank. Similar springs are reported to occur in a number of other places in this part of Idaho. It is possible that they represent one of the last phases of the dying volcanism.

"LAKE BEDS"

The valley of Lemhi River and part of the valley of Salmon River are underlain by indurated clastic deposits which have been termed "lake beds" by Umpleby.[16] In the literature describing the geology of Idaho this term is frequently used to designate clastic deposits formed at about the same time and under similar conditions. Some of these beds are not strictly lacustrine deposits, but it is expedient to retain the term for purposes of description.

In the area here considered the "lake beds" consist in large part of moderately well-indurated thin-bedded fine-grained rocks which may be of lacustrine origin. There is a considerable amount of sandstone and conglomerate, in part coarse and poorly rounded, whose appearance suggests that it is of fluviatile origin. Much of this material was probably brought down from the mountains by torrential streams, which dumped their loads in alluvial fans when they reached the gentler grade of the valley. If a lake filled the valley into which such a stream emptied, the detritus carried by the stream would be deposited in the water of the lake, forming a delta. In addition to the beds of purely sedimentary origin, whether lacustrine or fluviatile, there are in places considerable amounts of tuff and coarser pyroclastic rocks. Some lava flows are also interbedded with the formation. Near Salmon and Baker there are beds of lignite, some of which were worked before the railroad reached Salmon. The maximum thickness of the formation is many hundreds of feet. From

[14] Umpleby, J. B., op. cit. (Bull. 528), pp. 47–48.
[15] Idem, p. 48.
[16] Idem, pp. 35–40.

a reconnaissance examination on Bohannon Creek southeast of Salmon Umpleby[17] estimates that a thickness as great as 4,000 feet may be exposed there.

On the evidence afforded by the relations of the formation to other rocks and by small collections of plant remains made by Umpleby and by G. H. Eldridge and determined by F. H. Knowlton, Umpleby[18] considered that the formation is probably of Miocene age.

QUATERNARY DEPOSITS

Alluvium deposited to form flood plains by the present streams is indicated on Plate I along Salmon and Lemhi rivers. In addition there are narrow bands of recent alluvium along most of the tributary streams, and the gently sloping parts of the surface of the "lake beds" are covered by a layer of unconsolidated gravel.

STRUCTURE

The available data regarding the structure of the rocks near Salmon are given below. As detailed geologic work has not yet been done either here or in neighboring areas, much still remains to be learned. Some of the most fundamental features of the structure of the general region can not be more than surmised from the facts now known.

The structual features found in the rocks may be divided into four groups. These are (1) folds with northerly trends; (2) flexures or fractures with northwesterly trends; (3) flexures or fractures with northeasterly trends; (4) the comparatively minor faults and folds which are later than the other groups. The folding of the first group was observed in the metamorphic rocks. Folding or fracturing of the second and third groups is inferred from trend lines in this and near-by parts of Idaho. The minor faults and folds of the fourth group can be readily seen in the Tertiary rocks. They may have been produced in two separate periods but more probably originated in one period of crustal instability in which faulting and folding took place intermittently and with decreasing violence.

The folding in the metamorphosed sedimentary rocks, although widespread, appears nowhere to have been sharp. The greatest dip recorded is 35°, and most of the observed dips are under 20°. It seems probable that this thick formation has been bent into broad, open folds and that in this area there is only one principal fold, a syncline whose axis lies west of and roughly parallel to the crest of the Lemhi Range, which here trends nearly north. Minor flexures are undoubtedly present, but they can be deciphered only by detailed study. Fault breccia in small amounts was noted in several places

---

17 Umpleby, J. B., op. cit. (Bull. 528), p. 35.

18 Idem, pp. 38–39.

and has shared in at least part of the metamorphism to which the rocks have been subjected. Many of the strikes recorded by Umpleby in his papers on Lemhi County and the Mackay region accord with the conception of folds with axes trending a few degrees either side of north. However, some of the beds observed by him in the western part of Lemhi County and near Lemhi Pass and by the present writer in the central part of the county, especially along McDevitt Creek, strike more nearly east than north. These strikes may mark minor flexures or may have resulted from later movements.

On McDevitt Creek the contact between the metamorphosed quartzitic rocks of supposed Algonkian age and quartzite that presumably belongs at the base of the Paleozoic section seems to be unconformable. It is not parallel to the bedding in the overlying quartzite, and the only other possible explanation is faulting, of which there is no direct evidence. The general relations elsewhere also suggest unconformity but might be explained by faulting. In no place has the line of contact been observed.

In northwestern Utah, according to Richardson,[19] and in southeastern Idaho, according to Mansfield,[20] an unconformity occurs within the Ordovician at a horizon probably corresponding with that here described. The evidence for the existence of an angular unconformity at the base of the Ordovician rocks is thus fairly strong. If the unconformity exists, the first folding in the metamorphic rocks evidently preceded it and is probably, as believed by Umpleby,[21] of pre-Cambrian age.

One of the most striking features of the geologic maps of east-central and southeastern Idaho[22] is the number of areas of rock represented whose long axes have trends approximating to N. 40° W. These areas correspond roughly to some of the larger topographic features. In general the valleys are occupied by Tertiary and later

---

[19] Richardson, G. B., The Paleozoic section in northern Utah: Am. Jour. Sci., 4th ser., vol. 36, pp. 406–416, 1913.

[20] Mansfield, G. R. Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho: U. S. Geol. Survey Bull. 713, pp. 30–34, 1920.

[21] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof Paper 97, p. 39, 1917; Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, p. 49, 1913.

[22] Lindgren, Waldemar, The gold and silver veins of Silver City, DeLamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pts. 3, pl. 8, 32, 1900. Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, pl. 1, 1913; Some ore deposits of southwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, pl. 1, 1913; Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, pl. 1, 1917. Schultz, A. R., and Richards, R. W., A geological reconnaissance in southeastern Idaho: U. S. Geol. Survey Bull. 530, pl. 6, 1913. Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pl. 9, 1910; Geology of the phosphate deposits northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, pls. 9 to 14, inclusive, 1914. Mansfield, G. R., Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho: U. S. Geol. Survey Bull. 713, pl. 3, 1920; Coal in Eastern Idaho: U. S. Geol. Survey Bull. 716, pls. 14, 15, 1921. Umpleby, J. B., and Livingston, D. C., A reconnaissance in south-central Idaho embracing Thunder Mountain, Big Creek, Stanley Basin, Sheep Mountain, and Seafoam districts, Idaho: Idaho Bur. Mines and Geology Bull. 3, map 1, 1920.

formations, and the mountains by older rocks. The descriptions in the papers thus cited and in others referred to below show clearly that the present size, shape, and arrangement of the areas of outcrop of the formations result primarily from structural disturbances, although erosion has had a modifying influence. The overthrusts are among the most striking features of the structure of the region. The Bannock overthrust[23] is the largest of those known, and the others are probably in large part of similar age and related to it.

The trace of this thrust in Idaho trends northwest, although in Utah the trend is nearly north. Convincing evidence is presented by Richards and Mansfield that the thrusts took place in late Cretaceous or early Eocene time.

It is suggested that the general trend and position of the Beaverhead Mountains and Lemhi Range result from structural disturbances related to those just referred to, with the outlines modified by erosion and the deposition of later rocks. Umpleby[24] has suggested that the principal deformation of the Paleozoic rocks took place at about the end of Mesozoic time and is genetically related to the granitic intrusions, and further that there may be genetic connection between these intrusions and the Bannock and other overthrusts along the east front of the Rocky Mountains. This suggestion is in accord with the view stated above.

Study of the maps above cited shows that several of the areas of rock shown terminate abruptly along lines with an average trend of about N. 40° E. Furthermore, the widest part of the Snake River Plains[25] in Idaho and a number of valleys floored with alluvium have approximately similar trends. This northeasterly series of trend lines is a less obvious feature of the region than the northwesterly series just discussed but is sufficiently definite and persistent to be of real significance in the structure of the region. It may correspond with the transverse folding noted by Mansfield[26] in southeastern Idaho, or it may be in part of later origin. The valley of Salmon River for a number of miles above Salmon has such a trend. Where observed, the contact between the lava and metamorphic rock along the sides of the valley is depositional. There are faults in both the lava and the "lake beds," and it is probable that in places the contacts between these two formations are fault planes. How much of

---

[23] Richards, R. W., and Mansfield, G. R., The Bannock overthrust: Jour. Geology, vol. 20, pp. 681–709, 1912.

[24] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 39, 1917; Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, p. 49, 1913.

[25] Russell, I. C., The geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Survey Bull. 199, pl. 1, 1902.

[26] Mansfield, G. R., Types of Rocky Mountain structures Idaho: Jour. Geology vol. 29, pp. 444–468, 1921.

this part of the valley of Salmon River was produced by structural disturbances and how much by erosion can not be determined on known evidence.

Direct evidence is lacking as to the character of the structural features that are believed to govern the positions of the portions of the valleys of Salmon and Lemhi rivers here considered. By analogy with the better-known structure farther south it is supposed that the features of northwesterly trend are folds which may have been so compressed as to have broken, forming overthrusts, and that those of northeasterly trend are subordinate transverse folds, probably with associated faults, all belonging to the same general period of diastrophism.

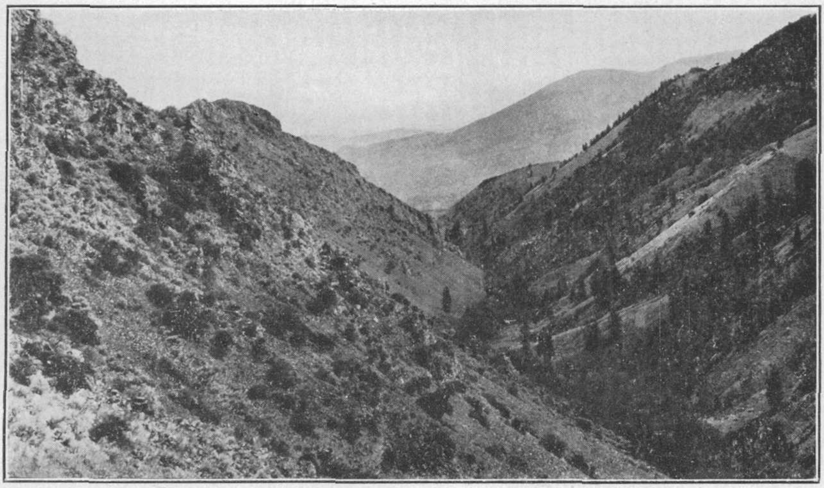
Tertiary lava lies well up on the flanks of the Lemhi Range and may in places even extend to the summit.[27] In a broad way, with a number of local exceptions, the lava dips away from the mountains as if it had been tilted during uplift. On the other hand, in numerous places the slope of the surface of old rocks on which the lava rests is more steeply inclined than the volcanic strata. In several places the lava terminates abruptly against steep and even precipitous slopes of metamorphic rock, such as that shown in Plate III, *A*. These various slopes appear to have been formed or at least modified by erosion before the advent of the lava, and hence indicate the existence of rugged topography in prelava time. The range was doubtless in existence before the eruptions began and was partly buried by them. Relative uplift of the range with respect to the river valleys on either side took place after most of the eruptions had ceased. The Salmon River and Beaverhead mountains have probably had similar histories.

The Tertiary sedimentary rocks grouped under the term "lake beds," like the volcanic rocks with which they are in part interbedded, slope up in general on the mountain flanks as if they had shared in the relative uplift. (See Pl. III, *B*.) In the valleys of Salmon and Lemhi rivers these beds are folded. In the cliffs along Salmon River a few miles below Salmon there is an exposure of a slight angular unconformity in the "lake beds." Whether this unconformity marks a mere local fluctuation in conditions or is of more general significance can be determined only by more detailed work.

