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Mineralogy and structure of the Stibnite Hill Mine Thompson Falls Montana

Pedro A. Marin Rivera

The University of Montana

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MINERALOGY AND STRUCTURE OF THE STIBNITE HILL MINE
THOMPSON FALLS, MONTANA

by

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B.A., Universidad Nacional, Bogota, Colombia, 1965

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The purpose of this investigation was to understand the type of mineralization, structure, mineralization-host rock relationship and the possible paragenesis of the vein which should prove valuable in my search for ore deposits in Colombia, South America. Most of our deposits are epithermal or mesothermal lode deposits and consequently similar to the type of deposit at Stibnite Hill. The localization of this mineralization is structurally controlled and is apparently related to the Thompson Pass fault or one of its satellite faults. The host rock is the Prichard Formation. The deposit is located in the West limb of an anticline which trends N 5-60°E. The textures, structures and primary mineral assemblage are characteristic of typical fissure cavity (open space) filling veins. Minor replacement of the wall rock and exsolution processes also exist. The mineralization is generally concordant with stratification. The normal faults in the mine are steep and have small vertical displacements no greater than 9 meters. The folds are characterized by either slight changes in attitude or are well contorted zones.

The paragenetic sequence is from oldest to youngest quartz, stibnite, pyrite, arsenopyrite, sphalerite and finally chalcopyrite. Quartz and stibnite formed intermittently throughout the entire mineralization period. This primary mineralization sequence can be considered practically constant both in vertical and horizontal dimensions.

Stibnite and arsenopyrite show deformation in several places along the vein system. The deformation was stress activated yielding athermal deformation. The types of deformation observed in the vein include deformation bands, curved bands, undulose extinction, kink bands, twinning and polygonization.
ACKNOWLEDGMENTS

I want to thank the Colombian Government in behalf of "INGEOMINAS" and especially to Dr. Jairo Vesga Ordoñez, for the opportunity they made possible for me to study and improve my knowledge in geology.

My deepest gratitude to Dr. James Talbot and all the professors who assisted me in acquiring my educational goals at the University of Montana. My special recognition to Dr. Ian Lange for suggesting the initial project, for patient advice in mapping, sample studies, and who read and corrected the manuscript.

I would like to thank Mr. John C. Lawrence and staff of the Stibnite Hill Mine, U.S. Antimony Corporation for the opportunity to work in the mine. Mrs. Shirley Pettersen was very helpful in typing the manuscript.

Also my sincere appreciation to my wife Martha Lucia and my daughter Luisa Fernanda, who gave me constant encouragement and companionship the entire two years we spent in the United States taking advantage of this opportunity.
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CHAPTER I
INTRODUCTION

The Stibnite Hill Mine is located 30.5 kilometers west of Thompson Falls, Sanders County, Montana, (Figure 1) just north of Prospect Creek between Antimony Creek and Cox Gulch. The study of this mine was undertaken because in Colombia, South America, most of our deposits are either epithermal or mesothermal lode deposits and consequently similar in many respects to this type of deposit at Stibnite Hill. The mineral assemblage and the different textures found at Stibnite Hill represent features of a typical fissure filling type vein. Antimony is the only element recovered and the vein gangue mineral is quartz at the Stibnite Hill Mine.

Antimony was identified in compounds by the ancients and it was known as a metal by the beginning of the seventeenth century and possibly much earlier. Antimony is not very abundant in the earth's crust, but is found in more than 100 minerals. It occurs in the native state, but much more frequently as the sulfide stibnite \( \text{Sb}_2\text{S}_3 \). It is also found as antimonides of the heavy metals and as oxides. Antimony is extracted from the sulfides by roasting to antimony oxide. The antimony is then reduced by salt and scrap iron. From oxides, antimony is also extracted by reduction with carbon. Antimony is a poor conductor of heat and electricity and has a hardness of between 3 and 3.5. The melting point of antimony
is 630.74°C, the boiling point is 1,740°C and the specific gravity of antimony is 6.6 (West, 1973).

When antimony is mixed with other metals it imparts strength, hardness and corrosive resistance to the alloys. It is marketed as the metal, oxide, antimonial lead and as the sulfide. Metallic antimony is sold under brand names. Each brand name represents metal with a guaranteed antimony content and an allowable maximum content of arsenic and other minor impurities which limit the uses of this element.

Antimony is used in the manufacture of storage batteries. Very high purity antimony metal (99.999 percent) is used in intermetallic compounds for semiconductors and other chemical applications. Antimony is used as a hardening agent in metals used in chemical pumps and tank linings. Antimony oxides are used in paints, plastics, and in white ceramics. Antimony sulfides are used in the manufacture of ammunition primers and bullets. For these reasons antimony is considered a strategic material. Antimony and many of its compounds are toxic. The maximum concentration of antimony dust in the air tolerated by human beings is 0.5 mg/cubic meter. Atmospheric concentrations of stibine should be less than 0.1 ppm (West, 1973).

The abundance of antimony in the earth's crust ranges from 0.2 to 0.5 ppm. In igneous rocks the abundance is 0.1 to 1 ppm. Deep-sea clays contain 1 ppm. Antimony is chalcophile in distribution and combines easily with sulfur and the heavy metals lead, copper, and silver.
More than 80 percent of the U.S. Smelter output of primary antimony is derived from imported antimony ores and lead ores. Domestic antimony ores account for 7 percent and by product antimony from lead-zinc ores accounts for 9 percent of the antimony produced. The U.S.A. imports about 50 percent of its antimony ores from the Republic of South Africa, Mexico and Bolivia (Brobst and Pratt, 1973).

Purpose and Scope

The study of the mineralogy and structures of the Stibnite Hill Mine was undertaken for the following reasons:

a. Most of our deposits in Colombia, South America, are either epithermal or mesothermal lode deposits and therefore similar to the type of deposit at Stibnite Hill.

b. Investigation of Colombian deposits is done by the direct observation of the geologist, generally without the aid of geophysical or drill hole data.

Therefore an understanding of the type of mineralization, structure, mineralization-host rock relationship and the possible paragenesis of the ores should prove valuable in my search for ore deposits in Colombia, South America.

Location

The Stibnite Hill Mine is located just north of Prospect Creek between Antimony Creek and Cox Gulch at an elevation of between 1,422 meters and 1,463 meters (Figure 1). The mine is 30.5 kilo-
EXPLANATION

Qg—Glacial & glaciofluvial deposits
Ys—Spokane Formation
Yr—Revet Formation
Yb—Burke Formation
Yp—Prichard Formation

8 kilometers

Fault, showing dip
Dashed where approximately located, queried where location uncertain. U, upthrown side; D, downthrown side. Arrows show relative horizontal movement

Vertical fault

Anticline
Showing direction of plunge
Syncline

Overturned anticline
Overturned syncline

FIGURE 1
meters west of Thompson Falls and it is marked on the Copper Gulch 15° quadrangle topographic map.

