STATE OF IDAHO
C. A. Bottolfsen, Governor

___________________________________
IDAHO BUREAU OF MINES AND GEOLOGY
A. W. Fahrenwald, Director

___________________________________
COPPER MINERALIZATION NEAR SALMON,
LEMIHI COUNTY, IDAHO

By

Alfred L. Anderson

___________________________________
University of Idaho
Moscow, Idaho
COPPER MINERALIZATION NEAR SALMON,

LEMIHI COUNTY, IDAHO

By

ALFRED L. ANDERSON

ABSTRACT

Because of the pressing demand for copper in the present war, attention has been directed to the copper deposits near Salmon, Idaho, particularly to the Pope-Shenon mine, which, because of its production of more than 2,400,000 pounds of copper, has been the largest and most consistent producer. The geology of the mine is described and the commercial possibilities discussed. It is concluded that the deposits are deep-seated; that deeper development should add greatly to ore reserves; and that, prices for copper being favorable, there is no apparent reason why work at the mines should not be resumed.

INTRODUCTION

PURPOSE AND SCOPE

This report deals largely with the geologic occurrence of the ore at the Pope-Shenon mine, the only copper mine near Salmon, Idaho, that has been recurrently active since Ross made his report on the copper deposits in 1925. Because of the pressing demand for copper in the present war effort, attention has again been directed to the deposits and particularly to the Pope-Shenon mine, which in the past has been the leading producer of copper. Because so little has been done on the others since Ross made his report, there is little to add to the data already available, except insofar as the findings at the Pope-Shenon may apply to the district as a whole. The Pope-Shenon mine has been opened at deeper levels and considerably more information on the occurrence and distribution of the ore and its persistence with depth is now available. These new data may be of assistance to those who may wish to engage in mining at the Pope-Shenon or in mines of similar kind in the region nearby.

LOCATION AND ACCESS

Most of the copper deposits lie on both sides of the Salmon River in the central part of Lemhi County, spaced rather widely in the southern part of the Eureka and in the western part of the McDevitt mining districts. 2/ The Pope-Shenon mine is in the Eureka district near the north end of the Lemhi

2/ Op. cit., p. 3., Sketch map showing the location of the copper deposits and the broader features of the geology.
CONTENTS

ABSTRACT ................................................................. 1
INTRODUCTION ............................................................ 1
  Purpose and Scope ................................................... 1
  Location and Access ................................................ 1
  Acknowledgments .................................................... 2
POPE-SHENON MINES ..................................................... 2
  Historical Sketch ................................................... 2
  Production ........................................................... 3
  Development ......................................................... 4
  Topography .......................................................... 5
  Geology .............................................................. 5
    Foreword .......................................................... 5
    Stratigraphic features .......................................... 5
    Structural features .............................................. 6
      Folding ......................................................... 6
      Cleavage ....................................................... 6
      Shearing ....................................................... 7
    Character of the deposit ....................................... 9
    Mineralogy ........................................................ 10
    Structural relations of the ore ............................... 11
    Ore shoots ....................................................... 12
    Tenor of the ore ............................................... 13
    Wall-rock alteration ........................................... 14
    Age and genesis ................................................. 14
CONCLUSIONS ............................................................ 15

ILLUSTRATIONS

Fig. 1. Plan of the workings of the Pope-Shenon mine ........ 4
Fig. 2. Longitudinal section of the Pope-Shenon mine showing stopes ........ 4
Fig. 3. Diagrammatic sketch of the ore on the intermediate level showing the relation to the fracture system ........ 8
Fig. 4. Diagrammatic sketch showing the localization of ore along diagonal fractures ........ 11
Range in Section 9, Township 20 N., Range 22 E., about 7-1/2 miles by air or 10 miles by road south-southeast of Salmon. It lies at an altitude of about 5,650 feet (aneroid) and affords a commanding view of the Salmon River Valley and the town of Salmon about 1,700 feet below.

Formerly Salmon was the terminus of the Gilmore and Pittsburg Railroad, which connected with the Oregon Short Line (Union Pacific system) at Armetad, Montana, 95 miles to the east, but in 1899 the line was abandoned and the tracks removed. Since then, Salmon and Lemhi County have been entirely dependent on automobile and truck transportation, the nearest railheads being at Armetad, Montana, at Darby, Montana, 74 miles to the north (Northern Pacific Railway), and Mackay, Idaho, 118 miles to the south (Oregon Short Line). Mail is received daily at Salmon, except Sunday, by mail truck from Armetad and by Salmon River stages from Pocatello, Idaho. Passenger stages run daily to and from Pocatello, via Blackfoot and Mackay (Salmon River stages), and to and from Missoula, Montana (Intermountain Transportation Company). Passengers also are carried on the mail stage to and from Armetad, Montana. Truck lines provide Salmon with adequate freight and express service.

Most of the traffic in and out of Salmon is on U. S. Highway No. 93 which extends north through Missoula and south through Challis. South of Challis the traffic follows U. S. Highway 93-A to Arco, then U. S. Highway No. 20 to Blackfoot, and U. S. Highway No. 91 from Blackfoot to Pocatello. These highways are surfaced and all of them graded, except for some miles north of Salmon and for some few miles on each side of Challis. Except to Missoula and Armetad, the highways cross no mountain passes, but occupy valleys and mountain basins. These highways are open to travel throughout the year.