Both the volcanic rocks and the "lake beds" along the valleys of Salmon and Lemhi rivers are cut by normal faults. More were observed in the volcanic rocks than in the "lake beds," but in neither formation were they mapped or studied in detail. None of those seen appeared to have a large throw. Most of them are probably somewhat later than the broad tilting and folding and are the results of the most recent adjustments in the earth's crust.

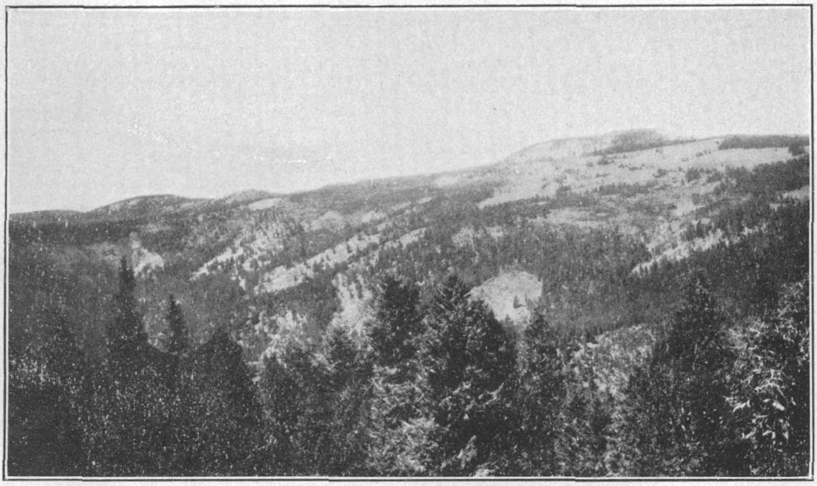
---

[27] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, p. 120, 1913.

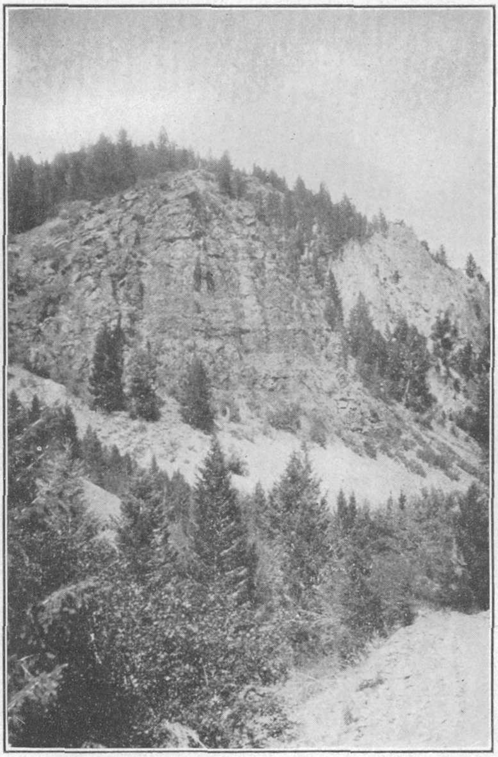


A. PERREAU CREEK NEAR THE TORMEY MINE, SALMON RIVER MOUNTAINS

Photograph by A. L. Anderson

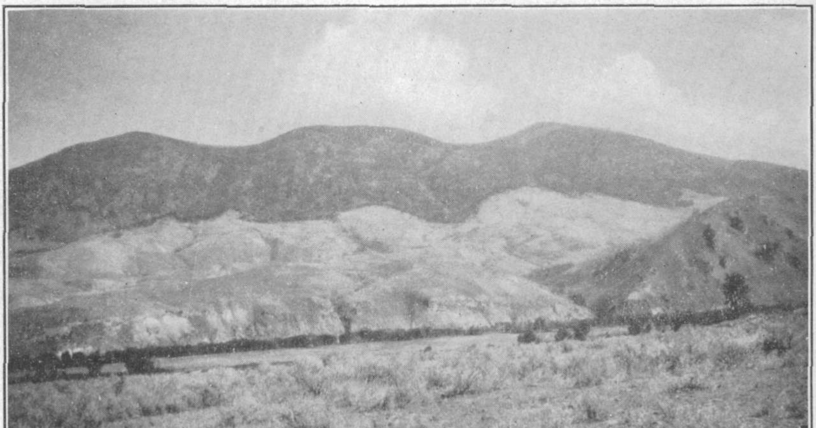


B. SALMON RIVER MOUNTAINS NEAR BALDY MOUNTAIN



A. PRECIPITOUS CONTACT BETWEEN METAMORPHIC ROCK AND TERTIARY LAVA EXPOSED ON THE LEFT SIDE OF WITHINGTON CREEK BELOW THE HARMONY MINE

The dark well-bedded rock is metamorphic, and that with jagged outlines and lighter color is lava



B. NORTH END OF LEMHI RANGE

The smooth and unforested slopes are underlain by "lake beds," the rough outcrops on the right are lava, and the forested upper slopes are on metamorphic rocks. The Pope-Shenon mine is near the edge of the timber near the left side of the picture

THE COPPER DEPOSITS

GENERAL CHARACTER

All the copper deposits here described are of the same general kind. They are shear zones in quartzitic rocks in which mineralization has been effected largely by metasomatic replacement but in part by fissure filling. Most of them are in the form of steeply inclined tabular masses of sheared and somewhat altered country rock in which there are shoots containing sufficient quantities of copper minerals to

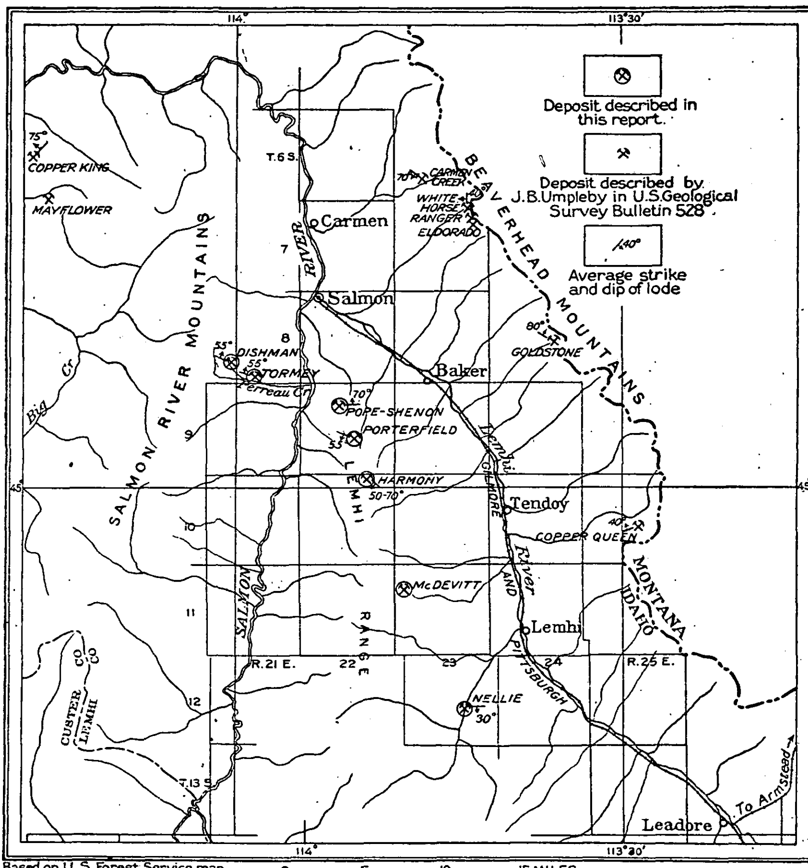


FIGURE 2.—Sketch map of part of Lemhi County, showing the location of known copper deposits

be mined as ore. The width of the known ore bodies varies from a few inches up to 20 feet. A number of the lodes have been drifted on for several hundred feet. Only certain portions of each lode, with rather definite limits along the strike, could be considered ore, and in most places the greater part of the remainder of the exposed portion of the lode is almost barren of valuable minerals. On inspection underground the lodes appear to be merely zones of shearing in rock of similar appearance to the surrounding country rock. Close examination with the microscope shows that much of the rock in these zones has been metamorphosed to a greater degree than the country rock at a distance from the deposits and in a somewhat different manner.

STRUCTURAL RELATIONS

The copper mines and prospects described in this report lie along a curved line that extends from a point near the head of Perreau Creek eastward across Salmon River, around the north end of the Lemhi Range, and down the east side of that range as far as Hayden Creek, as is shown in Figure 2. The total distance is about 28 miles. This line parallels rather closely the trend of the valley of Lemhi River. The distribution of the known deposits may be in part accidental, but the parallelism of their alinement with this depression of probable structural origin suggests the possibility that it may have genetic significance.

Most of the deposits containing notable amounts of copper minerals described by Umpleby in his report on Lemhi County lie on the west flank of the Beaverhead Mountains near the crest of the range, along a line that is nearly parallel to the trend of Lemhi Valley, as can be seen from Figure 2. They thus correspond in distribution on the east side of the valley to those examined in the present investigation on the west side. There are also a few copper deposits in the Salmon River Mountains and Yellow Jacket Range, nearer the large masses of granitic rocks, and two farther south in the Lemhi Range. The latter, known as the Colorado and Bruce groups, are the only copper deposits inclosed in limestone in this region. All the others are in quartzitic and schistose rocks. The Blue Wing deposits, on Patterson Creek, on the west side of the Lemhi Range, do not fit in any of the above groups.

The deposits in the western part of the county probably owe their position to the proximity of the granitic masses around Leesburg[28] and west of Yellow Jacket,[29] to which they are genetically related. The deposits in limestone in the southern part of the county are associated with quartz diorite intrusions,[30] and their location was doubtless directly determined by the position of the intrusive masses. The deposits, however, also bear about the same relation to the valley of Lemhi River as those described in the present report. The deposits on Patterson Creek differ from the others not only in

[28] Umpleby, J. B., op. cit. (Bull. 528), pl. 1.

[29] Umpleby, J. B., and Livingston, D. C., A reconnaissance in south central Idaho: Idaho Bur. Mines and Geology Bull. 3, map 1, 1920.