The accessibility to the mine from highway #10 is quite good. The first 16 kilometers of the access road are paved and the remaining 14.4 kilometers are dirt. This road is open all year in spite of season changes which include the severe winters which are common to the region.

Topography and Drainage

Thompson Falls, a small community in north-west Montana, is the county seat for Sanders County. It is located in an area where the terrain is steep, rugged and heavily forested. The present topography is a result of stream erosion and localized valley glaciation.

Clear Peak is the highest point in the area reaching 2,030 meters above sea level. The lowest area is the valley of the Clark Fork River which is at about 730 meters above sea level.

Residual soils and landslide materials cover the slopes of the mountains and it is common to find glaciofluvial deposits and recent alluvium in the lower parts of the valley. The main river, the Clark Fork River, flows northward. The Stibnite Hill Mine is located next to Antimony Creek which is a tributary of Prospect Creek which in turn flows into the Clark Fork River.

Development

The Stibnite Hill Mine was discovered in 1884, probably as a consequence of the obligated pass of the miners through Prospect
Creek to the Coeur d'Alene district and other districts in Idaho. The mine was not too prosperous in the beginning. However, because antimony is a strategic material, the mine was reopened during the Second World War. One hundred and thirty seven tons of antimony ore were shipped between 1940 and 1953. In the late 1960's the property was bought and mining was begun by the U.S. Antimony Corporation. The ore is processed by a heavy media separator. The corporation established a flotation plant in 1972. It has been enlarged in conjunction with the refinery to a present total production of 150 tons per day.

Previous Studies

Previous work in the Prospect Creek area includes a regional study of the different veins and ore manifestations in Burns Mining District by Clendenin in 1973. This thesis describes the surface vein exposures, vein mineralogy and macrostructures. However, the thesis does not include a detailed description of the relationships between the host rock and the mineralization or a detailed interpretation of the paragenesis of the ores.

The U.S. Antimony Corporation has subsequently had a detailed report of several drill holes at the Stibnite Hill Mine and several metallurgical reports done by various consultants.

Method of Study

In the Stibnite Hill Mine there are four tunnels or drifts all trending North $15^\circ$ to $25^\circ$ east. Many stopes are distributed along the main drifts (see Figure 2).
FIGURE 2

0  30.48 meters

20° Strike and dip of beds
20° Strike and dip of the veins
20° Strike and dip, when vein and beds are concordant
Vein projected to 1.10 meters above level
Vein barren of sulfides
Faults, dotted when inferred
Cross section
For safety reasons it was possible to work only in the drifts. The structural geology and the cartography of the veins in these drifts were done in accordance with McKinstry (1948) using a base map with a scale of 1"-20'. The left sidewall was always mapped. In doing this it is necessary to project all geological features to a uniform horizontal plane. This plane was 1.10 meters above the floor of the workings.

The left sidewalls were regularly sampled at 4.5 meters intervals unless structural and/or mineralogical conditions warranted closer sampling. All samples collected were oriented for future laboratory study of the host rock, structure and the mineralization relationships.

In the laboratory 16 thin sections of the different lithologies and 35 polished sections of the mineralization itself were prepared. Besides the polished sections, 75 samples were studied under the binocular microscope. Sketches of each sample and interpretations of all the textures and structures of each sample were accomplished.
Slightly metamorphosed rocks of the Prichard Formation of the lower Belt Supergroup (Figure 3), outcrop in the Stibnite Hill Mine area.

The various lithologies of this formation are very consistent in character throughout the area. Lithologies represented are:

a. medium-dark grey to medium grey and medium light-grey argillites

b. greyish blue biotite bearing argillites

In some areas quartzites of light grey color and very fine grain are characteristic. In general the interbedded units are composed of beds of usually one millimeter to several centimeters thick. A few beds especially the quartzites exceed several meters in thickness. These interbedded units constitute a distinctive banding which is not shown by any other formation in the area.

The Prichard Formation has been divided in two sub-groups (Hosterman, 1956). This subdivision was done because of very slight lithological differences. For example the Lower Prichard has the same lithology as the Upper Prichard, but contains less argillitic laminae (Norwick, 1972). This formation has a thickness of at least 5,490 to 5,970 meters (Harrison and Jovin, 1963). (The lower contact has never been found.) The Prichard Formation has been dated in different localities and gives ages which vary from
Figure 3
Standard Stratigraphic Column of the Belt Supergroup.
After Harrison, 1972. This Stratigraphic Column represents the rock units which outcrop in Washington, Idaho, and the adjacent areas of Montana.
1,100 m.y. to 1,500 m.y. (Reid and others, 1970). The most reliable age of this formation is 1,100 m.y. (Long and others, 1960).

The regional metamorphic grade of these rocks is quite low and varies from place to place. Toward the south near the Idaho batholith and to the west near the Kaniksu batholith, are rocks of high-grade metamorphism (upper amphibolite facies).

The igneous activity is expressed by batholiths, stocks, dikes and sills of different compositions, which intrude the Belt series of rocks. These igneous rocks are related to periods of igneous activity from the Precambrian to Mesozoic-Cenozoic time (Harrison, 1972). Precambrian sills of diabase to dioritic composition are common. Three batholiths, the Idaho in Central Idaho, the Kaniksu in northeastern Washington and the Nelson in British Columbia (Canada) and a series of stocks such as the Herrick near the St. Joe River and the Gem stocks in the Coeur d'Alene district intrude the Belt series and younger rocks. Because of their similarities in age composition (quartz monzonite to diorite) many researchers have suggested that all these bodies are the exposed parts of one great igneous mass (Park and Cannon, 1943).

The structural history of the region is characterized by two important features:

a. gentle folding of the rocks over extensive areas, with intense folding locally.

b. a series of north-west trending major faults of large lateral displacement (Figure 1).
These structural features reflect Cretaceous-Tertiary events, but some of them are clearly remnants of Precambrian events.

The structure in the area is not very complicated. However, numerous local steep and even overturned folds, no longer than 5 kilometers, are common. Also the rocks occur in great open folds in which the dips are usually less than $45^\circ$ and in extensive areas where the rocks are essentially flat.