The Pope-Shareon mine is easily accessible. U. S. Highway No. 93 is followed for the first four miles south of Salmon. From there a road, much of it unimproved, leads to the mine. Because of the aridity of the region, the winter snow is light and offers no obstacle to travel either to the mine or to points outside the county.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his gratitude to Fred Brough and Challis Hall, who kindly furnished transportation to and from the mine during the course of the study and who also provided data on mining operations and assisted in obtaining information on past production. Mr. Brough accompanied the writer underground the first day, pointing out many features that did much to hasten the progress of the work. Recognition also is due Don Smith, then at the mine, who gave his time in assisting the writer in the underground examination.

POPE-SHERON MINE

HISTORICAL SKETCH

Although the presence of copper in parts of the district was known as long ago as the late fifties, little copper mining was attempted until after
1911. Claims were located at the Pope-Shanon in the early nineties, but the locations were for gold, not copper. The first copper locations were two years later.

Apparently little work was done for a decade or more, although smelter records show that some ore was shipped to Anaconda, Montana, by Langendorf and Company in October, 1908. Next, a shipment of hand-sorted ore was reported in 1917, ½ followed two years later by 360 tons of 12 per cent copper 2/. The destination of the 1917 and 1919 shipments was not given, and no record appears in the files of the Montana and Utah smelters.

By 1918 the development had gone far enough to show the presence of a body of copper ore, much of which was too thoroughly oxidized for gravity concentration. In 1919, a chloridizing plant was built at the mine and was in operation during 1920 and 1921. The ore mixed with sodium and calcium chlorides was fed to a revolving furnace and heated sufficiently to volatilize the copper as copper chloride which was caught in a Cottrell precipitator. Mixed with limestone and coke, and fed to an oil-heated reverberatory furnace, the copper chloride was reduced to metallic copper. Because of the high cost of extraction and operational difficulties, the work was abandoned.

On August 1, 1922, the property was leased to W. M. and G. A. Snow. The mill was changed over into a gravity concentrator equipped with jigs, tables, and a small flotation unit, and supplied with sulphide ore from a stope above the No. 5 level, then connected to the mill by tramway. Shipments of concentrates were then made to the International Smelting and Refining Company, beginning late in 1922 and continuing into early 1924. Late in 1925, operations were suspended and the mine was idle for several years thereafter.

In 1927 or 1928, the mine was reopened by the Hinder-Stillman Company and concentrates were shipped during 1928, 1929, and 1930. The mine closed in 1929 and later was lost in default. It was relocated by Fred Brough in 1937 as the Grandview mine and some shipments of hand-sorted ore were sent to the smelter in 1937 and 1938. The low price of copper then forced suspension of operations, but a further shipment credited to Joe Jones was made in April, 1939. In July 1941, the mine was leased to L. J. Bills, the mill re-equipped, and shipments of concentrates resumed. From August to December, 1941, the shipments were credited to Mr. Bills, but in February, March, and May, 1942, the shipments were by the Salmon Development Company. In July, 1942, the property reverted to its owners, Fred Brough and Challis Hall.

PRODUCTION

Data on production, as obtained from the records of the International Smelting and Refining Company, the Anaconda Copper Mining Company, and the American Smelting and Refining Company, show that 154,1 tons of crude ore and 2,074.4 tons of concentrates have been shipped from the Pope-Shanon

1/ Bell, R. N., Nineteenth Annual Report of the Mining Industry of Idaho for the year 1917, p. 72, 1918.
mine. Since the reported shipments of 1917 and 1919 could not be verified in smaller records, they are not included. The amount of copper produced by chloridizing and reduction at the mine in 1920 and 1921 was not learned. The total amount of copper produced exceeds 2,400,000 pounds.

Production by years is given in the table that follows.