[30] Umpleby, J. B., op. cit. (Bull. 528), pp. 88-89.

position but also in the presence of sufficient tungsten to cause them to be prospected for that metal.[31]

The other ore desposits in pre-Tertiary rocks in Lemhi County described by Umpleby are susceptible of grouping in similar fashion. Most of them are scattered through the Salmon River Mountains and Yellow Jacket Range, in the western part of the county, but there are also a number in the limestone west of the upper part of

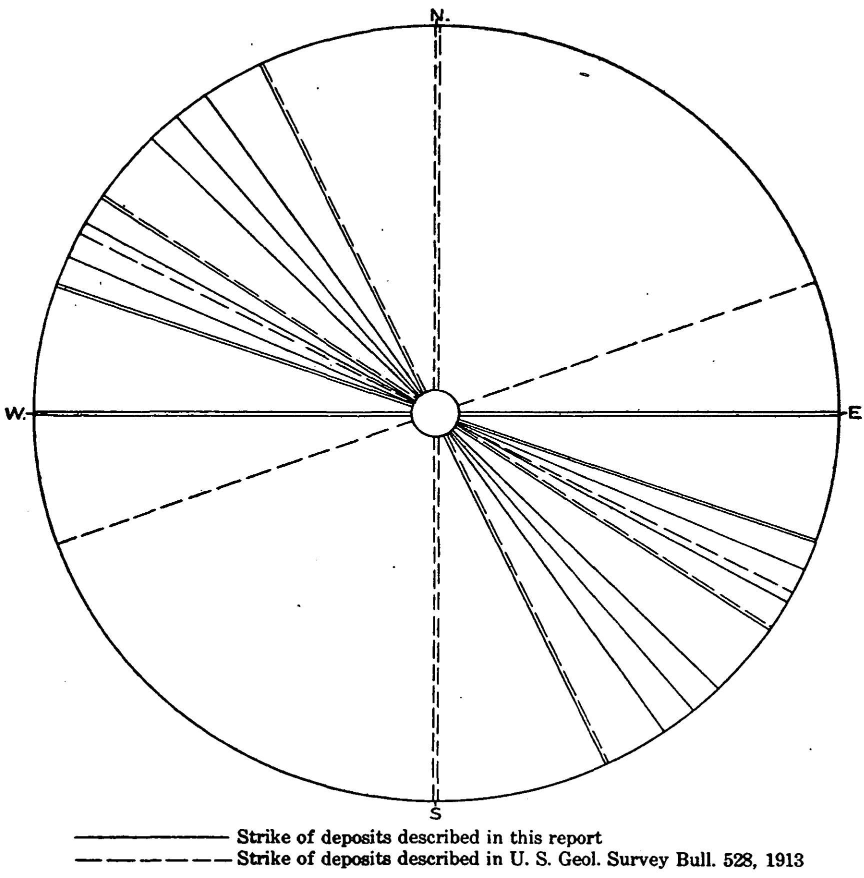


FIGURE 3.—Diagram showing observed strikes of copper deposits in Lemhi County

Lemhi River, and nearly as many along the west slope of the Beaverhead Mountains. As the location of many prospects and some mines is not known, the number of deposits in the different groups can not be accurately stated.

The attitudes of the lodes indicated in Figure 2 vary considerably, and the strikes of many of them do not parallel the imaginary lines drawn through the groups on the opposite sides of the valley of Lemhi

[31] Idem, pp. 110–111.

River. However, when all the known strikes of copper deposits in Lemhi County are assembled in a diagram (fig. 3), the greater number fall into a group in which the divergence either way from a mean of N. 49° W. is less than 25°. This mean is not far from the average trend of N. 40° W. possessed by a large group of major structural axes in the general region. The data summarized in this diagram and in the similar one shown in Figure 4 are not complete. The strikes of a number of lodes in the county are unknown, and many of the lodes have variable trends. The mathematical averages

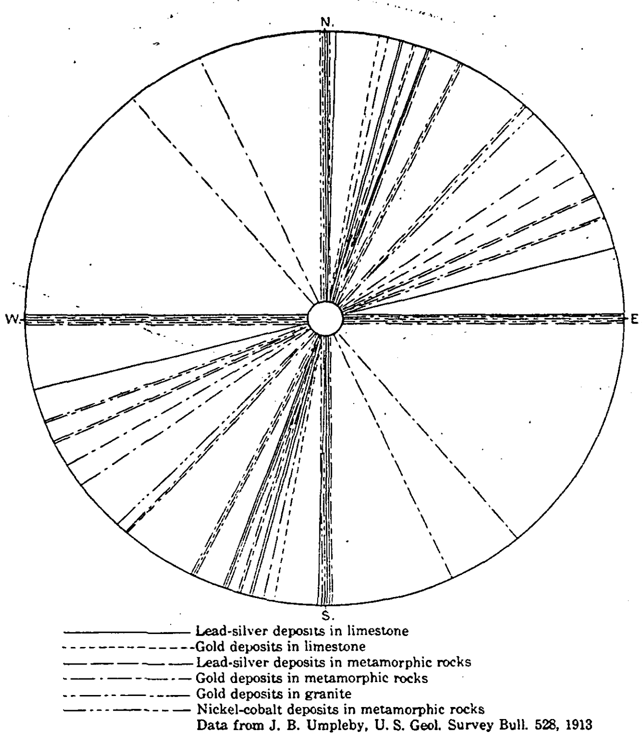


FIGURE 4.—Diagram showing observed strikes of ore deposits other than copper deposits in Lemhi County

given are to be regarded as convenient and concise means of expressing general relations rather than as precise quantities. The strikes of the other ore deposits in Lemhi County for the most part vary widely from the mean of N. 49° W., as can be seen by a glance at Figure 4. With only two exceptions the recorded strikes fall in the northeast quadrant. Most of them lie in the northerly half of the quadrant, and the mean is N. 39° E. This is almost exactly at right angles to the mean of the strikes of the copper deposits and corresponds very closely to the average trend of N. 40° E. shown by many topographic features and geologic boundaries in the general region. As stated in the section on structure, it is probable that these northeasterly trends are the result of diastrophic movements that were widespread but not as powerful as those which produced the structural features with northwesterly trends. Only a few of the lodes accord in strike with either the bedding or the schistosity of the inclosing rock. The different kinds of lines used to record strikes in Figure 4 serve to indicate differences in the general characteristics of the deposits. It must be remembered, however, that any such subdivision of the ore deposits in pre-Tertiary rocks must be somewhat arbitary. All these deposits, as Umpleby[32] has pointed out, have characteristics in common and gradations between them. The strikes indicated in Figures 3 and 4 might be further subdivided, but with the rather scanty data now available it seems best to consider them simply as falling into two general groups, one with northwesterly and the other with northeasterly trends.

It appears from the facts outlined above that the ore deposits considered are grouped with reference either to granitic intrusions or to structural axes. Further, the strikes lie in two groups at right angles to each other and conform closely to the average trends of two of the major groups of structural axes in the region. The shear zones and fractures containing the deposits were probably produced during and as a result of the orogenic movements that took place at the end of the Mesozoic era. The variations in strike and still more in dip are to be accounted for by local variations of numerous possible kinds.

At two places on the property of the Harmony Mines Co. there are pairs of lodes coming together at small angles. These lodes appear to have resulted from the splitting of shear zones rather than from the intersection of independent sets of fractures. It seems likely that similar conditions will be encountered elsewhere. There has not been sufficient crosscutting at any of the mines to discover whether the full lateral extent of the mineralized ground has been determined. In all the ore shoots there are slabs of almost barren rock intercalated in the ore. What is true on a small scale may be found to be true on a larger scale—that is, there may be in places zones of sheared and mineralized rock near and approximately parallel to known lodes but separated from them by rock so little altered that it offers no clue to their presence. That shearing and subsequent mineralization have taken place along several zones in the same locality is shown by the conditions on the Harmony property and at the Dishman prospect. At the Harmony there are at least two mineralized zones in addition to the two pairs already mentioned, or a total of six. At the Dishman the rock is mineralized in places over a considerable area across

[32] Umpleby, J. B., op. cit. (Bull. 528), pp. 81–82

the strike of what appears to be the major shear zone. However, the meager development work done here has not sufficed to show the presence of any such definite and continuous zones of shearing as exist at the better-developed properties. It is possible, therefore, that the structural conditions at this locality caused the mineralizing solutions to be diffused over a wider area and to deposit their load along discontinuous fractures separated by considerable amounts of barren rock.

In a number of the deposits there are cross fractures lined with gouge or breccia intersecting the main load at various angles. The rock along some of these fractures is mineralized or altered in a manner similar to that of the main deposit. These fractures are clearly of premineral origin and doubtless merely record variations in the stresses that produced the shear zones. Others that are not mineralized cut mineralized rock and are evidently of later date. Only one of the postmineral faults so far discovered in the mines offsets the lode as much as 20 feet, and none has caused serious difficulty in following the lodes.

ORE SHOOTS

In all the deposits visited in which sufficient development work has been done the valuable ore is confined to rather definitely restricted ore shoots of moderate size. Typical shoots have average widths of the order of about 10 feet and stope lengths of a few hundred feet. Shoots of average size will yield over 20,000 tons of ore, and if they prove to be persistent in depth they may furnish several times this amount. Present developments indicate that a vertical range of at least 200 feet can be confidently expected, and there is nothing in the known geologic relations of the deposits to preclude the possibility that ore shoots may be found to persist downward considerable distances below the lowest present development. In the vicinity of Hailey, Idaho, where the development is much more extensive, there are deposits of lead-silver ore formed in the same period as the copper deposits near Salmon, and under somewhat similar conditions which have not proved to be persistent at depth. Some of the ore shoots near Hailey, however, have been followed much farther below their outcrops than any of those near Salmon, and there is still a possibility that other shoots at greater depth exist.

In none of the deposits has more than one shoot been proved to exist, but this may well be due merely to lack of extensive development. The ore shoot in general occupies the greater part of the known width of the lode but is bordered at both ends along the strike of the lode by comparatively barren rock. As a rule the transition between ore and waste appears to take place rather abruptly. The waste rock in the lodes contains very small amounts of metallic minerals and somewhat less quartz than the ore, and it may show less bleaching and softening.

At the two most extensively developed properties the shape and size of the ore shoots have been in part approximately determined, and there is some evidence as to the reasons for their location and attitude. In the Harmony mine, as is shown in Figure 7, the ore shoot is at the intersection of the Leapyear and Contention lodes, and its rake is determined by the inclination of the intersection. Much the greater part of the ore lies on the upper side of this intersection, and most of that mined was along the Leapyear lode. At the Anderson workings on the same property similar conditions appear to exist, although here the development is much less extensive. At the Pope-Shenon mine, as is shown in Plate IV, the pitch of the ore shoot is approximately parallel to the dip of the schistosity. The flattening of the upper part of the ore shoot as it exists at present is probably the result of leaching by surficial water.

The precise cause for the localization of ore shoots doubtless differs in different lodes. However, from the somewhat scanty data at hand it is believed that the general rule is that an ore shoot may be expected at any place in a lode where conditions during ore deposition were particularly favorable to the circulation of mineralizing solutions. The composition of the country rock varies so slightly that it probably had little influence in the production of ore shoots in most places. The rocks are siliceous, rather fine grained, and tightly cemented. They are not very readily permeable, even along the shear zones, and the movement of ore-bearing solutions in quantity was limited to places where the rock was more open. The greater the volume of solution the greater the quantity of ore deposited. Any set of conditions producing more than average permeability in the rock along a shear zone might have resulted in an ore shoot. At the Pope-Shenon mine it was a zone of somewhat unusually pronounced schistosity; at the Harmony mine it was the abundance of fracturing at intersections of shear zones. Each lode must be studied individually in detail in order to deduce the probable situation and attitude of possible ore shoots. It must be borne in mind in such a study that fracturing to have the desired effect must have been produced prior to the termination of hypogene mineralization. Postmineral faults obviously could have no influence on the production of ore shoots, although they might well influence the redistribution of the metals by processes of oxidation.

HYPOGENE MINERALIZATION

The deposits have been formed along shear zones partly by replacement and partly by vein filling. The minerals in the unoxidized parts of the lodes comprise quartz, micas, chlorite, epidote, chalcopyrite, pyrite, magnetite, specularite, and delafossite. Sphalerite is present in very small amount. Bornite is an abundant ore mineral in the Nellie group but is almost entirely absent elsewhere. Barite was noted at the Pope-Shenon mine only. The nonmetallic minerals, except the vein quartz, are largely the components of the original rock with the modifications suggested below. In the discussion that follows only the effects of hypogene mineralization are considered. The results of supergene processes are set forth in the succeeding section.

The ore bodies consist of roughly lenticular bands of variable size and composition lying approximately parallel to the sides of the lode. In places, especially near the sides, there are bands of soft gouge. Some bands consist of sheared country rock which in the hand specimen shows little alteration. Others are bleached and somewhat softened. Between the bands of country rock and penetrating them in places are stringers and lenses of massive white quartz. The metallic minerals are disseminated in both country rock and quartz, and in places they are concentrated into irregular bands of nearly solid sulphide. The sulphide minerals associated with the quartz are on the whole more coarsely crystallized than those in the country rock. The latter, however, have a much better developed crystal form.