Faulting in the region is more complicated. Precambrian movement along the Osburn strike-slip fault was described by Hobbs and others (1965). This is the most extensive fault and makes the pronounced linear feature called the Lewis and Clark line (Billingsley and Locke, 1939). Precambrian movement occurred along the Hope strike-slip fault (Harrison, 1972), which runs parallel with Clark Fork River approximately 17.8 kilometers east of the Stibnite Hill Mine. The Thompson Pass fault (Ransome and Calkins, 1908), which runs parallel to and about 11.2 kilometers north of Osburn fault, has a right lateral displacement of 3.2 kilometers and a vertical displacement of almost 1.6 kilometers (Hobbs and others, 1965). The south block was raised. This fault parallels Prospect Creek and is the nearest major fault to the Stibnite Hill Mine. The age and duration of movement on this fault is not well known but it may be as old as the Osburn fault.

The Cretaceous-Tertiary structural features were superimposed on the Precambrian features and apparently rejuvenated them in some places (Harrison, 1972). As a consequence of this dynamic period,
normal faults of relatively small displacement developed. These faults controlled the mineralization not only in the Stibnite Hill Mine but also apparently in the Coeur d'Alene district.

Host Rock

The host rock at the Stibnite Hill Mine is the Prichard Formation. The vein mineralization in the mine is related to two rock types which were classified in the field as phyllite and quartzite. These two units form an alternating sequence. It was possible to determine top and bottom relations of the units by graded bedding. These two lithologies can be easily recognized in the field because of their physical differences. One lithology is dark grey in color with very fine laminations, in some instances less than 2 millimeters thick. This rock was classified as a phyllite. The other rock or quartzite is light grey to white in color, massive in appearance and has beds which vary in thickness from a few centimeters to 2 meters (Figures 4, 5, 6).

Sixteen thin sections from the footwall and hangingwall units yielded the average composition depicted in Table 1.

The relationship of these minerals is summarized below:

a. The most important distinguishing textural feature is the size of the mineral grains. The size of the grains in the quartzite are 5 to 10 times larger than in the phyllite.

b. Detrial quartz grains from the quartzite and phyllite shows undulose extinction. Most
FIGURE 4.

Cross Section AA'

0 46 meters

--- vein, dotted when inferred

1  tunnel

Phyllite

Quartzite
FIGURE 5

Cross Section BB'

0 — 46 meters

--- --- --- --- --- vein, dotted when inferred

1. tunnel

Phyllite

Quartzite
Stibnite Hill Mine

FIGURE 6

0 30.48 meters

Vein projected to 1.10 meters above level

Vein barren of sulfides

Phyllite

Quartzite
Table 1. Average Composition of the Host Rocks

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<thead>
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<th>Mineral</th>
<th>Phyllite</th>
<th>Quartzite</th>
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<tbody>
<tr>
<td>Quartz</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>Potassic Feldspar</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>7%</td>
<td>15%</td>
</tr>
<tr>
<td>Sericite</td>
<td>50%</td>
<td>20%</td>
</tr>
<tr>
<td>Biotite</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Chlorite</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Opaque Minerals</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Zircon</td>
<td>(trace)</td>
<td>(trace)</td>
</tr>
</tbody>
</table>
grains are round or sub-angular in shape. In general, the quartz grain shows little dust or cloudiness. The quartz grain size varies between 0.2 and 0.35 mm in diameter (0.02 to 0.15 mm in the phyllite).

Quartz is also present in veinlets no wider than 1 mm thick in the quartzite. These veinlets probably formed during mineralization. In one thin section at least two different age cross-cutting veinlets were observed.

c. Sericite, much more abundant in the phyllite, is present either as minute crystals or as elongated crystals. The crystals tend to be located in planes and form incipient foliation. In the quartzite the sericite fills the interstices between the other minerals, especially between quartz and feldspar.

The sericite in these rocks formed as a result of low grade metamorphism and formed from clays and at the expense of feldspars.

d. The feldspars include both plagioclases and potassium feldspars. In many cases it was almost impossible to make a distinction between them due to their fine crystal size. Some crystals show albite twinning and because their relief is slightly higher than quartz they are believed to be close to albite
in composition. In general the feldspar grains show higher concentrations of dust or cloudiness than quartz. This was used also in their identification. These crystals appear to be detrital in origin.

e. Biotite, although not common is more abundant in the phyllite as minute crystals. It was possible to observe that this mineral grew at expenses of the feldspars, apparently as a product of regional metamorphism.

f. Chlorite is present in either tiny crystals or in elongated crystals. Some of the elongated crystals have anomalous blue interference colors. Therefore, they are thought to be characteristic of the pennine variety. The smaller crystals are always associated with biotite suggesting a possible chloritization of these crystals as consequence of a low grade retrogressive metamorphism.

g. An accessory mineral, which is slightly more abundant in the quartzite is zircon.

h. The opaque minerals are more abundant in the phyllites. They are either in aggregates or in single well developed euhedral crystals. The well crystallized forms are arsenopyrite and some of them (Plate #1) show some replacement by quartz.
Generally quartz does not replace sulfides. Arsenopyrite generally forms euhedral crystals. It apparently formed in the wall rock during the period of mineralization by replacing or using some of the wall rock material such as iron. It was subsequently partially replaced by younger quartz. It is generally found near the stibnite mineralization. Some pyrite usually accompanies the arsenopyrite when the arsenopyrite is found in aggregates. The origin of these aggregates is not known. Some of them have a helicitic texture or nonopaque minerals (relicts) and are totally surrounded by opaque minerals. This suggests that they crystallized at a different time and these aggregates are of a replacement origin too.

In one hand sample of quartzite (Figure 13, #31), the opaque mineral magnetite occurs along the stratification in zones no wider than 1 mm thick. This mineral is associated with zircon and both are probably detrital in origin.

1. The minerals present, which include chlorite, sericite, biotite and the incipient foliation of these rocks which is parallel to stratification, indicate the grade of metamorphism of the host rock is in the biotite zone of the greenschist facies.
The hydrothermal mineralization in the vein apparently did not affect the wall rocks since the textures and composition of the wall rocks do not change away from the vein. However, quartz veinlets found in the wall rocks adjacent to the veins probably formed during the mineralization epoch.

Structural Features of the Mine and Ore Controls

The Stibnite Hill Mine is located on the west limb of an anticline (Clendenin, 1973) in which the beds have a regional strike of N 5° to 60°E and dip West at 5° to 30°: The limb of this anticline was refolded yielding small superimposed structures (Figures 7, 8). They can be divided into pre- and post-mineralization folds. However, the time of formation of these folds is unknown.