### Ore Shipments from the Poe-Shenon Mine

<table>
<thead>
<tr>
<th>Date</th>
<th>Shipper</th>
<th>Material</th>
<th>Dry weight tons</th>
<th>Copper per cent</th>
<th>Silver oz./ ton</th>
<th>Gold oz./ ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 1908</td>
<td>Langsdorf &amp; Company</td>
<td>Crude</td>
<td>21.7</td>
<td>15.48</td>
<td>1.40</td>
<td>0.05</td>
</tr>
<tr>
<td>1922</td>
<td>Snow Bros. Conc.</td>
<td>&quot;</td>
<td>345.0</td>
<td>Average</td>
<td>25 per</td>
<td></td>
</tr>
<tr>
<td>1923</td>
<td>&quot;</td>
<td>&quot;</td>
<td>1,462.0</td>
<td>approx.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1924</td>
<td>&quot;</td>
<td>&quot;</td>
<td>781.0</td>
<td>imately</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1928</td>
<td>Winder-Stilman Co.</td>
<td>&quot;</td>
<td>666.0</td>
<td></td>
<td>64.4</td>
<td>0.05</td>
</tr>
<tr>
<td>1929</td>
<td>&quot;</td>
<td>&quot;</td>
<td>996.0</td>
<td></td>
<td>1.60</td>
<td>0.05</td>
</tr>
<tr>
<td>1930</td>
<td>&quot;</td>
<td>&quot;</td>
<td>412.0</td>
<td></td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>8-31-37</td>
<td>Fred Brough</td>
<td>Crude</td>
<td>21.5</td>
<td>15.17</td>
<td>0.90</td>
<td>0.01</td>
</tr>
<tr>
<td>9-20-37</td>
<td>&quot;</td>
<td>&quot;</td>
<td>19.2</td>
<td>11.65</td>
<td>0.60</td>
<td>0.015</td>
</tr>
<tr>
<td>10-11-37</td>
<td>&quot;</td>
<td>&quot;</td>
<td>22.5</td>
<td>14.42</td>
<td>1.00</td>
<td>0.015</td>
</tr>
<tr>
<td>11-20-37</td>
<td>&quot;</td>
<td>&quot;</td>
<td>27.1</td>
<td>9.99</td>
<td>0.60</td>
<td>0.015</td>
</tr>
<tr>
<td>1-20-38</td>
<td>&quot;</td>
<td>&quot;</td>
<td>55.8</td>
<td>10.10</td>
<td>0.60</td>
<td>0.015</td>
</tr>
<tr>
<td>Apr. 1939</td>
<td>Joe Jones</td>
<td>&quot;</td>
<td>6.3</td>
<td>6.44</td>
<td>0.81</td>
<td>0.05</td>
</tr>
<tr>
<td>2-14-41</td>
<td>Theron Kidd Conc.</td>
<td>&quot;</td>
<td>3.1</td>
<td>24.93</td>
<td>1.60</td>
<td>0.015</td>
</tr>
<tr>
<td>Aug. to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec. 1941</td>
<td>L. J. Bills</td>
<td>&quot;</td>
<td>45.5</td>
<td>27.56</td>
<td>1.62</td>
<td>0.051</td>
</tr>
<tr>
<td>10-6-41</td>
<td>L. J. Bills</td>
<td>&quot;</td>
<td>2.4</td>
<td>25.08</td>
<td>1.58</td>
<td>0.055</td>
</tr>
<tr>
<td>Feb, Mar,</td>
<td>Salmon Development Co.</td>
<td>&quot;</td>
<td>25.6</td>
<td>22.76</td>
<td>1.20</td>
<td>0.04</td>
</tr>
</tbody>
</table>

### DEVELOPMENT

The Poe-Shenon mine has been developed by a series of six tunnels, numbered consecutively, starting with the one highest on the mountainside. The workings are much the same as when Ross examined the property in 1923, except that the No. 6, then a tunnel 40 feet long in barren rock opening at the rear of the mill, has been extended to cut the lode and has since become the main working level. This level has about 1,755 feet of drifts and crosscuts, or almost as much as the rest of the mine, and is connected by raises with an intermediate level 70 feet above and with the No. 5 level 160 feet above. The Intermediate level has 400 feet of drifts. Altogether, there are more than 5,610 feet of drifts and cross cuts in the mine. There are also stopes between the No. 6 and Intermediate levels, between the Intermediate and the No. 5, and between the No. 5 and the No. 4. A winze has also been sunk on the No. 6 level to a depth of 40 feet. These workings are shown in plan and longitudinal sections in Figures 1 and 2.
Fig. 1. Plan of the workings of the Pope-Shenon mine
Fig. 3 Longitudinal section of the Pope-Shenon mine showing stopes
TOPOGRAPHY

The mine lies well up the west slope of the Lemhi Range just above the line where the smooth, sagebrush-covered, lower slopes meet the more rugged, timber-covered, intermediate slopes. At and above the mine, the slopes are steep, in places nearly precipitous, but, except for scattered cliffs and ledges of bedrock, the surface is covered with extensive masses of talus, which, with the bedrock, slope at an angle of about 35 degrees. At the portal of the No. 6 tunnel, the altitude is about 5,650 feet (aneroid) or about 850 feet less than the portal of the No. 1 tunnel. Above the mine the slopes rise to nearly 9,000 feet. Below, the slopes reach the floor of the Salmon River Valley at about 3,500 feet.

For a description of the regional topography, the reader is referred to the reports by Umpleby 1/ and Ross 2/.

GEOLOGY

Foreword

The broader features of the geology of Lemhi County have been presented by Umpleby 3/ and Ross 4/, and no attempt is made herein to supplement the descriptions already given.

The only rocks of pertinent interest are those that contain the ore, namely, a thick sequence of metamorphosed sedimentary strata, believed to belong to the Belt series (pro-Cambrian) and known to be the oldest rocks in the region. Volcanic and sedimentary strata ("lake beds") of Tertiary age underlie the sagebrush-covered slopes below the mine, but, since these are younger than the deposits and have had nothing to do with the mineralization, discussion of them is omitted.

The older metamorphosed strata have been bent into broad, gentle folds and sliced by a well-defined cleavage which, in general, is schistose. Local zones of shearing independent of the folds and cleavage have localized the ore deposits.