During and before the hypogene mineralization the rock was subjected to great pressure. All the rock in the lodes is more crushed than that at a distance, and in numerous places there has been so much crushing and rearrangement of the constituents under pressure as to convert the rock in and near the lodes into schist. The character of the alteration shows that it could not have been produced by pressure alone without the addition of foreign material. The constituents of the metallic sulphides may be confidently assumed to have been introduced during mineralization. Magnetite and specularite are so abundant in places as to make it evident that ferric oxide has been added. Silica was brought in and deposited in veinlets and probably also interstitially in the mass of the rock. The bleaching and softening noted are largely the result of the formation of sericite. This colorless mica was produced in large part by alteration of the biotite and chlorite of the original rock. Such an alteration implies the introduction of alkalies, especially potassium, from some outside source. The sericite or fine-grained muscovite was one of the last nonmetallic minerals to crystallize.

The epidote seen in several specimens of country rock obtained near ore bodies crystallized later than the groundmass of the rock. In the ore from the Porterfield prospect there are segregations of epidote evidently formed during mineralization. Probably part of the epidote was formed during the regional metamorphism and is not directly connected with the mineralization.

Part of the rock from the Pope-Shenon mine has a peculiar banded or layered structure. Such rock was not noted in place, but a number of specimens were found on the waste dump. They presumably came from the main stope. In some specimens the layers take the form of irregular concentric ellipsoids; in others they are slightly curved and subparallel. In both varieties the rock breaks more readily along the boundaries of the layers than in other directions. In most of the specimens with concentric layers there is a much less distinct set of flat, parallel bands cutting across the ellipsoids. These bands probably mark the original bedding. The concentric layers are evidently entirely independent of the bedding planes. Alternate layers are black and green. In some specimens with subparallel layers the lighter layers are nearly white, but the dark ones contain larger proportions of the black material than in the specimens with ellipsoidal structure. The layering is not very clear-cut. In most specimens the dark layers shade off into the lighter ones more gradually on one side than on the other. Most of the dark layers are less than a tenth of an inch wide. The light ones are in general wider, some being over a quarter of an inch wide. Some specimens of this banded material bear striking resemblances in general appearance to organic forms.

The banded rock, like the rest of the country rock, consists essentially of quartz and micaceous minerals. The color of the dark layers is caused in part by black metallic minerals and in part by a greater concentration of biotite in these layers. A small part of the metallic material is magnetite, but much the greater portion is a copper-bearing mineral, which has been determined to be delafossite. This mineral is later in origin than the quartz grains and fills interstices and cracks in them. Part of the colorless mica appears to be of even later origin.

The delafossite is entirely without crystal form and is so hard that it can not readily be scratched with a steel needle. The mineral was determined by Edward Sampson to be rather feebly anisotropic in polished section. It is sufficiently magnetic to be attracted by a strong electromagnet but is distinctly less magnetic than the magnetite which accompanies it. Before the blowpipe the mineral is almost infusible but becomes strongly magnetic. A small amount of the material was separated as well as possible from the other constituents of the rock by means of an electromagnet and heavy solutions, and was submitted to W. T. Schaller for determination. As can be seen from the analysis quoted below, a considerable amount of impurities remained with the mineral in the sample. The mineral itself is very readily soluble in hydrochloric acid, and all the soluble silica, the insoluble material, and the material lost on ignition listed in the analysis are to be regarded as impurities. After allowance is made for these, the composition of the mineral agrees fairly well with the theoretical composition of delafossite. As its physical characteristics, so far as determined, also agree with those of that mineral as given by Rogers[33] and no similar mineral is known, its correlation with delafossite seems established. The "loss on ignition" consists of water, sulphur, iodine, organic matter, etc., from heavy solutions.

Analysis of delafossite from the Pope-Shenon mine

[W. T. Schaller, analyst]

	Analysis	Composition after impurities are deducted	Composition calculated from formula $Cu_2O.Fe_2O_3$
Cuprous oxide (Cu_2O)	27.94	45.80	47.29
Ferric oxide (Fe_2O_3)	33.06	54.20	52.71
Insoluble matter	30.94		
Soluble silica (SiO_2)	.70		
Loss on ignition	6.62		
	99.26	100.00	100.00

In the few published descriptions of this rare mineral[33] it is said to be associated with kaolin or similar clayey material. The mineral first analyzed by Rogers was collected by Tovote[34] at Bisbee, Ariz., where, he reports, it is sufficiently abundant to constitute commercial ore. Both the delafossite from Bisbee and that from Kimberly, Nev., came from the deepest part of the oxidized zone. At the Pope-Shenon mine there is a little oxidation in some of the ore from the level on which the delafossite was found, but many of the specimens containing the mineral show no evidence of oxidation or weathering. This fact and the intimate association of micas and magnetite with the delafossite lead to the belief that the mineral is here of hypogene origin. However that may be, it appears to have been produced by rhythmic deposition from a fluid that was diffused into the rock from openings produced by joints.

[33] Friedel, M. C., Sur une combinaison naturelle des oxydes de fer et de cuivre, et sur la reproduction de l'atacamite: Compt. Rend., vol. 77, pp. 211–214, 1873. Dana, E. S., System of mineralogy, 6th ed., p. 259. Rogers, A. F., Delafossite, a cuprous metaferrite from Bisbee, Ariz.: Am. Jour. Sci., 4th ser., vol. 35, pp. 290–294, 1913; Delafossite from Kimberly, Nev.: Am. Mineralogist, vol. 7, pp. 102–103, 1922.

[34] Tovote, W. L., Bisbee—a geological sketch: Min. and Sci. Press, vol. 102, pp. 206, 207, 1911.

The rock in cuts on what is known as the "big ledge" along the ridge crest above the Harmony mine and on the property of the Harmony Mines Co. contains considerable magnetite. Specimens of the country rock rendered schistose during mineralization contain disseminated grains and crystals of magnetite. There are bands of nearly massive magnetite which under the microscope can be seen to be in part replaced by specularite.

The gravel on Hayden Creek contains pebbles of magnetite and specularite, some of which are so little waterworn that they were probably derived from near-by talus slopes. It is reported that on the ridge tops in this vicinity there are numerous exposures of such material in place.

In most of the copper deposits visited chalcopyrite and pyrite are the only hypogene sulphides visible in the average ore. The chalcopyrite is much more abundant than the pyrite and was formed somewhat later. Bornite is the principal ore mineral in part of the ore on the Nellie group and is almost certainly of hypogene origin. Traces of zinc are reported in a few of the smelter returns on shipments from the Harmony and Pope-Shenon mines. These doubtless result from the presence of sphalerite, as tiny grains of this material are reported to have been observed in some of the ore.

The average ore mined carries 2½ to 6 per cent of copper. Lenses of ore containing 10 to 20 per cent of copper have been found, but few of these are large enough to be mined separately. Most of the high-grade unconcentrated ore shipped has been obtained by careful hand sorting. The ore in most of the deposits examined contains negligible amounts of gold and silver. Few shipments of concentrates from the Pope-Shenon and Harmony mines contain much over a dollar's worth of precious metals to the ton. Ore from the Dishman prospect, however, is reported to carry gold to the value of a few dollars to the ton. In contrast to these, most of the deposits in Lemhi County containing appreciable quantities of copper described by Umpleby were worked primarily for their gold content.

Barite was found in a narrow vein at the Pope-Shenon mine. This vein contains also small amounts of oxidized copper minerals and cuts diagonally across the main zone of shearing. The barite has a dark, smoky color, in places with a violet tinge, and shows well-marked zonal banding. This mineral was not observed elsewhere. It was formed later than the main deposit.

OXIDATION AND ENRICHMENT

Small amounts of oxidized ore containing malachite, azurite, cuprite, and in places native copper are present in exposed parts of all the deposits, and at some of the deposits such ore has been mined and shipped. In the Pope-Shenon mine, especially on the upper levels, so much oxidized ore was found that a chlorination mill was erected to treat it. Most of the sulphide ore in the mines shows incipient oxidation. On the other hand, unoxidized sulphides are found at or close to the surface in all of them. In general the amount of oxidized ore is small compared to that of the nearly unaltered sulphide ore. Erosion is evidently so efficient on the steep slopes where the deposits crop out that in most deposits it almost keeps pace with oxidation. At the head of the gulch in which the Anderson workings of the Harmony Mines Co. are situated is a small cirque, which indicates that here glaciation has played a part in removing the softened oxidized parts of ore bodies.

In specimens from a number of the mines small amounts of chalcocite were found. Its relations to the other sulphides show clearly that here, as in most other regions where it occurs, the chalcocite was deposited by downward-percolating water that derived its copper content from the leached upper parts of the ore bodies. Chalcocite contains a larger percentage of copper than chalcopyrite, and its presence in otherwise unaltered sulphide ore implies that such ore is of comparatively high grade. There is so little chalcocite in the average ore exposed in any of the mines, however, that it can be positively identified only under the microscope, and its absence in the deeper ore probably does not result in a sufficiently marked decrease in average copper content to be of commercial importance. Much of the chalcocite shows incipient alteration to oxide material of indefinite composition, such as has been termed copper pitch ore.

AGE AND GENESIS

The mineral associations in the copper deposits are those generally recognized as characteristic of deposition at rather high pressure and temperature. It appears that the first stage of mineralization was the alteration of the rock in and near the shear zones. This alteration is similar to but more intense than the metamorphism of the great masses of quartzitic strata termed in this report the "metamorphic rocks." The nonmetallic minerals in both the country rock and the lodes are similar and represent the introduction of new material as well as the recrystallization of material already present. The elements added were silica, iron, and alkalies. The quantities added were somewhat greater, and the rock is locally more schistose in the lodes than in the country rock at a distance from them. The metallic minerals were introduced into the lodes at a somewhat later stage, and the vein quartz, at least in part consolidated later than the sulphides. Chalcopyrite was the last hypogene sulphide to crystallize.

Evidence has been presented to show that the shear zones were produced during a period of diastrophism at the end of the Mesozoic era, and further that the movements at that time may be related to the intrusion of the batholith of central Idaho. As already stated, regional metamorphism in the quartzitic rocks probably resulted from the action of aqueo-igneous agencies. The similar alteration in the rocks of the lodes is almost certainly of closely related origin—that is, it is due to waters emanating from the granitic magma, which were also the only adequate source for the copper and sulphur of the deposits. The excess iron, silica, alkalies, and possibly other substances introduced during mineralization probably were also derived from such waters.

No igneous rocks except the intensely altered dike in the Pope-Shenon mine were found in direct association with the ore bodies. The only intrusive rocks known near the copper lodes visited are the small dacite masses of probable Tertiary age near the Porterfield prospect and between that locality and Salmon Hot Springs. The lodes, however, present none of the well-known characteristics of deposits formed in connection with Tertiary lavas. The only known igneous masses in the region that are adequate and suitable to serve as a source for mineralization of the type found are the granitic rocks of the batholith of central Idaho and its offshoots. This statement is in accord with the conclusion of Umpleby [35] regarding the similar and evidently related deposits elsewhere in Lemhi County which he describes.