In general the pre-mineralization folds are small closed folds and appear to be penecontemporaneous with the sedimentation. They contrast sharply with the attitude of the beds in the limb of the anticline. The zones showing this type of folding are not common. It was observed, for example, in location 106, Fig. 13, in tunnel #1 (Figure 7-A) that the mineralization broke into these closed folds. Therefore, these closed folds are apparently older than mineralization.

The post-mineralization folds which affected the vein are characterized by either slight changes in the attitude of the beds
FIGURE 7

0 2 meters

Quartzite —— Phyllite —— Mineralization

A Vein follows bedding plane but apparently follows fracture developed in fold axis.

B Vein forming monocline. Vein may be pre-folding in age because deformation in Stibnite is greatest in the flexure zone.
Schematic figures showing the different kinds of folds found at Stibnite Hill Mine. The first two figures represent part of the contorted zones near the end of tunnel #1 (Fig. 13). The last figure corresponds to a folded area in the survey station #21, tunnel #2.
or by well contorted layers. When the beds show slight changes in attitude they form monoclinal folds (Figure 7-B). These structures do not persist for more than 6 to 2 meters. The youngest folds are always associated with the major faults of the mine at the end of tunnel #1 and in survey station #2 in tunnel #2 (Figure 8-C). The folds are in the less competent rocks (phyllites) and are enclosed in the more competent and unfolded rocks (quartzites) (Figures 8-A, B,C). The origin of these youngest folds is unknown but they may have been produced as consequence of movement along the competent beds. Drag folds then formed in the less competent phyllite.

The possibility exists that some of these youngest folds are associated with minor faults, although it was impossible to prove. The stibnite observed in polished sections associated with the post-mineralization folds showed the greatest deformation in the entire mine (Figure 13).

The faults observed at the Stibnite Hill Mine are normal. Most of these faults tend to have a north-south strike and dip westward between 65° and 85°. Some faults strike north-west and dip west. The vertical displacement measured on these faults by the author varies from a few centimeters to 1.6 meters. The largest displacement on a fault measured by a staff geologist of the mine is 9 meters. However, the most common displacement is between 10 and 60 centimeters. However, in several faults it was impossible to determine the amount of displacement because of the lack of diagnostic offset structural or sedimentary features. In general, the gouge
displayed in these faults is not conspicuous; some of them have a thin gouge no wider than a few centimeters and others do not show any gouge at all. However, in tunnel #1, location 21, Figure 13, there is a series of parallel faults constituting a distributive faulting (Billings, 1942). The fault, with the greatest displacement seen in the mine by the author (1.60 meters), has a gouge zone 60 centimeters wide. Because of this fault gouge zone is located very near to the surface, some of the gouge may be supergene in origin. Another possibility although less plausible, is that this fault could have been reactivated several times and given rise to a wide gouge zone. The time of formation of these faults is unknown but almost all of them are post-mineralization in age because they offset the vein. The origin of these faults may be associated with either the east-west forces associated with the Montana Lineament located 16 kilometers to the south, or to the adjustment along beds caused by the refolding of the homocline (Crowley, 1963).

The strike length of fissure vein deposits is characteristically greater than the dip length (Bateman, 1942). The reverse situation is generally true for the mines located in the area between St. Regis in Mineral County, Montana and the Coeur d'Alene district in Idaho. Most of them are not more than a few tenths of meters long and several hundred meters deep. The attitudes of the veins vary but most trend west or north and dip 45° or more southward. Consequently, it is expected that this mine will have a longer dip length than strike length.
The mineralization at the Stibnite Hill Mine is structurally and mineralogically a "simple" type of deposit (White, 1951, 1962). The antimony deposits of the "simple" type are characterized by stibnite in a siliceous gangue. Rarely native antimony may be present. In general the associated minerals may include: pyrite, arsenopyrite, and sphalerite. In some mines a little gold and small amounts of other metals such as mercury and silver may accompany the stibnite.

The mineralization occurs in a vein of variable thickness (Figure 2). The vein varies in width from 5 centimeters to 96 centimeters. It is essentially a fissure filling accompanied by minor replacement and later exsolution processes. The vein, over most of its extent is conformable with the bedding (Figures 2, 4, 5). In many cases the vein occurs between two types of rocks, quartzite and phyllite. The location of the fissure and the subsequent mineralization appears to have been controlled by the contrasting rock competence. When the foot wall is formed by the more brittle rock (quartzite) the vein tends to be wider and richer in stibnite, and laterally and possibly vertically more persistent. However, this relationship does not always hold. In several places quartzite has the reverse position and in other places the vein is totally enclosed within the phyllite (see Figure 6). Moreover, in some places, the vein narrows, swells and disappears, but always, when the vein appears it is conformable with the bedding. In some areas, especially when the host rock is the phyllite, the mineralization splits into stringers, each one no wider than 5 centimeters thick,
in a zone of about 80 centimeters wide. This configuration forms a "linked" vein (individual veins are linked by cross veinlets, Bateman, 1942). In these areas, the stringers and the barren rock are mined as a single lode.

The vein often shows crustification banding which is more conspicuous toward the bottom of the mineralization. This crustification banding consists of a sequence of quartz layers alternating with stibnite bands plus or minus other minerals such as sphalerite and arsenopyrite (Figure 9). In some places it can be seen that the vein grew intermittently from the wall rocks inward toward the center of the mineralization. However, the vein is not bilaterally symmetrical and it can therefore be classified as an "asymmetrical vein" (Bateman, 1942).

In general the boundary between the vein and the host rock is quite sharp. These boundaries are free of gouge where the vein is conformable. However, when the vein cross-cuts the bedding planes, some gouge may be present (no wider than 2.5 centimeters). Therefore this vein is a "free wall vein" (Bateman, 1942).

Rock fragments are commonly found within the vein especially when it is wide. These rock fragments are either of quartzitic or phyllitic composition. The presence of these rock fragments is not restricted to any specific site, although in some places they tend to be located toward the edges of the mineralization and in other places towards the center of the vein. The size of these rock fragments is very variable and ranges from a few millimeters to 14 centimeters across. The quartzite fragments are more angular
Phyllite fragments with arsenopyrite crystals (—) located in or near the rock fragments.