Stratigraphic Features

The country rock at the Pope-Shellon mine is a dark green, impure quartzite and quartzitic argillite, in places containing intercalated beds of lighter colored rock. Bedding, in general, is rather indistinct, but can be distinguished on close examination. The bedding planes commonly are closely spaced, in places several to an inch, but thicker beds up to a few inches do occur. Many of the beds are in part built up on interfingering lenses a


5
fraction of an inch thick and a few inches long. In general, the bedding has been obscured by a fairly pronounced schistosity, more prominent along the mineralized zones than elsewhere. The schistosity is far more conspicuous than the bedding, and from even a short distance may be easily mistaken for bedding. The strata also are cut by a set of closely spaced joints and these, too, from a distance give the impression of bedding structures. Much of the talus that skirts the outcrops and mantles the slopes are angular rock fragments bounded by these joint surfaces.

Individual minerals in the rock are difficult to recognize, except in thin section under the microscope. Ross 1/ points out that the rock has been completely recrystallized and that in addition to the recrystallized quartz, there are variable amounts of fine-grained sericite, muscovite, chlorite, and dark green biotite, none of which exceed one millimeter in longest dimension. Fine-grained magnetite is reported to be present in places, particularly in the proximity of mineralized areas. Epidote appears locally.

These strata are, in general, more highly metamorphosed than those in the northern part of the state, and direct correlation with any given member of the Belt series cannot be made. Although dynamic stresses may have had something to do with the degree of metamorphism, particularly along the general zones of shearing, materials supplied by escaping emanations from the Idaho batholith as it slowly cooled below probably have had a far greater influence in changing the rock strata to their present metamorphosed condition.

Structural Features

Folding.

Through much of the mine the beds appear to strike about N. 15° - 20° E. and dip about 35° E. Locally, the strike swings as much as 30° west of north and the dip flattens to about 10° E. A dip steeper than 35° was observed in but one place. There appears to be an absence of drag folding even along the local zones of shearing. The mine appears to be located on the west flank of a broad syncline whose axis lies just west of the roughly parallel to the crest of the Lemhi Range. Apparently, the thick series of strata is too strong to permit any except very broad, gentle folds. There appears to be no relation between the folding and the distribution of the ore deposits.

Cleavage.

The rock cleavage is fully as conspicuous underground as on the surface and largely controls the way the rock breaks when blasted. Consequently, the cleavage is the most noticeable structural feature along the drifts and crosscuts. The cleavage is independent of the attitude of the bedding. It strikes a few degrees east or west of north and dips 55° to 70° West, or practically at right angles to the dip of the bedding. However, there is some local variation in strike and dip, and at one place, probably near a fault, the strike is near N. 40° W.

The cleavage is due to an essentially parallel alignment of the platy minerals, and, therefore, is a schistose rather than the fracture variety. This schistose structure is characteristic of the entire rock sequence and is, consequently, regional rather than local. The structure, however, is better developed in some places than in others. It is not to be confused with a local schistosity found along and parallel to the zones of shearing where it is more or less closely associated with the shearing and the mineralization. The general cleavage apparently has been induced by regional stresses, probably by the same stresses responsible for the folding. The regional cleavage like the folds has had little or nothing to do with the localization of the ore deposits or the distribution of the ore within the deposits.

Shearing.

Since zones of shearing that cut the folds and cleavage of the metamorphosed strata are in control of the location and formation of the ore deposits, they are structural features of the first order of importance and need be discussed in considerable detail. These zones may occur singly, or, as at the Pope-Shenon mine, there may be several of them linked together and related as parts of a major system of shearing. Because of the ore association, it is important that the characteristics of the major shearing and its component parts be fully understood.

That there existed at the Pope-Shenon mine a broad and complicated zone of shearing made up of smaller, roughly parallel, overlapping and branching zones, was not evident until the work was carried along on the No. 6 level. Then two important zones of shearing linked together by a branching shear were uncovered and each followed by drifts, the more prominent one on the south being a downward extension of the single one exposed on the higher levels of the mine (Fig. 1). Together, these comprise a master shear zone more than 40 feet wide, the member zones measuring from a few feet to 20 feet wide. Because of inadequate exploration, the major zone of shearing may actually be very much wider. Its known length exceeds that of the drifts on the several levels, but again the full limits have not been determined. Because of the nature of the shearing, it may have an expected length of at least several thousand feet, although any component member of the zone may not be so persistent. The major zone of shearing has a general easterly trend and steep northerly dip. The minor zones that compose it also have easterly trends, but show some variation in strike and dip.

The more northerly of the two zones was the first to be intersected in the No. 6 crosscut, the second appearing about 30 feet beyond. Since the first appeared to be more prominent than the other, the drift was directed along it in an east-northeasterly direction for about 80 feet, the shearing dipping about 70° N. and occupying about the full width of the drift. At the 80-foot point, the shear zone branched, the more prominent part continuing on in directions ranging from N. 70° E. to N. 80° E., the other extending about S. 70° E. to its intersection or junction with the second zone of shearing that was uncovered in the crosscut. The main branch was then drifted on for about 260 feet where it was lost in the side of the drift. For the full distance, the shearing held its course to the northeast, its direction ranging between N. 65° E. and N. 60° E., its dip between 65° N. and 80° N. The zone appears to be 6 to 8 feet wide along the drift.
The branch that links the north shear zone with the one on the south has a length of about 40 feet. It appears to curve and become a part of the second shear zone just as it was a part of the first. The shearing, however, is neither so broad nor so prominent as in the two zones it joins together. It forms a zone about 2-1/2 feet wide.