The sequence of events appears to have been as follows: At about the end of the Mesozoic era large masses of granitic magma were intruded. As a result of the consequent heat and pressure, probably aided by emanations from the cooling magma, the impure quartzitic rocks that form the lowest part of the stratigraphic column were extensively metamorphosed. These rocks were probably already folded as a result of previous diastrophism. Powerful earth movements took place at about the same time as the batholithic intrusion. Probably crustal disturbances were initiated early in the magmatic period and continued during and for a time after the intrusion. Among the comparatively minor effects of the disturbances were shear zones and fractures, along which the magmatic emanations, following the paths of least resistance, concentrated. Consequently the rock adjacent to these zones was first more intensely metamorphosed, and then sulphide minerals and quartz were deposited in the rock and in fissures in it.

OUTCROPS

The outcrops of the copper deposits are rather inconspicuous. Some are marked by small amounts of limonite, scattered copper stains, and lenses and irregular masses of quartz, but others show little more than indistinct shearing in the rock. In some the shearing

[35] Umpleby, J. B., op. cit (Bull. 528), pp. 81-82.

and subsequent alteration have been sufficient to give the rock a schistose appearance. The rock in some of the shear zones has in places been bleached nearly white. In most of them, however, thorough oxidation has not extended far below the surface, and hypogene sulphides are found at shallow depth or may even appear at the surface.

In the area containing the known copper deposits there are few satisfactory outcrops of rock in place. Most of the rock not covered by soil is concealed under extensive accumulations of talus. This makes the search for mineral deposits difficult, especially as there is little in the broader features of the lithology or structure that is of assistance to the prospector. Copper deposits of the type of those here described are probably confined to the metamorphic rocks, and their distribution may be related to some of the larger structural features of the region, but the known relations are not sufficiently restricted and definite to be of much aid in prospecting. The best that can be done is to examine carefully the outcrops and talus in the general zone containing the known deposits for any indication of mineralization. Any evidence of shearing should be studied, for it is entirely possible that a shear zone which contains an ore shoot at depth may show little sign of metallization at the surface. Distinction should be made between shear zones and zones of brecciation, in which angular fragments of rock torn from the walls are held in a paste composed of ground-up rock of similar appearance. Such breccias are fairly common in the metamorphic rocks but are not known to be mineralized. Once a promising shear zone has been found, search should be made along it for outcrops of ore shoots or places where shoots may be inferred to be present at slight depth. Any evidence of comparatively intense alteration in the rock is a favorable indication, but the presence of sulphide minerals or their oxidation products is the most satisfactory guide for further prospecting. There appears to be in general somewhat more quartz in the ore shoots than in barren parts of the shear zones, so that an abundance of quartz is also a favorable sign. It is also well to look for intersections of shear zones or cross fractures of any kind, because at such places ore shoots are more likely to have been formed than elsewhere. Indications of this sort might warrant a certain amount of development, even though there was little direct evidence of metallization in the outcrop.

On the property of the Harmony Mines Co., where rock outcrops are better and more extensive than in many other localities in the vicinity of Salmon, at least six lodes are known to be present. This suggests that careful prospecting might be rewarded in the vicinity of known ore bodies where the bedrock is less well exposed.

OPERATING CONDITIONS AND FUTURE OF COPPER MINING

Although mining has been in progress in Lemhi County for over half a century, copper mining in this region is a comparatively new thing. None of the mines in the county had made regular shipments of copper ore before 1918, and much of that shipped previously was found in mines that were worked principally for gold. None of the deposits worked primarily for copper have been sufficiently developed to show their ultimate possibilities, and local conditions governing cost of production and markets were not studied in detail, although some data are available. From the facts at hand, however, some idea of the future possibilities of the deposits may be gained.

The average ore mined carries from 2½ to 6 per cent of copper and negligible amounts of gold and silver. None of the substances deleterious to smelting are present in appreciable amount. The sulphide ore can be satisfactorily concentrated by simple means. It is reported that recoveries of more than 90 per cent are obtained by the use of table concentration, supplemented by oil flotation. The concentrates carry about 20 per cent of copper or a little less. Gravity concentration without the aid of flotation results in the recovery of only about 60 per cent of the copper.

Most of the known deposits crop out on steep mountain sides hundreds of feet above the streams at their bases. As a result they have been developed by means of tunnels, with consequent convenience and economy in underground haulage. The ore is quickly and cheaply sent from the mine portal to the mill on aerial tramways. On the other hand, transportation of supplies and men up the slope to the mine is slow and laborious.

The ore is mined by overhead stoping. The rock is hard but not excessively so. Both ore and country rock stand fairly well. Untimbered prospect tunnels remain for the most part in good shape for years. Drifts above which stoping is in progress require timbering, and there are local zones of fractured rock that will not stand without it, but the amount of timber required in drifts and stopes is in general moderate. The mountains are forest-clad and furnish an abundant supply of lumber of sufficiently good quality for underground use.

Transportation of supplies to the mill sites below the mines and of ore and concentrates from them is a matter of some difficulty and expense. Wagon roads connect the mill sites of most of the properties with the main highways, and others could be constructed to reach the prospects not now accessible by this means. The mine roads are rough, unfinished, and poorly graded, but the distances are not great. The distance to a main highway is everywhere well under 10 miles, and that from the junction with a highway to a railroad station is only a few miles farther. Ore is hauled over the roads throughout the year, but during the winter hauling is attended with some difficulty. The ore and concentrates shipped are consigned to smelters in Salt Lake City, Utah.

Labor conditions in the district are fairly good. Many of the farmers possess a knowledge of mining and constitute a body of intelligent and industrious men from which to recruit miners in addition to those who follow that trade exclusively. The supply of men is adequate for present needs except during the short seasons when many men are needed on the farms.

From the available information it is evident that the district contains a number of copper deposits in which there are rather small shoots of ore of moderate grade and streaks of high-grade ore. Sufficient ore to continue mining on the present or a somewhat larger scale for a considerable number of years can probably be found. The character of the ore and the containing rock, the size and attitude of the ore shoots, and the topographic situation of the deposits are all rather favorable to mining on a small scale. Labor conditions are probably about as good as in the average mining district at the present time, but transportation costs are doubtless higher than those of many districts. H. A. C. Jenison [36] of the United States Geological Survey, who has made a special study of such matters, estimates that under the general conditions prevailing in this district refined copper can not be produced at a cost of much less than 12 cents a pound, without allowance for depreciation, taxes, and similar charges. Except under the most careful and efficient management and with suitable mine and mill equipment the cost might well be higher. He adds that at the present time the copper-mining industry in the United States is about 25 per cent overdeveloped. The increase in the world's consumption of copper in the near future can easily be counterbalanced by increased production from mines in South America and Africa. In view of these facts investment in new copper mines should be undertaken with great caution. Only under the most favorable circumstances and skillful management can newly opened copper mines be expected to become successful.

MINES AND PROSPECTS

The copper deposits examined during the present investigation are here described in the order of their geographic position, from northwest to southeast. A brief description of one recently opened prospect that is worked principally for lead and silver is added. For descriptions of other copper deposits in Lemhi County the reader is referred to

[36] Personal communication.

Umpleby's report on the ore deposits of that county.[37] The present section is believed to include descriptions of all the copper mines and prospects that have been actively worked in the last few years.

There are half a dozen other prospects near Salmon which have shipped small amounts of copper ore in recent years, as shown by the records of the United States Geological Survey, but regarding which nothing was learned during the visit to the area in the summer of 1923. These are the Blue Bird, Castle Rock, Gold Point, Patton, Royal Gold, and Ruby properties. Most of them are probably in the Beaverhead Mountains and are presumably inactive at present.

There were probably few shipments of ore mined primarily for copper from Lemhi County prior to 1911, although this metal was present in some of the gold and lead-silver ore shipped before then. The total amount of copper obtained from such ore was probably not large. Umpleby,[38] whose field work in the county was done in 1910, estimated the value of the copper ore produced in the county as $40,000. The table below, compiled by C. N. Gerry, statistician, of the United States Geological Survey, gives the production of copper ore from 1911 to 1922. In the summer of 1923 two mines were producing steadily, and a third was preparing to start regular production, so that the tonnage of copper ore produced in the county may be expected to increase markedly.

Copper ore produced in Lemhi County, Idaho, 1911–1922

[Compiled by C. N. Gerry]

Mine	Date	Ore (short tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)
Blue Bird	1917	8	3.66	68	1,432
Castle Rock	1915–1916	12	2.15	449	1,533
Copper Queen	1911–1922	2,601	930.77	5,006	529,758
Gold Point	1915–1918	9	10.41	89	2,671
Harmony	1916–1922	17,250	9.83	923	753,952
Patton	1914 and 1917	62	.08	7	10,402
Pope-Shenon	1917–1922	2,096	5.18	476	297,969
Ranger	1917	13	58.19	175	869
Royal Gold	1915	22	4.71	82	3,235
Ruby	1917	20	2.20	156	3,248
Tormey	1918–1922	213	.69	116	80,161
		22,306	1,027.87	7,546	1,685,230

DISHMAN PROSPECT

The Dishman prospect is on a gulch on the left side of the north fork of Perreau Creek, in the Salmon River Mountains, about 1,500 feet vertically above the bed of the stream and 8,000 feet above sea level. It is roughly 6 miles west of the point where Perreau Creek

[37] Umpleby, J. B., op. cit. (Bull 528), pp. 69, 70, 88, 89, 110–111, 120–124, 127, 155, 164.

[38] Idem, p. 50.

enters Salmon River. The workings comprise one tunnel about 50 feet long, another about 170 feet long, and a number of cuts and shallow openings. The cabin is at a spring a short distance above the workings. The country rock is siliceous slate that is nearly black in color. The principal slips in the two tunnels examined strike N. 70° W. and dip 50°–60° N. Along these slips is gouge and altered slate, with some quartz, chalcopyrite, pyrite, and the oxidation products limonite, malachite, and chrysocolla, and they are reported to contain enough gold to be of some commercial value. Both tunnels also cut a number of smaller slips with diverse strikes and dips, along some of which there is gouge and a little pyrite. The tunnels and cuts are distributed over a few hundred feet of mountain side and are evidently in a zone of shearing in the slate in which there has been sporadic mineralization. The developments are insufficient to demonstrate whether or not any ore bodies of commercial size exist here.

TORMEY MINE

The Tormey copper mine is on the north side of Perreau Creek, probably in unsurveyed sec. 34, T. 21 N., R. 21 E. It is at an altitude of over 6,000 feet above sea level. There is a group of cabins belonging to the property on a small creek north of the mine, and some buildings on Perreau Creek just south of the mine and 1,000 feet below it. Both camps are connected with Salmon by roads, but that to the camp on Perreau Creek is the better one for automobiles.

The claims were originally located by John Tormey a number of years ago, and most of the development work on them was done by him. Shipments of hand-sorted ore have been made at various times from 1918 to 1920, which according to the records of the United States Geological Survey aggregate 187 tons containing 70,125 pounds of copper, 0.69 ounce of gold, and 116 ounces of silver. Some of the sorted ore contained as much as 17 per cent of copper.[39] Late in 1922 the deposits were leased by W. M. and G. A. Snow and R. E. Wickham, who sorted and shipped 26 tons of ore containing 10,036 pounds of copper. In the summer of 1923 they were engaged in erecting a small concentrating mill at the camp on Perreau Creek and otherwise preparing to put the property on a producing basis.

The present mine workings consist of two tunnels and some small cuts. One of the tunnels, known as the Greenhorn, is almost directly above the camp on Perreau Creek and was formerly connected with it by a tramway. The lessees plan to build an aerial tram here. This tunnel is 385 feet long, and there are short crosscuts off it and stopes above it, as is shown in Figure 5. The other tunnel, known as the

[39] Bell, R. N. (State inspector of mines), Twenty-first annual report of the mining industry of Idaho, for the year 1919, pp. 98-99, 1920.