FIGURE 9

Schematic diagram of a typical vein sample 9, figure 13, at Stibnite Hill Mine displaying crustification banding. Deformation of stibnite decreases with age of stibnite generations. Sphalerite represented by +.
and almost always surrounded by vein quartz often with a cockade structure. This texture is very diagnostic of fissure vein filling (Figures 9, 11). The fragment angularity is a result of breakage of the brittle quartzite and a lack of chemical reactivity with the mineralizing solutions. The phyllitic fragments are less angular and many of them, especially the small fragments 3 to 4 millimeters across, show evidence of replacement by stibnite and are totally surrounded by stibnite. In several places where the phyllite is the host rock it was possible to observe ribbon structures which are very thin dark bands of host rock separated by thicker bands of vein quartz (Figure 10). This situation is the result of repeated breakage along the wall rock interface and then quartz plus or minus sulfide mineralization. In some places these rock fragments may constitute "horses" or slivers of rock surrounded by vein material.

When the vein branches, divides and joins again forming brecciated zones.

The origin of these rock fragments may be the result of one or more of the following:

A. Mechanical brecciation occasioned by the force and pressure of the mineralizing solution.

B. Tectonic brecciation occurring during mineralization.

C. Chemical solution of the host rock. The mineralizing solution entered the host rock through pre-existing fractures in some instances dislodged pieces of the wall rock by solution which subsequently became coated with the mineralizing matter.
FIGURE 10.

Schematic diagram of vein sample 48, figure 13 showing ribbon texture between host rock (phyllite) and quartz.
Schematic figure of vein sample 114, figure 13 showing ribbon and cockade textures and wall rock fragments. Shaded areas represent stibnite rich zones. Sphalerite represented by +.
The three processes may have acted at the same time. However, the angular nature of the fragments suggests that the mechanical and tectonic brecciation may have been more important.

The mineral assemblages in the mines located east of the Idaho-Montana border in the Coeur d'Alene district include a small number of minerals in major quantities. A regional zonation exists in the region. With a very few exceptions, lead-zinc-silver deposits are located in and north of the Osburn fault. Most of the copper deposits are found south of the fault associated with the Wishard Sill, which is located along the Idaho-Montana border. Exceptions include a small vein of rich silver bearing tetrahedrite located south of the fault and the copper bearing Copper Rocks Mine north of the fault (Campbell, 1960).

This zonation appears to be related to both structural controls and the Wishard Sill. The lead-zinc-silver mineralization seems to be related or controlled by the Osburn and parallel faults. However, in the Coeur d'Alene district the large faults are barren (Bateman, 1942). The copper belt seems to be controlled by basic igneous rocks (sills and dikes) of dioritic composition (Wallace and Hosterman, 1956). Although the mineral assemblages in the Stibnite Hill Mine is different from those mines, the ore in this mine is also structurally controlled. The main structural element which controlled the location of mineralization may have been either the Thompson Pass fault or one of the satellites faults within the area.
Primary Mineralogy

The minerals found in the Prospect Creek district mines include galena, sphalerite, chalcopyrite, silver bearing tetrahedrite and gold.

The primary mineral assemblage at the Stibnite Hill Mine is very simple and includes stibnite, sphalerite, pyrite, arsenopyrite and lesser amounts of chalcopyrite. The vein gangue mineral is quartz. Only stibnite is recovered.

The most abundant mineral found in the Stibnite Hill Mine is stibnite (Sb$_2$S$_3$). It is found either as massive aggregates or as delicate prismatic or columnar crystals some as long as 3 centimeters. Some crystals occur in radiating or curved configurations. Stibnite occurs with quartz as an intergrowth, which often displays a perfect crustification banding toward the edges of the vein. In general the abundance varies from 5 percent to 40 percent of the vein. When stibnite is present as aggregates the size of the grains vary from few tenths of a millimeter to 5 to 6 millimeters in length.

In almost all polished sections, stibnite reveals some degree of deformation and perhaps all grains show undulose extinction. This is because stibnite deforms easily (Plates 9, 10, 11, 12). It was possible to observe in some specimens at least four generations of stibnite alternating with quartz bands. Between each generation there was apparently a period of no deposition of gangue or ore minerals. The first generation in the vein is always a quartz band. Stibnite replaces almost all minor constituents especially sphalerite, arsenopyrite and chalcopyrite.
Sphalerite (ZnS) is the second most abundant sulfide. It was always observed in rounded aggregates no more than 5-6 millimeters across. This mineral is not very abundant and its greatest concentration in the vein is 6 to 8 percent. It appears, from color observations to be richer in iron toward the edges of the vein. This could be a result of either a change in temperature or in response to the availability of iron. With a few exceptions sphalerite tends to be related to the younger stibnite generations, or at the earliest with the second generation of stibnite. In some places sphalerite was seen partially replaced by younger stibnite.

Arsenopyrite (FeAsS) is present in aggregates, euhedral crystals, as isolated grains or in tiny seams no longer than 3 centimeters. The average size of these grains is several tenths of millimeters, although some of them reach 2-3 millimeters in length. The greatest concentrations of arsenopyrite were always observed in the wall rock or in the rock fragments especially of phyllitic lithology. Also arsenopyrite is quite common in the mineralization itself, but always associated with or close to the rock fragments. Its abundance is not greater than 5 percent. Arsenopyrite apparently formed in the host rock during the period of mineralization by utilizing iron-bearing wall rock material. Arsenopyrite was also observed replacing pyrite. The supply of material used in the growth of pyrite evidently ceased and or the solution became rich in arsenic and attacked pyrite for the iron. Etched pyrite rimmed by arsenopyrite resulted. These crystals are associated with former avenues of transportation
(fractures) (Plate #3). Also arsenopyrite was partially replaced, in some places, by younger generations of quartz (Plates 1 and 5). Some crystals of arsenopyrite show evidences of cataclastic deformation (Plate #8).

Pyrite (FeS$_2$) is present in the mineralization as aggregates or as single crystals. Its greatest concentration is always in or adjacent to the host rock and in accumulations of no greater than 2-3 percent. In general the pyrite grain size is between 1-2 millimeters across but a few of them are up to 4 or 6 millimeters across. Pyrite in some areas, shows partial replacement by arsenopyrite. The dynamic processes which affected the stibnite mineralization were apparently not strong enough to produce deformation in the strongly bonded but brittle pyrite (the stresses apparently resulted in stibnite and arsenopyrite).

Chalcopyrite (FeCuS$_2$) is present as a minor constituent (less than 1 percent). It was always found associated with sphalerite, either in fractures in sphalerite or along its edges forming tiny crystals. It was generally necessary to use the highest objective power (200x) to see them (Plate #4). The textural appearance of the chalcopyrite and the fact that the sphalerite lattice can accept copper at higher temperatures suggest that chalcopyrite exsolved from sphalerite.