The second or south shear zone is the most important so far uncovered and has been followed through on all levels of the mine. For some distance its trend is about N. 70° - 80° E., or closely parallel to that of the zone on the north, but farther in its course changes to due east and then east-southeast, causing it to swing away at ever increasing distances from its neighbor. The shearing along the zone is not altogether continuous. Just beyond the first raise to the No. 5 level, it passes into the wall of the drift and is lost, but another of greater prominence appears in the drift and crosscut 20 feet to the south. This one also appears to die away, but the drift shortly picks up a zone of shearing across a transverse fault of unknown but probably small magnitude and continues on it as far as the work has gone. A short distance beyond the fault the trend of the shearing changes from about N. 70° - 80° E. to directly east and then to S. 70° E., the south-east trend being interrupted locally not far from the face of the drift by a change back to the northeast, then again to the southeast. This change in the direction of the shearing is also well shown on the Intermediate level (Fig. 1) and begins to show on the No. 5 level not far from the face. In the west part of the mine where the strike is to the northeast the dip is about 70° N., but as the strike changes direction to east and southeast the dip tends to steepen and in the east part of the mine is 80° N. to nearly vertical. This increase in dip is shown on the map (Fig. 1) by the closer spacing of the levels in the eastern part of the mine.

The south zone of shearing seems to be broader than that on the north, and in part better defined. It has been exposed for a distance of 650 feet and is from about five to as much as 20 feet wide. The shearing may be even broader near the far end of the No. 5 level, but the increase in width may be the result of branching, the exposures being such as not to make the relations entirely clear.

One other zone of shearing of minor magnitude is exposed in the long crosscut driven south from the No. 6 level near the center of the mine. This shear zone lies oblique to the others and strikes about N. 35° W. and dips 70° to 80° S.W. It provides additional evidence of the complex relations of the major zone of shearing.

These individual zones of shearing may be distinguished from the un-sheared rock not alone because they have localized mineralization, but also because they are marked by a fairly well defined schistosity parallel to the shearing itself which in part has obliterated the regional schistosity. These shear zones also show more evidence of crushing and rock alteration than the surrounding rock.

Individually, the shear zones are structurally complex, made up for the most part of two sets of fractures, one parallel to the shearing or local schistosity and the other oblique thereto, each set marked by bands and stringers of ore as shown in Figure 3. Since the ore has been deposited largely by replacement of the rock bordering the fractures, the fractures
Fig. 3. Diagrammatic sketch of the ore (black) on the intermediate level showing relation to the fracture system.
themselves have been obliterated, though the record remains in the distribution of the ore itself. Fractures parallel to the zone of shearing strike about N. 70° E. or S. 70° E. (depending on the local trend of the zone), and dip 70° – 80° N.; whereas the oblique fractures strike about S. 70° E., where the main shearing is northeast and about S. 45° to 50° E., where the shearing is S. 70° E. In either case, the oblique fractures dip about 70° S.W. The fractures parallel to the shearing are the most prominent. There may be several of them along the shear zone, but those along the walls are generally most conspicuous. Where the prominent fractures are along both walls, they are commonly joined by diagonal fractures. If along one wall the diagonal fractures may extend out to one side or the other, or if the main fractures follow the center of the zone of shearing, the oblique fractures may extend out on both sides. Some of the fractures parallel to the shearing are not persistent, but die away and are replaced by others that overlap and carry on the shearing. Prominent fractures may appear on one wall and then within a short distance shift to the other. Generally, minor parallel slips appear at random throughout the shear zone.

The oblique or diagonal fractures commonly persist to the walls of the shear zone and then fade away. Most of them are breaks of minor magnitude, but some are strong enough to influence the direction of shearing and, as in the eastern part of the mine, may even in part control the direction of the shear zone itself. Those of minor magnitude may be a few inches to several feet long; those of greater magnitude may be as long as 20 feet and may have a marked influence on the shape and size of the ore body, in places producing marked bulges in the hanging wall. Most of the oblique fractures of minor magnitude join the fractures parallel to the shearing at a sharp angle, but some of the larger ones curve as they come in from the walls and join or become a part of the system of fractures parallel to the shearing.

There are also some cross fractures that trend about N. 25° E. and dip about 60° W. These cut the shear zones, contain a little gouge, but have produced no appreciable offsets. They contain no ore, but have served as channels for descending surface waters and are bordered by zones of surficial alteration.

The displacement along these zones of shearing apparently has been negligible, perhaps a few inches or at the most a few feet. Because of the lack of variation in the metamorphosed strata, offsets are not clearly distinguishable. Grooves and striations were not observed, but the relations of the oblique fractures suggest that the displacement has been essentially in an horizontal direction, the hanging wall having moved east with respect to the foot wall. Yet movement in such a direction does not seem to account for all the observed structural complexities and until more is known about the direction and amount of movement along the various zones of shearing, the direction of application of stresses must remain in doubt. Because of the developed schistosity, the stresses responsible must have been intense and deeply applied.