Rattlesnake, is over a quarter of a mile farther upstream and a little higher up the slope than the Greenhorn tunnel. The Rattlesnake tunnel is about 300 feet long, and two short drifts lead from it, as is shown in Figure 6.

The rock in the vicinity of the Tormey mine is black and gray quartzitic slate and slaty quartzite. The bedding is indistinct but appears to have a general dip to the east and to be nowhere steeply inclined. The Greenhorn tunnel follows a zone of shearing. The principal slips are indicated in Figure 5. Near the portal the strike of the shearing is about N. 30° W. Farther in it swings gradually around to about N. 70° W. The dip in most places where observed is about

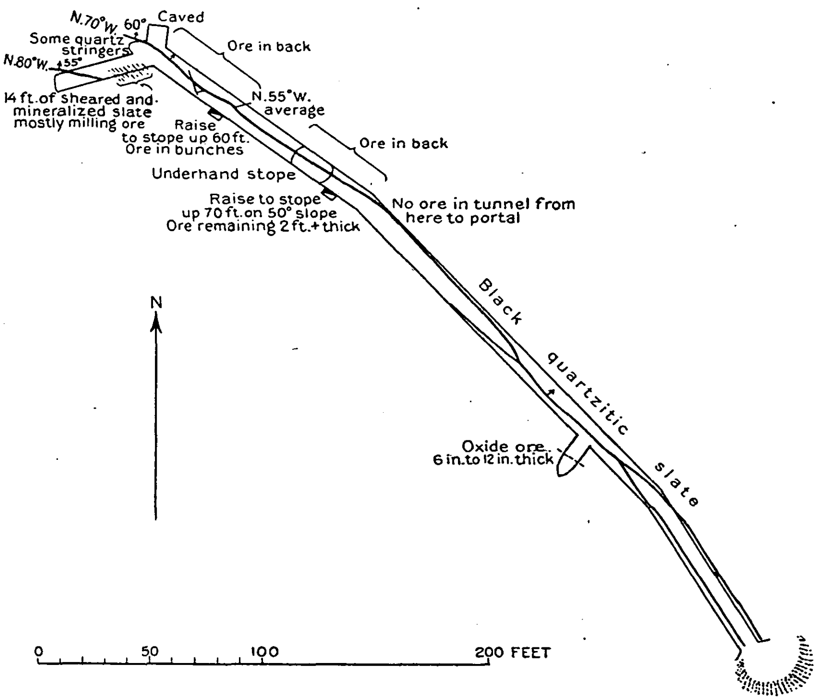


FIGURE 5.—Geologic sketch map of Greenhorn tunnel, Tormey mine

55° NE. No ore is visible in the first 270 feet of the tunnel or in the face, but there are two stretches 50 feet and 40 feet long in which ore shows in the back of the tunnel. In the space between these stretches there are some bunches of ore. Stopes extend most of the way from a point near the face of the tunnel to a point about 120 feet from the face and for a few score of feet above the tunnel. The stopes are nowhere more than a few feet wide, but the exposures in them and in the crosscut at the end of the tunnel appear to indicate that a considerably greater width of ore suitable for concentration may be found on further development. The ore consists of chalcopyrite and pyrite in a gangue of quartz and altered slate. Cracks in the chalcopyrite are lined with narrow bands of chalcocite, each of which shows copper oxide material of indefinite composition in the middle. Some of the ore in surface exposures is oxidized. The oxidization and enrichment noted are so small in amount as to be of little commercial consequence.

The Rattlesnake tunnel (fig. 6) is a crosscut trending about N. 5° E. About 210 feet from the portal it cuts a shear zone which strikes about N. 60 W. and dips about 55° SW. A drift on this zone about 20 feet long discloses a band of chalcopyrite ore about a foot wide.

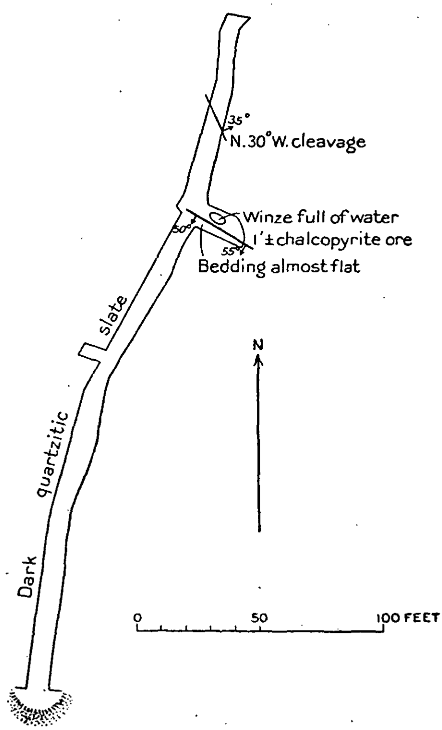


FIGURE 6.—Geologic sketch map of Rattlesnake tunnel, Tormey mine

POPE-SHENON MINE

The Pope-Shenon mine is near the north end of the Lemhi Range, in sec. 9, T. 20 N., R. 22 E., about 8 miles by road southwest of Salmon. The property comprises 12 unpatented claims. There is a blacksmith shop and a compressor room at the mine, and a concentrating mill, boarding house, and other buildings below it. The haulage tunnel of the mine is connected with the mill by a tramway.

Some claims were located here in the early nineties by Lige Stroud and James Fenning and held as a gold prospect.[40] Two years later

[40] Most of these historical data were supplied by P. J. Shenon, of Salmon.

Thomas Pope, Red McDonald, Thomas Andrews, and Richard Clark located two copper claims. Later Philip Shenon acquired a two-thirds interest. About 1917 the property was taken over by some Salt Lake City people. In 1917 one shipment of hand-sorted ore was made,[41] and in 1919 there were shipments amounting to 360 tons containing an average of 12 per cent of copper.[42]

By this time development had proceeded far enough to show the presence of a body of copper ore, much of which was considered too thoroughly oxidized to be efficiently concentrated by gravity. As a result of experiments with samples of the ore at the University of Utah a chloridizing plant was built at the mine in 1919 and operated in 1920 and 1921. In this plant[43] the ore was crushed and mixed with chloride material. Common salt and calcium chloride slag produced in the process and returned were used. The ore and chloride were fed to a revolving furnace and heated sufficiently to fuse the surface of the mass. The copper was volatilized as copper chloride. The fumes were passed first through a flue in which the furnace dust was removed and then into a Cottrell precipitator. The precipitated copper chloride fume was mixed with limestone and coke and fed to an oil-heated reverberatory furnace. The products were metallic copper and calcium chloride slag, both somewhat impure. The experiments with this process gave favorable results, but it is reported that in practice at this mine the difficulties encountered were so great that work was abandoned.

On August 1, 1922, W. M. and G. A. Snow took a lease on the property. They have remodeled the mill into a gravity concentrator equipped with jigs, tables, and a small oil-flotation unit. The chalcopyrite ore now being mined has proved suitable for treatment in this mill. From September 25, 1922, to August 14, 1923, a total of 940 tons of concentrates with an average content of 22 per cent of copper was shipped to a smelter at Salt Lake City, Utah. The smelter returns show that in one shipment the concentrate carried a trace of zinc and in three others it carried about 0.5 per cent of calcium oxide. The silver content was less than 1 ounce to the ton in most shipments, and the gold content was 0.01 ounce to the ton or less in all but one shipment, which ran 0.11 ounce to the ton. The ore mined is considered by the Snow Brothers to average about 6 per cent of copper.

The mine has been developed by a series of six tunnels, numbered consecutively, starting with the one highest up the mountain side. All of them follow the lode except the lowest, which is a tunnel 40 feet long in barren rock opening at the rear of the mill. All but this one

---

[41] Bell, R. N., Nineteenth annual report of the mining industry of Idaho, for the year 1917, p. 72, 1918.

[42] Bell, R. N., Twenty-first annual report of the mining industry of Idaho, for the year 1919, pp. 97–98, 1920.

[43] Bradford, Robert, The volatilization process at the Pope-Shenon mine; Min. and Sci. Press, vol. 123, pp. 263–266, Aug. 20, 1921.

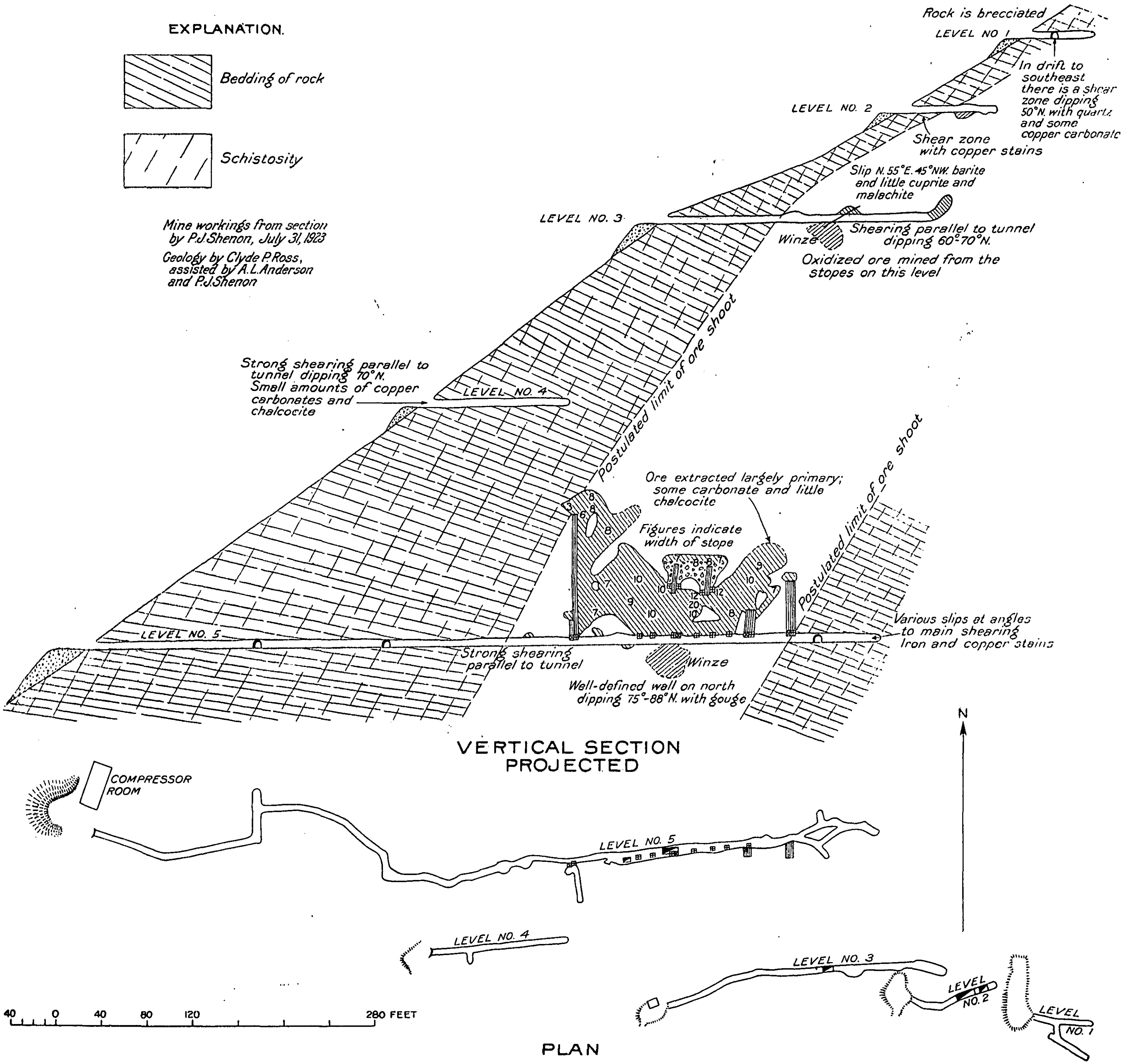
are shown in Plate IV, which is based on a map and longitudinal section prepared by W. M. Snow and P. J. Shenon in July, 1923. There are in all about 1,475 feet of drifts, a large stope from tunnel No. 5, smaller stopes from tunnels Nos. 2 and 3, and three raises, besides a few shallow prospect openings not mapped.