Secondary Minerals

Most of the secondary minerals observed at the Stibnite Hill Mine are the product of the decomposition of stibnite. The four
antimony oxide minerals found include kermesite, valantinite, cervantite and stibiconite. The first two are well crystalized minerals. Cervantite and stibiconite, which are also known as antimony ocher are poorly crystallized substances. These two minerals may be synonymous (Vitaliano and others, 1952). Kermesite \((2\text{Sb}_2\text{S}_3\cdot\text{Sb}_2\text{O}_3)\) is the result of partial oxidation of stibnite. Valentinite \((\text{Sb}_2\text{O}_3)\) forms under more oxidizing conditions. Stibiconite \((\text{Sb}_2\text{O}_4\cdot\text{H}_2\text{O})\) is the oxidation end product (Dana, 1896).

These minerals are found in the fractures in the weathered zones. The yellowish to white colored mineral can be either valentinite or stibiconite (Dana, 1896). However, the possibility exists that some of this material is arsenolite \((\text{As}_2\text{O}_3)\). Also associated with the wall rocks and covering the fractures surfaces is the secondary green arsenic mineral scorodite \((\text{FeAsO}_4\cdot2\text{H}_2\text{O})\). The concentration of the secondary minerals is not high and in the different polished sections never amounts to more than 4 percent of the rock. Only stibnite is recovered at the mine. Optical methods were used to identify the oxide minerals.

**Paragenesis**

Bateman (1942) stated that the usual paragenetic sequence is: gangue minerals then the oxides and finally sulfide minerals.

In accordance with Lindgren (Newhouse, 1928), the minerals which form the primary assemblage at the Stibnite Hill Mine would have the following order of crystallization: (earliest to latest) quartz, pyrite, arsenopyrite, sphalerite, chalcopyrite and stibnite (Park
and others, 1964). This mineral succession shows a general increase in the atomic number of the involved elements, a decrease in hardness of the minerals, and an increase in the melting and boiling points (only in elements such as O, S, Sb and As) and a decrease in solubility of the sulfide minerals in igneous solutions (Wells, 1915). It has been demonstrated that the Wells' series (Solubility or Shuerman's series) often parallels the mineral depositional sequence in the veins with the host soluble sulfide occurring furthest from the emanative center. This sequence may also parallel a progressive decrease in the temperature of formation of the minerals (Newhouse, 1928). However, recently Park and others (1964) stated that "this sequence is based upon the mineral stability ranges and is fairly constant for most deposits, regardless of depth and temperature of formation, and regardless of origin--whether direct magmatic, pegmatitic, hydrothermal, pneumatolytic or metamorphic". This sequence has resulted from the study of countless polished sections of many ore deposits throughout the world.

The sequence of mineral deposition in the veins at the Stibnite Hill Mine is generally easy to determine because of the generally unambiguous fissure filling textures. It was possible to observe in many places along the vein distinct crustification bands which are superimposed on one another. The crustification, which is generally more prominent toward the bottom of the vein, is based primarily on intercalation of quartz and stibnite. However, these mineral bands consist of a mixture of both quartz and stibnite with
one mineral generally much more abundant. The first mineralization band consists of almost 100 percent quartz and often forms a comb texture. Observation of the growth of quartz crystals and stibnite crystals within the different bands shows that growth occurred from the bottom toward the top (i.e. #9, Figure 13) or from the top down (i.e. #109, Figure 13), but it was never apparent that the mineralization grew both from the top down and bottom upwards toward the center of the vein. At least four stibnite and four quartz mineralizing periods were observed in many specimens in the vein system.

In different places where the crustification banding is prominent it was possible to observe hypidiomorphic textures in both quartz and stibnite. The texture is more prominent in stibnite (Plate #2). Stibnite crystals were deposited against faces of pre-existing quartz crystals and vice versa which indicates that stibnite and quartz grew intermittently.

The paragenetic sequence of the primary assemblage is summarized in Figure 12. Quartz was the first mineral deposited in the vein and stibnite followed. Pyrite and arsenopyrite formed by replacement of the host rock and in the vein itself. Arsenopyrite sometimes replaces pyrite (Plate #3). This suggests that pyrite was the third mineral to crystallize and arsenopyrite the fourth. In the earliest stages of stibnite mineralization it was not possible to see a direct relation of stibnite, pyrite and arsenopyrite. Arsenopyrite was always found as euhedral crystals totally surrounded by younger stibnite suggesting that these stibnite generations could have
FIGURE 12.
Paragenetic sequence of mineral deposition at the Stibnite Hill Mine.
crystallized later than pyrite and arsenopyrite. Sphalerite, with one exception, was always observed together with second or younger generations of stibnite and often is replaced by still younger stibnite. Chalcopryte occurs along fractures in and around sphalerite and appears to have exsolved from sphalerite (Plate #4).

In summary, the textures show that while the mineralization changed with time, overlap of quartz and sulfide mineral formation existed. Quartz and stibnite continued to crystallize intermittently throughout most of the period of mineralization.

It is possible to see in the polished sections, in a few places, a zonation between the minor mineral constituents which include pyrite, arsenopyrite and sphalerite. Pyrite and arsenopyrite prefer sites in or near the phyllitic wall and phyllitic fragments.

Deformation

Stibnite is classified as a "soft" mineral because of its physical properties. It is easily deformed with very slight stresses. For this reason care must be taken when polishing a sample because rough polishing can easily cause structural changes which may yield incorrect textural interpretations. This situation seems to be quite common for stibnite (Ramdohr, 1969).

The different deformations observed at Stibnite Hill Mine appear to be the result of athermal processes. The deformations seen include: slip, bending, kinking, polygonization and twinning. They are due essentially to superimposed stresses.
Slip can be considered a translation which requires no change in structural packing. Under the microscope it appears as parallel lines or lamellae. Slip is obtained when one portion of a crystal slides relative to the other and it starts when one component of the shear stresses reaches its critical value. The result is that the slip planes form parallel to the main directions of stress.

A deformation band in a crystal is defined as a zone which differs in crystal orientation with respect to the remainder of the crystal. These zones under the microscope show a slight difference in birefringence or extinction with respect to the remainder and they differ from primary twinning by lacking a precise symmetrical relation with the remainder of the host.

Permanent bending originates when a crystal supported a stress which was reflected in changes in the lattice and optical directions across the crystal. The crystal therefore does not extinguish all at once when seen between crossed nichols and the microscope stage is rotated. The crystal therefore shows undulose extinction. The bending causes undulose extinction, anomalous optical properties, curved cleavage, curved twin planes and curved crystal faces.