Character of the Deposit

All the ore at the Pope-Quinn mine lies along the complex zones of shearing and has been deposited for the most part by replacement of the altered
quartzitic rock and subordinately by filling of fractures. The deposits are in the form of steeply inclined tabular masses of sheared rock, the ore distributed along the schistosity and fractures parallel to the shearing and along the fractures oblique thereto. They form lodes rather than veins.

The zones of shearing are not uniformly mineralised, but the ore is contained in sheets that have rather definite limits along the strike. Where lightly mineralised, the lodes may appear to be merely zones of shearing in rock of similar appearance to the surrounding country rock, but close examination shows that much of the rock in the zones has been more highly altered or metamorphosed than the country rock at a distance, the increased alteration seemingly a consequence of the intense localized shearing and the altering action of the mineralising solutions.

Mineralogy

The Pope-Shannon has both primary and oxidised ore, but little attention has been given the oxidised ore since the early twenties. The minerals in the unoxidised parts of the lodes comprise chalcopyrite, pyrite, delafossite, sphalerite, magnetite, quartz, micas, and chlorite. The chalcopyrite is by far the most abundant mineral and with subordinate amounts of pyrite forms roughly tabular bands of variable size about parallel to the long direction of the lodes, also narrow stringers and seams that extend obliquely across the lodes. There are also disseminated grains in the country rock, in places concentrated into irregular bodies of nearly solid sulphides. Sphalerite was not observed but is inferred because of reports of traces of zinc in the ore shipments. The altered country rock containing micas and chlorite is the chief gangue. Small irregular masses and stringers of quartz appear here and there but are minor, and most of the sulphides mined are in the country rock.

Delafossite (Cu9O4FeP2O7) intimately associated with magnetite and mica, is an interesting mineral in the Pope-Shannon mine, being present in considerable abundance and mined as ore in parts of the stope. This black ore has a peculiar banded or layered structure and in part takes the form of irregular concentric ellipsoids and of slightly curved and subparallel bands. Considerable ore of this kind appears along the No. 5 level and some on the No. 6. Since the ore appears below as well as above the zone of oxidation, it is believed to be primary. Apparently it was produced by rhythmic deposition from a fluid that was diffused into the rock from openings produced by joints.

Barite has been found in a narrow vein that cuts diagonally across the main zone of shearing in the No. 3 level of the mine. This barite is younger than the main copper deposit and probably belongs to a later epoch of metallisation.

The oxidised parts of the ore contain much malachite and some azurite, cuprite, and in places a little native copper. These minerals were so abundant in the upper levels that the chlorination mill was erected to treat the oxidised ore. The west margins of the shoots contain these oxidised minerals, particularly malachite, even on the No. 6 and Intermediate levels, but primary sulphides also are present. Much of the sulphide ore, except on the lower levels shows incipient oxidation. Some of the ore mined above the No. 5 level contained small amounts of chalocite, recognizable mostly
Although much of the ore has been deposited by replacement of sheared and altered quartzite, the influence of the schistosity and of the fractures parallel and oblique to the shearing in controlling the distribution of the ore is generally very evident. A band of ore a few inches to several feet thick may lie along one of the walls of the shear zone and stringers of ore generally less than an inch thick may extend obliquely out toward the opposite wall, trending in an east-southwest direction and dipping steeply southwest. This relation shows to particular advantage in the roof of the Intermediate level just above the east raise and Figure 3 is a sketch of the exposure there revealed. The ore is close to the foot wall of the shear zone and comprises a band of massive sulphides about 8 to 10 inches wide parallel to the drift fringed by stringers on either side which extend out obliquely to the walls of the drift. The stringers are less than an inch thick but they comprise an essential part of the milling ore.

In many places high-grade seams joined together by diagonal stringers lie along both walls of the shear zone. These hanging and foot wall seams may be as much as 15 to 20 feet apart, but generally they are within 8 or 10 feet of each other and may close in to 4 or 5 feet. Generally as the distance between them decreases, the stringers between become more numerous and the ore body of higher grade. The ore also may follow one wall at a time and may change from one to the other as the guiding fractures on either wall strengthen or weaken.

Master diagonal fractures that enter the main zone of shearing and curve so as to lie parallel thereto also have had a marked influence in localizing ore. These fractures may extend into the walls for considerable distances but the ore is mostly localised in the band or along the oblique fracture just before it changes direction to conform with the shearing (Fig. 4). These fractures may enter from either the hanging or the foot wall. Since the fractures dip steeply southwest, the ore rises upward into the hanging wall, end followed upward, appear to reverse the direction of dip of the mineralized zone, though actually they produce large bulges in the hanging wall. Because of this relation, the last stopes on the No. 6 level is inclined to the south instead of to the north, and the stope at the east end of the Intermediate level stands nearly vertical, the hanging wall in places dipping steeply south though the foot wall itself still has a steep dip to the north. The junction of these southwesterly dipping lateral fractures with the main zone of shearing is reported to determine the position and pitch of some of the best ore bodies.

In places the diagonal as well as the seams parallel to the shearing abut against thin seams of gouge in cross slips. The ore seams do not appear to be offset and the cross seams contain no ore. However, here and there the ore is reported to be spread out alongside the cross seams and to make small bodies of high-grade.