The country rock is a dark-green, impure quartzite with light-colored beds in places. The bedding can be seen in most exposures when closely examined but is not obvious at a distance. The beds are built up of interfingering lenses a fraction of an inch thick and a few inches long. The strike in the more distinctly bedded exposures is about N. 30° E., although in several places it appears to swing farther to the north. The maximum dip observed is 35° E., and the minimum is less than 10° E. There is a moderately pronounced schistosity striking in general a few degrees east of north and dipping about 60° W. About a quarter of a mile north of the mine an outcrop of a rock resembling conglomerate has recently been found.[44] This rock contains boulders as much as a foot in diameter of darker-colored quartzite in a quartzitic matrix similar to most of the rock in the vicinity. This is the only exposure of this sort known in the metamorphic rocks.

The lode strikes nearly east and dips 70° N. An ore shoot is exposed for 200 feet on level No. 5. The shearing and alteration of the rock continues in both directions beyond the shoot, but only meager amounts of valuable minerals are present. Near the innermost face on this level there are a number of small slips with various strikes, along which are brecciated quartzite, gouge, and small amounts of oxidized copper minerals. There is an irregular band about a foot wide of soft yellow material parallel to the strike of the lode. The composition of this material has not been determined, but it is thought to have been a fine-grained porphyritic dike. Similar material has been found in the stope above. It contains fragments of rather calcic feldspar and chlorite and other alteration products derived from its original ferromagnesian minerals.

In the stope above this level the shoot has been followed vertically upward for 125 feet. The average width mined is somewhat less than 10 feet, but near the middle of the stope a maximum width of 20 feet was attained. The unmined masses left in the stope are in part of low grade but contain also some good ore. Their shapes and positions have resulted rather from variations in mining methods under different managements than from variations in the character of the ore. The copper in the ore of the main stope is principally in the form of chalcopyrite, but small amounts of chalcocite are generally present, and oxidized minerals are found in places, especially near

[44] Shenon, P. J., letter of Oct. 4, 1923.



PLAN AND VERTICAL SECTION OF POPE-SHENON MINE

Section is parallel to average strike of lode and shows geologic relations of the ore body

33094—25. (Face p. 36)

the borders of the stope. Oxidized ore is reported to have been mined from the small stopes on the upper levels. In a small stope on level No. 3 there is a narrow vein containing barite and small amounts of oxidized copper minerals. It strikes N. 55° E., dips 45° NW., and cuts the main zone of shearing. The occurrence of the rare mineral delafossite at this mine is described in some detail on pages 23–24.

PORTERFIELD PROSPECT

J. Porterfield has a copper prospect on the west side of Mulkey Creek in the Lemhi Range, at an altitude of somewhat more than 8,000 feet above sea level. It is near the center of T. 20 N., R. 22 E., probably in sec. 22.

The prospect is developed principally by a tunnel about 190 feet long, of which 50 feet is in mineralized ground. There are less extensive workings, also showing mineralization, above this tunnel, and a cabin near two small springs about 700 feet vertically below it.

The country rock is a dark-greenish impure quartzite or siliceous slate. In the tunnel its cleavage, which apparently coincides in direction with the bedding, strikes N. 75° W. and dips 25° S. Near the cabin is a small dike of weathered gray porphyry that has approximately the composition of dacite. This dike appears to strike about N. 80° E. The "float" found indicates the presence of other similar dikes in the vicinity. The last 50 feet of the main tunnel follows a slip striking about N. 65° W. and dipping 55° S., along which there is considerable brecciated and altered rock and some malachite and limonite. Some of the mineralized rock on the dump contains epidote in clusters of small crystals.

HARMONY MINE

The Harmony mine is near the head of Withington Creek in the Lemhi Range. The property consists of 21 unpatented claims and a mill site in sec. 2, T. 19 N., R. 22 E., and adjoining sections. The mill and lower camp are at an altitude of about 7,000 feet above sea level, and the mine buildings and portal of the main haulage tunnel are 1,200 feet vertically above the lower camp and are connected with it by an aerial tram.

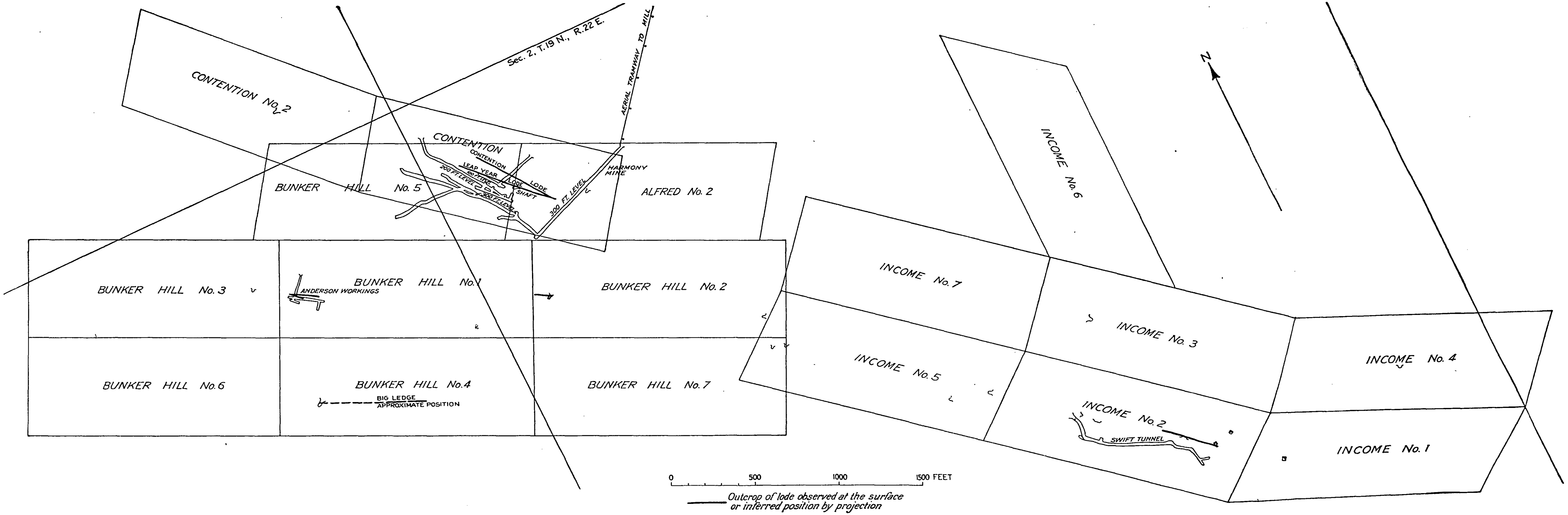
The ore deposits here were probably discovered a considerable time ago, but little development work was done before the Harmony Mines Co., the present owner, acquired the property in 1916. This company maintained a small production up to 1919, when a concentrating mill equipped with crushing machinery, classifiers, and tables was built. A flotation plant was added later. The mill is reported to be able to treat a maximum of 200 tons of ore a day, but less than half that amount is fed to it. Since the completion of the mill a steady production of concentrates has been maintained except in 1921, when in common with many other copper mines the Harmony suspended operations. The records of the United States Geological Survey show that from 1916 to 1922, inclusive, 842 tons of crude ore and 1,502 tons of concentrates were shipped. The crude ore shipped contained 132,297 pounds of copper, 0.68 ounce of gold, and 130 ounces of silver. The concentrates contained 621,655 pounds of copper, 915 ounces of gold, and 793 ounces of silver and were derived from 16,408 tons of ore milled. The smelter returns from the 42 shipments made from January 4 to December 10, 1923, show that the concentrates had an average content of 22.7 per cent of copper, 1.58 ounces of silver, and 0.01 ounce of gold to the ton, 19.8 per cent of silica, 25.4 per cent of iron, and 24.7 per cent of sulphur.

The principal underground workings are on the Contention claim, and comprise three levels, known as the 100-foot, 200-foot, and 300-foot levels. On the 100-foot level there is a crosscut tunnel 265 feet long and a drift 160 feet long with a stope above it. The portal of the 200-foot level is 78 feet vertically farther down the mountain than that of the 100-foot level, and there are 1,000 feet of drifts and crosscuts on this level. The 300-foot level is the haulage level of the mine, and its portal is 95 feet vertically below the portal of the 200-foot level. Stopes and raises connect the 200-foot and 300-foot levels, and there is a small stope on the 100-foot level. The 300-foot level comprises over 2,500 feet of drifts and crosscuts. These three levels and the principal workings in other parts of the property are shown on Plate V.

In addition to the main mine, whose workings are outlined above, the Harmony property includes the Anderson and Income workings and several small shafts and cuts. The portal of the Anderson workings is 425 feet above and about 2,000 feet west of the portal of the 300-foot level of the main mine. The Anderson workings comprise about 510 feet of drifts and crosscuts now open, with stopes above, one of which extends about 100 feet to the surface.

The portal of the Swift tunnel, the principal tunnel on the Income group, is at about the same altitude and somewhat over 3,100 feet southeast of the portal of the 300-foot level of the main mine. The Swift tunnel is about 900 feet long, and there are shallow shafts and short tunnels above it.

On the Harmony property the rock is a dark argillaceous quartzite with some light-colored, more siliceous beds. The dark rock is less green in color than that near the Pope-Shenon and Porterfield properties. The bedding in many exposures can be seen at a glance, even from a distance. The average strike is about N. 30° W., and the dip is 15° S. or less. The rock shows little schistose cleavage.



SKETCH MAP SHOWING RELATIONS OF LODES ON PROPERTY OF HARMONY MINES CO.

The two lodes in what may be termed the Harmony mine proper are called the Leapyear and Contention veins. Besides these there are on the company's property the two lodes in the Anderson workings, the "big ledge" near the crest of the mountain, a lode exposed on the Bunker Hill No. 2 claim, one or more lodes on the Income claims, and possibly others. The principal production to date has been from the Leapyear and Contention veins, especially from the Leapyear. There are small stopes on both the lodes in the Anderson workings. The other deposits mentioned have been prospected to

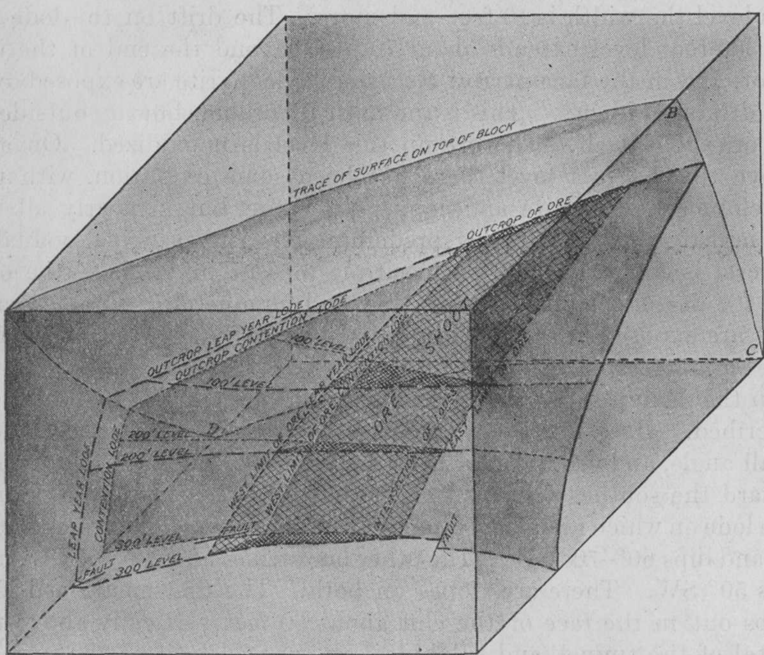


FIGURE 7.—Block diagram showing relations of ore shoot in Harmony mine to Contention and Leapyear lodes

some extent, but little ore has been mined from them. The known lodes are indicated on Plate V, except the "big ledge," which crops out on the Bunker Hill No. 4 claim.