Kink bands are due to slip along closely spaced surfaces creating a shortening approximately parallel to these surfaces. The change in orientation can be abrupt, although it can vary from a very low to a high angle (60°) with respect to the remainder of the crystal. Kink bands may be accompanied by fracturing.
Twinning is defined as an intergrowth of two or more single crystals of the same species, so that some lattices are parallel in their orientation, whereas others are in reversed positions. They have been divided into primary and secondary twins. The primary twins form during the growth of the crystal. A good example of this kind of twins are the albite twins in plagioclase. Secondary twins are those twins due to deformation and they are formed after the crystalization. It is not always possible to clearly distinguish between them. Wedge-shaped and curved polysynthetic twins in plagioclase, microcline and other metamorphic minerals associated with deformation appear to be good examples of secondary twins. The deformation twinning mechanism appears to be very similar to that of slip transformation or transformation gliding. For this reason we can have, in some instances, a mixture of this phenomenon which can be difficult to tell apart. Little work has been done on secondary twinning in sulfide minerals.

Polygonization is considered to be a recovery process (Plate #12) where a strained lattice reorders into unstrained sub-grains which are separated by coherent low angle, sub-grain boundaries. This process is known as annealing (Spry, 1969). Therefore this process, which often takes place in the region of the bent portions of kink bands, is apparently the first step in recrystallization and is the result of both stress and slight changes in temperature. If strain takes place at reasonably high temperatures, for example, under low grade regional metamorphic conditions, the strained lattice may be immediately followed by polygonization.
Studies of the different polished sections show that the deformation varies from incipient deformation (Plate #6) to incipient polygonization (Plate #12). Because the mineralogy assemblage includes stibnite, sphalerite, arsenopyrite, and pyrite which all have different physical properties, it is logical to suppose that each mineral of this sequence will behave differently in response to a stress. Sphalerite and pyrite are not deformed signifying that the dynamic processes reflected in the mineralization were not strong enough to produce deformations in those minerals or that the other, softer minerals deformed rather than transmitting the stresses. Arsenopyrite was slightly deformed (cataclastic deformation). Although it has been observed that all these minerals are commonly deformed in other localities in Coeur d'Alene district, the deformation seen in the Stibnite Hill Mine is never as intense as that seen in the Coeur d'Alene district.

Sphalerite requires special techniques in order to see deformation. The polished samples of sphalerite were etched with HI (hydroiodic acid--50 percent concentration) for different lengths of time (30 seconds to several minutes) and observed with ordinary light. No sphalerite sample showed any deformation. In the samples where the stibnite showed the greatest amount of deformation the sphalerite did not show any deformation. Therefore, either (1) the different dynamic processes involved during and after mineralization did not affect the sphalerite, or (2) the sphalerite is younger than the deformation. The textural relationships strongly suggest the former hypothesis.
All the deformation experiments done on pyrite by other workers have been done with single crystals (Atkinson, 1975). However, it is believed that the results can be applied to aggregates with a large degree of certainty. Pyrite is considered to be at low temperatures, an extremely strongly bonded but brittle substance. The physical properties decrease with either increasing confining pressure and/or temperature. It has been observed in the laboratory, that pyrite at temperatures between 20⁰ and 400⁰C and pressures between 1b to 3kb (very shallow to 10 kilometers depth conditions), was only deformed by cataclasis. With increasing porosity plastic deformation takes place.

The pyrite found in the vein assemblages is in aggregates or single crystals. No traces of cataclastic deformation were seen in the pyrite. Several samples were etched with HI acid with negative results.

Arsenopyrite is present as well developed single crystals or in aggregates either in the host rock or in the vein mineralization. Arsenopyrite showed fracturing and in some instances was accompanied by small displacements along the fractures (Plate #8). Those crystals in the host rock fragments showed more deformation than those arsenopyrite crystals found in the vein itself. This circumstance may be explained by (1) the difference in transmitting the stresses by the two media which is related to the relative plasticity of the various materials, or (2) two ages of arsenopyrite mineralization. The paragenetic sequence greatly supports the first possibility.
Deformed stibnite is very common in the mineralization assemblages and occurs both in folded and faulted zones. However, the greatest deformation is seen in the folded areas (Figure 13). Areas exist where the original texture of stibnite apparently has been totally changed. The deformation of stibnite produced as a consequence of the faulting of the vein was not so conspicuous. However, in some samples associated directly with faults, it was possible to observe different kinds of deformations, including undulose extinction, deformation bands, and very abundant cataclastic deformation. Recrystallization (recovery process) in this mineralization was not seen. This suggests that the dynamic processes were not as great as those associated with the Coeur d'Alene district where recrystallization occurred.

In the mine the deformation of stibnite in areas devoid of folds and faults may be the result of at least two possibilities:

a. Due to force of crystallization
b. Due to post-mineralization tectonic processes.

A possible way of deforming stibnite is by the "force of crystallization" (a crystal growing in a solid medium creates expansive forces which vary according to the crystallographic directions). Although stibnite is classified as a mineral of low force of crystallization, some deformed crystals of stibnite were seen against previously crystallized primary quartz suggesting that they may have been deformed during crystallization (Plate #6). However, in other areas no deformation of stibnite was observed.
The greatest deformation in stibnite was always observed in the earliest generation of stibnite (Plate #7). This suggests that these early generations were involved in the greatest numbers and/or intensity of deformational stresses. The mineral stratification planes and fractures are the result of repeated structural adjustments along the vein. Several types of deformations including deformation bands, curved deformation bands and kink transformations are present in the stibnite (see Plates #7, 9, 10, 11, 12). This deformation is very conspicuous when the mineralization is not concordant with the host rock stratification. In these areas the first generations of stibnite revealed more deformation than the youngest stibnite. However, some deformation is present in the youngest generations in these areas.
Stibnite Hill Mine

FIGURE 13

0 30.48 meters

○ (9) sample location

+ (19) oriented sample location

■ Low deformation in stibnite

● Moderate deformation in stibnite

▲ High deformation in stibnite

—— Veins

——— Vein barren of sulfides
The mineralization within the Stibnite Hill Mine is structurally controlled and is apparently related to the Thompson Pass fault or one of its satellite faults (Figure 1). This is apparently the situation for all mines in the area between Saint Regis, Mineral County, Montana, and the Coeur d'Alene district in Idaho. However, the mineral assemblage at the Stibnite Hill Mine is different from all other mines found in that region of intense faulting.

The host rock for the stibnite mineralization is the Prichard formation, age 1.1 billion years (Long and others, 1960). The deposit is located in the west limb of an anticline which trends N 5-60°E (Clendenin, 1973).