The ore has been little disturbed by post-mineral faulting. In places a little gouge may appear along one of the walls but nowhere in conspicuous quantities. Because of the absence of appreciable post-mineral movement,
Fig. 4. Diagrammatic sketch showing the localization of ore along diagonal fractures.
the ore is firm and stopes remain open without being timbered.

**Ore Shoots**

The ore shoots are of moderate size. The main ore shoot (Fig. 2) has been stoped for about 180 feet on the No. 5 level, 170 feet on the Intermediate, and 280 feet on the No. 6 level. Its average width is just under 10 feet, but reaches a maximum of 20 feet. Ore has been stoped from the No. 6 to the No. 4 levels, a vertical distance of more than 400 feet, but since ore remains in the floor of the No. 6 level and in the bottom of a 40-foot winze sunk below the No. 6, the full limits of the shoot are unknown.

The shape of the ore shoot is uncertain. The stopes lengths on the different levels probably have resulted from variations in mining methods and in the grade of the ore mined under different managements than from any such variations in the actual distribution of the ore itself. The greater stoping length along the No. 6 level may mean that marginal ore also was stoped but left unmined in the levels above or that much ore remains unmined above the Intermediate level. As confirmation of the second view is the fact that ore lies in the roof of the eastern half of the Intermediate level and has been followed upward from the east end of the Intermediate to a point about 65 feet above the level; the top of the stope showing 3 to 4 feet of massive sulphides which with fringing stringers make an ore body 5 to 6 feet wide with possibly several feet of milling ore still concealed in the walls. Were the stope continued upward at the present angle, it would pass about 60 feet ahead of the face on the No. 5 level. This stope appears to have been driven upward on the pitch of the ore body at an angle of about 70 degrees. The absence of ore in the face of the drift on the No. 5 level may mean that the No. 5 drift merely entered a barren zone in the ore shoot. Although on the upper levels the pitch of the main ore shoot appears to be steeply west, the offsets in the stopes below confuse the relations and the pitch may actually be different from that believed to exist.

A small stope 80 feet long and 20 feet high to the east of the main stope on the No. 6 level affords proof that other ore shoots exist along the zone of shearing, though perhaps not equal in size to the one just described.

Smaller ore shoots also appear along the zone of shearing in the north drift on the No. 6 level but have not been fully explored. A stope about 30 feet long, 25 feet high, and 4 feet wide has been made on the shoot near the front part of the drift. Just beyond is another stopa about 80 feet long and 10 to 15 feet high, and than a third about 35 feet long and 30 to 40 feet high. Since there are no exploratory cross cuts on the higher levels, the upward continuation of these shoots has neither been demonstrated nor disproven.

The factors in control of the localization of the ore shoots are not fully understood. The distribution of the workable bodies of ore apparently conforms with the distribution and spacing of the fractures that have been favorable to the movement of the mineralizing solutions. These favorable zones appear to be where the shearing has been most intense, particularly where it has produced a marked schistosity.
Mention has already been made of the manner in which the ore lies along the schistosity and the fractures parallel to the schistosity or shearing, as well as in the fractures oblique thereto. The spacing of these fractures has much to do with regulating the amount of ore as well as the dimensions of the ore body. Mention also has been made of the localization of ore along the more prominent lateral fractures where they bend into the main zone of shearing and the influence these have had in controlling the position and pitch of some of the best ore.

However, the factors that control the location of these structurally favorable areas remain obscure, though horizontal shearing stresses can account for the shear and oblique fracture system. The variation in the angle dip of the individual shear zone may have some bearing on the localization of the ore shoots, but the present development has not revealed what this relation might be. The same may be said of the variation in strike. In the upper levels the exposed ore shoot follows the shearing of east-northeast trend, but on the No. 6 and Intermediate levels the ore also follows the east-south-east shearing. Whether the change in direction has been accompanied by any material change in the quantity and grade of ore was not learned. The smaller shoots appear to favor the shearing of east-northeasterly trend, changes to the southeast being marked by barren zones. Undoubtedly, the movement along these curved zones of shearing has provided the necessary openings for the circulation of the mineralizing solutions, but until more is known of the characteristics of the major shearing, the problem of ore shoot control must be left largely unsolved.

Tenor of the Ore

Most of the ore mined has carried from 2-1/2 to 6 per cent copper, but there have been small bodies containing 10 to 20 per cent copper, few of which were large enough, however, to be mined separately. By careful hand sorting, crude ore carrying 10 to 15 per cent copper has been shipped to smelters. Concentrates have carried about 25 per cent copper. In either crude ore or concentrates, the precious metal content has been negligible. The crude ore shipped has contained less than an ounce of silver and generally less than 0.01 ounce of gold per ton; the concentrates, less than 1.6 ounces of silver and 0.1 ounce of gold per ton.

No sampling of the ore bodies was attempted, but access was had to some of the old sampling records of the American Smelting and Refining Company and the International Smelting and Refining Company. These show that the stopes above the No. 4 level carried 3.13 per cent copper and 1.0 ounce of silver and 0.08 ounce of gold per ton over a 4-1/2 foot width of the lode (Fig. 2).