The average strike of the Contention lode is N. 30° W., and that of the Leapyear lode is N. 40° W., but the strikes of both vary considerably. The Contention lode on the 100-foot level strikes more nearly N. 20° W. The average dip of both is about 60° SW., but in this also there is considerable variation. In some places in the stopes the dip flattens greatly. The ore is reported to be in general richer in the flat parts of the lode than in the intervening steeper parts. As is shown in Plate V and Figure 7, the two veins join, but only one vein has been found to the southeast of the junction, and they may merge into one. However, the small amount of crosscutting that has been done on the 300-foot level is insufficient to determine this point. The ore shoot that is being stoped has a rake approximately parallel to the line of juncture of the two lodes as is shown diagrammatically in Figure 7. Most of the ore is on the northwest side of the line of juncture. The ore has been followed in the Leapyear lode for 230 feet from the junction on the 300-foot level and found to have a width of 6 to 10 feet. In the stopes above this level the width is 10 feet and more. The drift on the lode on the 300-foot level extends about 70 feet beyond the end of the ore shoot, and in the face narrow seams of chalcopyrite are exposed over a width of 10 inches. This is the most favorable showing outside of the ore shoot itself. The ore on this level is unoxidized. On and above the 200-foot level there has been some oxidation, with the development of cuprite and copper pitch ore, but in nearly all the ore mined sulphide minerals predominate. The principal valuable mineral is chalcopyrite. Chalcocite is present in much of the ore, but the amount is insignificant. Several unmineralized, gouge-lined slips are exposed in the workings, and two of these offset one of the lodes a few feet.

In the Anderson workings the conditions are similiar to those just described. Here also there are two lodes which come together at a small angle, and ore is found near the junction, but the lodes diverge toward the southeast instead of the northwest, as in the Harmony. The lode on which more development work has been done strikes N. 64° W. and dips 60°–70° SW. The other one strikes about N. 55° W. and dips 50° SW. There are stopes on both. The first-mentioned lode crops out in the face of the cliff about 90 feet vertically above the portal of the tunnel, and sulphides are exposed in it at the surface. The other lode has been stoped to the surface, a distance of about 100 feet. Two slips are exposed near the portal of the crosscut tunnel through which the lodes were developed. Both strike N. 55° W. and they dip 75° and 60° SW.

The lode known as the "big ledge" has been developed only by shallow cuts. It is on the south side of the crest of the Lemhi Range above the Anderson workings. The location of the lode on Plate V is only approximate. Where observed, the strike is N. 55° W. and the dip 55° SW. The lode is marked by strong shearing and the development of considerable chlorite and magnetite and a little specularite. The exposures are rusty, probably from the oxidation of pyrite.

On the north slope of the range between the "big ledge" and the Harmony mine another lode is exposed at what is known as the upper shaft. The strike is about N. 65° W., and the dip is 70° SW. Considerable quartz is present.

The Swift tunnel on the Income group follows a shear zone with steep southerly dip, in places nearly vertical. Near the inner end of the tunnel the shear zone is offset several feet to the south on a fault that appears to strike nearly north and dip west. No sulphides were observed in the tunnel, but at somewhat more than 200 feet in from the portal the lode is reported to contain some gold. Copper ore is reported to have been found in shallow shafts above and about 900 feet southeast of the portal of the tunnel, in what may be a continuation of the same lode.

PROSPECTS ON McDEVITT CREEK

There are a number of prospects along McDevitt Creek, which is near the southern boundary of T. 19 N., R. 23 E., but no work was in progress on them at the time of visit in September, 1923. Some of the prospects have long been abandoned, and on none of them has extensive development work been done. The prospect that is reported to have the largest amount of underground workings is on the south fork of the creek near the northwest corner of T. 18 N., R. 23 E., probably in sec. 7. Its altitude is more than 7,000 feet above sea level. At this prospect there is a log cabin near the stream, a tunnel on the left side a short distance downstream from the cabin, and another on the right side still farther down, with a log blacksmith shop at its mouth. The tunnel first mentioned trends N. 85° W. for about 50 feet, then N. 80° W. for nearly 50 feet more. At about 60 feet in from the portal there is a winze, and a short distance farther in a drift 25 feet long trending S. 56° W. The other tunnel is about 410 feet long. For a distance of nearly 300 feet it trends about S. 5° E., and then it swings around to about S. 25° E. near the face.

The country rock of this and the other prospects on McDevitt Creek is dark-gray slaty quartzite. Somewhat over half a mile downstream from the prospect there is an exposure of such rock in which ripple marks are well preserved. The bedding here strikes nearly east and dips 20° N. Near the mouth of the longer tunnel the bedding appears to strike N. 45° W. and to dip somewhat less than 15° NE.

About 250 feet from the portal of the lower tunnel a small excavation in the east side of the tunnel discloses some small irregular stringers of quartz containing chalcopyrite. There is also some chalcopyrite disseminated in the rock adjoining the stringers. In the last 30 feet or so of the tunnel a fault zone of gouge and brecciated and bleached quartzite is exposed. This zone strikes about N. 25° W. and dips 60° or more SW.

At the portal of the tunnel on the left side of the stream there is a breccia zone about 5 feet wide which strikes nearly north and dips about 75° W. From the portal to the winze the rock in the tunnel is barren and unbrecciated. In the winze and the workings beyond it the rock is mineralized and the ground is much broken. The mineralization produced a number of small and irregular stringers of quartz containing chalcopyrite and some malachite. Many of the quartz stringers lie nearly horizontal.

PROSPECTS ON HAYDEN CREEK

The mineral deposits on Hayden Creek, which lies largely in T. 17 N., R. 23 E., and joins Lemhi River a short distance below the railroad station at Lemhi, are among the first found in the county. They are reported to have been prospected by the Mormons who built Fort Lemhi, near the present railroad station of Tendoy, about 1854, but little has been done with them since that time. In 1923 Webster Atwood was the only man reported to be developing prospects on Hayden Creek. He owns the Nellie group, nearly 7 miles from Lemhi and another prospect several miles farther up Hayden Creek. The latter was not visited but is reported by Mr. Atwood to be only very slightly developed as yet. On the Nellie group there are open cuts on both sides of Hayden Creek. One of those on the left side is nearly 20 feet wide; the others are smaller.

The rock in this vicinity is a green schist. It is probably of sedimentary origin but is more thoroughly metamorphosed than any of the other rocks observed in the course of the present investigation. In the large open cut the schistosity strikes east and dips 28° S. The attitude of the bedding could not be determined. In this open cut the mineralized zone is exposed for a width of about 12 feet, with a body of barren schist in the middle. Numerous narrow bands of quartz containing chalcopyrite lie along the schist planes. The rock contains a little pyrite and calcite and is in places stained with limonite and manganese oxide. A carload of ore was shipped from this prospect several years ago by the former owners. The present developments are insufficient to establish the dimensions of the ore body in any direction, but some of the ore uncovered is of good grade. The face of the small open cut on the right side of the stream, nearly opposite that just described, was covered with slide rock at the time of visit, but specimens from that cut show considerable bornite and some pyrite. The bornite is probably hypogene but is slightly later than the pyrite. A little supergene chalcocite is present.

Mr. Atwood,[45] the owner of the claims, has recently found about a quarter of a mile up Hayden Creek from the exposures just described a large vein of white quartz containing intercommunicating cavities, some of which are large enough for a man to enter. These cavities contain a pulverulent brown substance consisting largely of hydrous manganese oxide. The vein strikes east and dips 18° S.

SILVERTON PROSPECT

The Silverton prospect, owned by Dee Matlock and H. Bielenberg, is about 3 miles northwest of Salmon, a short distance northeast of the road to Leesburg, in the Salmon River Mountains, in sec. 35, T. 22 N., R. 21 E., at an altitude of about 5,600 feet above sea level. The principal underground working is a tunnel approximately 450 feet long, with a raise from it to the surface. The work at this prospect was done in 1923, and a carload of lead-silver ore has been shipped.

The country rock is green to gray, more or less shaly quartzite. The bedding is indistinct but appears to be inclined at low angles. There is a shear zone with a strike of N. 80°–85° E., dipping in general steeply to the north, and a number of small slips with various attitudes. The rock is somewhat altered and in places contains layers of vein matter a few inches wide parallel to one another and to the shearing. The vein matter consists largely of quartz, in part chalcedonic. Calcite is abundant in places. The most abundant ore mineral is galena, principally fine grained, found in the raise near the surface. This mineral has been in part altered to cerusite and other oxidation products. Small amounts of cuprite and copper carbonates are present in some of the ore, and native copper is reported to have been found in gouge along some of the slips.

[45] Atwood, Webster, letters of Oct. 22 and Nov. 26, 1923.

INDEX

Page

Access to the area 2
Acknowledgments for aid 2
Age of the copper deposits 26–27

Beaverhead Mountains, features of 4

Copper deposits, general character of 15–16
structural relations of 16–20

Delafossite, occurrence and composition of 23–24
Dishman prospect, description of 31–32

Enrichment, supergene, extent of 25–26
Eureka mining district, geologic sketch map of part of 8

Faults of the area 11–14
Folds and faults, features of 11–14

Genesis of the copper deposits 26–27
Granitic rocks, features of 9

Harmony mine, description of 37–41
Harmony Mines Co., lodes on property of, map showing 38
Hayden Creek, prospects on 42–43
Historical sketch 2–3

"Lake beds," description of 10–11
Lava, Tertiary, contact of, with metamorphic rock, plate showing 15
Tertiary, description of 9–10
Lemhi Range, features of 4
north end of, plate showing 15
Lemhi River, source and course of 4
Location of the deposits 1–2

McDevitt Creek, prospects on 41–42
McDevitt mining district, geologic sketch map of part of 8
Manganese, occurrence of 43

Page

Map, geologic, of parts of the Eureka and McDevitt mining districts 8
geologic, of the area 8
showing relations of lodes on property of Harmony Mines Co 38
Metamorphic rocks, contact of, with Tertiary lava, plate showing 15
description of 5–8
Mineralization, hypogene, action and effects of 22–25
Mining, conditions of and outlook for 29–30

Nellie claims, description of 42

Ore deposits, strikes of 16–20
Ore shoots, features of 20–21
Outcrops of ore, features of 27–28
Oxidation, effects of 25–26

Paleozoic rocks, features of 8–9
Perreau Creek, plate showing 14
Pope-Shenon mine, description of 34–37
plan and vertical section of 36
Porterfield prospect, description of 37
Production of copper ore, 1911–1922 31

Rocks of the area 5–11

Salmon River, valley and tributaries of 4–5
Salmon River Mountains, features of 5
plate showing 14
Schaller, W. T., analysis by 24
Scope of the report 1
Silverton prospect, description of 43
Strikes of copper deposits, directions of 16–18
Structure of the rocks 11–14

Topography of the area 4–5
Tormey mine, description of 32–34
Tungsten, occurrence of 17