Normal faults offset the vein and are steep and have small vertical displacements no greater than 1.6 meters. The greatest displacement in the mine is 9 meters and was measured by a mine geologist. The folds are characterized by either slight changes in attitude (monoclines) or by well contorted zones.

The hypogene mineralogy at the Stibnite Hill Mine is simple and includes stibnite, pyrite, arsenopyrite, sphalerite, chalcopyrite and quartz. This mineralization is therefore classified as a "simple antimony type deposit" in accordance with White (1951; 1962).
The textures, structures and primary mineral assemblages are characteristic of typical fissure cavity (open space) filling veins. Minor replacement of the wall rock and exsolution processes also exist. The mineralization is generally concordant with the stratification. The vein thins and often splits into stringers, or gradually dies out when the vein becomes discordant with the stratification. The vein eventually appears again parallel to stratification along the strike.

The wall rock alteration caused by the mineralization was negligible. However, quartz veinlets found in the wall rock were probably formed during the mineralization.

In several places where the crustification banding is well developed, it was possible to determine that the mineralization grew toward the center of the vein and at least four periods of stibnite deposition occurred. The textures suggest that intervals of no deposition existed between mineralization epochs. The paragenetic sequence may be seen in Figure 12. Quartz and stibnite overlap the periods of deposition of the other minerals which include pyrite, arsenopyrite, sphalerite and chalcopyrite. Deformation of stibnite was observed in all generations. Sphalerite, arsenopyrite and chalcopyrite did not show any deformation textures. They may be younger than the deformation, or their stronger physical properties may have resisted deformation. The latter possibility appears more plausible.
In a few places it is possible to see zonation between the minor minerals including pyrite, arsenopyrite and sphalerite. The zonation consists of alternations between these minerals and also a relationship to the wall rock fragments. Sphalerite, which was always observed associated with the younger stibnite generations, is apparently richer in iron toward the edges of the vein. This circumstance can be explained by one of the following:

1. change in the physico-chemical conditions in the solution,
2. change in availability of iron.

However, the primary mineralogical composition of the Stibnite Hill Mine in broad sense can be considered practically constant both in horizontal and vertical dimensions.

Stibnite and arsenopyrite show deformation in several places along the vein system. The deformation was stress-activated and athermal (Spry, 1969). The deformation not associated with folds and faults may have formed in one of the following ways:

1. Force of crystallization. Although stibnite has a low force of crystallization, some deformed stibnite crystals were seen against previously crystallized quartz and these stibnite crystals may have been deformed during their crystallization (Plate #6). However, in other places no deformation in stibnite associated with quartz was observed, which argues against this. Also, later stresses applied against
stibnite-quartz mixtures would probably result in
the softer mineral (stibnite) deforming against the
harder mineral (quartz).

2. **Dynamic processes which affected the host rock-mineralization association.** This hypothesis is supported by the fact that the various stibnite generations show deformation but the earliest generations show greater deformation than the youngest generations. The deformation is more prominent when the vein is not concordant with stratification. Intense deformation of the stibnite in the mine was always observed in zones of intense normal faulting and folding. However, the deformation in stibnite is most prominent in areas of intense folding (Figure 13).

Deformation in sphalerite, chalcopyrite, and pyrite was not seen. These minerals are more strongly bonded than stibnite. The stresses applied to the vein system were apparently not great enough to produce brittle deformation in these minerals. Although arsenopyrite has a greater hardness than some of those minerals, it was slightly deformed yielding a cataclastic texture (Plate #8). This circumstance may be explained by the fact that arsenopyrite is a brittle mineral with no plastic behavior in low athermal deformation.

The highest degree of deformation observed at the Stibnite Hill Mine was polygonization (Plate #12).
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APPENDIX A

Plates at the Stibnite Hill Mine

Symbols used:

Sb -- Stibnite
Qtz -- Quartz
Ap -- Arsenopyrite
Sp -- Sphalerite
Cp -- Chalcopyrite
Py -- Pyrite
Qtzite -- Quartzite
Rf -- Rock fragments
Plate #1

Euhedral arsenopyrite (Ap) partially replaced by Quartz (qtz) in quartzite (Qtzite). Locality 104 Figure 13. Magnification 40x.
Plate #2

This plate shows a hypidiomorphic texture of stibnite (Sb). Stibnite was deposited against pre-existing quartz crystals (Qtz). Locality 109, Figure 13. Magnification 16x.
Plate #3

Pyrite (Py) partially replaced by arsenopyrite (Ap). Directly related to avenues of transportation (Qtz vein). Lightest gray arsenopyrite (Ap). Locality 114 Figure 13. Magnification 50x.
Plate #4

Exsolution texture in which chalcopyrite (Cp) was exsolved from sphalerite (Sp). Locality 109, Figure 13. Magnification 100x.
Plate #5

Arsenopyrite (Ap) partially replaced by quartz (Qtz) in which arsenopyrite (Ap) reveals corroded edges. Locality 83, Figure 13. Magnification 50x.
Plate #6

This plate shows apparent deformation of stibnite due to either the force of crystallization against pre-existing quartz crystals (Qtz) or tectonism. Apparently two generations of stibnite may be seen, (1) the deformed band (center) and (2) the equal granular crystals (left). Locality 114, Figure 13. Magnification 16x.
Deformation bands in the first generation of stibnite (Sb) probably caused by tectonic adjustments in the vein. Horizontal bands are either twin lamellae or deformational bands. Smaller bands within the larger bands are apparently deformational in origin (Ramdohr, 1969). Locality 49, Figure 13. Magnification 25x.
Plate #8

Cataclastic deformation of arsenopyrite (Ap) light gray in rock fragments (Rf). Locality 100, Figure 13. Magnification 40x.
Plate #9

Cataclastic deformation of stibnite (Sb) represented by microfaults NW-SE trends, after growth of deformation twinning. Locality 100, Figure 13. Magnification 50x.
Plate #10

Apparently kink deformation in stibnite (Sb) or corrugated lamellae (Ramdohr, 1969) associated with deformation bands. Locality 100, Figure 13. Magnification 50x.
Plate #11

Bent growth or deformation twin bands of stibnite (Sb). Locality 100, Figure 13. Magnification 50x.
Plate #12

Polygonization texture is the greatest amount of deformation revealed by stibnite (Sb) in the mine. Unstrained subgrains (E-W orientation) of stibnite (Sb) were developed (Spry, 1969). Locality 19, Figure 13. Magnification 40x.