Six samples from the stope between the Intermediate and No. 5 levels (Fig. 2) gave results as follows: (1) width of 2-1/2 feet, 16.4 per cent copper; (2) width of 2-1/2 feet, 20.5 per cent copper; (3) width of 4 feet, 4 per cent copper; (4) width of 5 feet, 5.5 per cent copper; (5) width of 5 feet, 4.5 per cent copper; and (6) width of 5 feet, 6.0 per cent copper. A sample from the west edge of the same stope had 4.36 per cent copper and 0.3 ounce of silver per ton along a strip 4-1/2 feet wide.

One sample of the ore at the far east end of the Intermediate level
(Fig. 2) showed 15.06 per cent copper and 1.2 ounce of silver and 0.01 ounce of gold per ton across 5-1/2 feet. In a small stope just above, 4 feet of ore carried 2.15 per cent copper and 0.5 ounce of silver and 0.015 ounce of gold per ton.

One 5-foot sample at the bottom of the 40-foot winze below the No. 6 level (Fig. 2) had 1.67 per cent copper; another of the same width showed 2.04 per cent of copper. Both had but a trace of gold and each 0.4 ounce of silver per ton.

Six samples along the north zone of shearing on the No. 6 level, all but one in the first stope, showed results as follows: (1) 2 feet of ore in drift 50 feet west of stope, 8.24 per cent copper; (2) 2.7 feet at west edge of stope, 15.55 per cent copper; (3) 2-1/2 feet, 11.30 per cent copper; (4) 2-1/2 feet, 9.17 per cent copper; (5) 2 feet, 12.37 per cent copper; and (6) 3 feet, at the east edge of stope, 5.76 per cent copper. Except for one sample the silver averaged less than 0.2 ounce per ton and the gold less than 0.01 ounce.

Wall-rock Alteration

The mineralizing solutions have induced some changes in the country rock in and along the lodes, but the changes are not marked and the altered rock still has much the same appearance as the surrounding rock, though metamorphosed to a somewhat greater degree than that at a distance. The rock in and along the lodes shows the results of greater pressure, is more crushed, and is in part converted into schist. The grains of chlorite and mica tend to be larger than those in the country rock and show a more conspicuous orientation. In places, quartz has been added. Some of the rock also is bleached and softened and in part changed to sericite, apparently by alteration of the biotite and chlorite of the original rock.

Age and Genesis

The mineral associations in the altered wall rock are those generally recognized as characteristic of formation at moderately high temperature and pressure. The alteration of the rock in and near the zones of shearing appears to represent the first stage of the mineralizing process and differs from the regional metamorphism only in its greater intensity. Metalliferous minerals were introduced along the more intensely altered zones later, perhaps when temperatures were somewhat lower.

The deposits show none of the characteristics of the ore deposits genetically related to Tertiary intrusive rocks. On the contrary, the little difference between the wall-rock alteration and the regional metamorphism of the quartzitic rock, except in degree of intensity, suggests a close relation between them and, therefore, with the Idaho batholith. Emanations given off by this cooling granitic mass is believed to have been responsible for transforming the sedimentary strata that it invaded into metamorphic rock by supplying the materials and heat necessary to form the minerals the rock now contains. Later, fluids from a deeper source within the congealing batholith apparently were directed along channels opened by deep-seated shearing. The rock along these channelways was then rather intensely altered, appreciably more so than the surrounding rock, and the ore was deposited shortly.
after. Since it is now generally believed that the batholith was emplaced and consolidated during Cretaceous time, the ore deposits, a late phase of the magmatic activity, are probably late Cretaceous.

CONCLUSIONS

Since the copper deposits show no evidence of a shallow-seated origin but are localized along deeply seated zones of shearing and possess the characteristics of deposits formed at depth, they may be expected to show a considerable vertical range and, therefore, to persist below any level yet reached in mining. Consequently, the ore at the Pope-Shenom mine should continue below the No. 6 level with little change, probably to such depth as increasing mining costs would make deeper work unprofitable.

Much ore, however, may yet remain above the No. 6 level, particularly between the Intermediate and the No. 5 in the eastern part of the mine and possibly between the No. 5 and No. 4 in the ground not yet reached by drifts. Additional ore may also be present along the zone of shearing in the north part of the mine and should be sought in cross cuts and drifts from the Intermediate, No. 5, and perhaps the No. 4 levels. The major zone of shearing as a whole has not been adequately explored and the possibility of uncovering additional lodes on systematic development should be considered. Several hundred feet of additional depth may be gained by adit-levels driven lower on the slope, preferably along the main zone of shearing. Still greater depth can be had by shaft or winze from the lowest adit that can be driven. Sufficient ore to continue mining on a moderate scale for a considerable number of years seems probable.

In searching for ore, attention should be given any evidence of shearing, particularly such shearing as has been accompanied by comparatively intense alteration. It is possible that a shear zone barren where first uncovered may have ore in other parts either on the strike or at depth. Shear zones, therefore, should be explored along the strike on each of the levels.

Although considerable of the ore carries 6 or more per cent copper, successful mining can be carried on only under the most careful and efficient management and with suitable mine and mill equipment, and then, probably only when the price of copper is above normal levels.