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The Geology and Ore Deposits of Jardine, Montana

Wolter Duykers

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THE GEOLOGY AND ORE DEPOSITS
OF
JARDINE, MONTANA

by
Wolter Duykers

A Thesis
Submitted to the Department of Geology
In Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
May 1938
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# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Plate</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Generalized Geologic Map of the Southern Part of Park County</td>
<td>3</td>
</tr>
<tr>
<td>II</td>
<td>Arsenopyrite in Biotite Quartz Schist</td>
<td>15</td>
</tr>
<tr>
<td>III</td>
<td>Gold in Quartz</td>
<td>16</td>
</tr>
<tr>
<td>IV</td>
<td>Illustration Showing the Association of Gold and Quartz</td>
<td>16</td>
</tr>
<tr>
<td>V</td>
<td>Illustration Showing the Association of Gold, Quartz, and Scheelite</td>
<td>16</td>
</tr>
<tr>
<td>VI</td>
<td>Scheelite in Quartz</td>
<td>17</td>
</tr>
<tr>
<td>Subject</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Geography</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Physical Features of the Region</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Petrography</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Biotite Quartz Schist</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Muscovite Biotite Quartz Schist</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Quartz Amphibole Schist</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Diabase</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>The Ore Deposits of Jardine</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Historical Notes</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Description of the Deposits</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Mineralogy</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Chalcedony</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Arsenopyrite</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Scheelite</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Pyrite</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Marcasite</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Galena</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Limonite</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Aluminum and Iron Sulfate</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Anglesite</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Paragenesis</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Genesis of the Deposits</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Conclusions on Origin</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Conclusions</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Scheelite Exploration</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Bibliography</td>
<td>29</td>
<td></td>
</tr>
</tbody>
</table>
The subject to be covered by this paper is based upon field study made during a six week stay at Jardine while the author was acting as assistant to Dr. G. F. Seager. The work began on June 19, 1937 and ended on July 31 of the same year. The period between June 19 and June 26 was spent in a reconnaissance survey of Jardine and vicinity. About one-half of this time was spent on foot and the remaining time was utilized in making automobile traverses through the outlying parts of the district. The extremes of the automobile traverses were Crevass Mountain and Gardiner, Montana. The equipment used included a base map supplied by the U.S. Forest Reserve Office, an aneroid barometer, and a Brunton compass. As a result of this survey, samples were obtained from significant points, control stations for triangulation purposes were established, and information concerning
The time extending from June 26 to July 31, excluding three days spent in underground work, was consumed in the preparation of a topographic map of the land area immediately surrounding Jardine. A plane table and alidade was used in this task. The map was made on a scale of 1" = 200 ft. and on it were plotted contours of the topography at intervals of 25 feet, strikes and dips of the exposed formations, and buildings and sheds. Also, a large scale map was made of the two major open cuts on the property on a one inch to forty foot scale. While mapping proceeded, samples, and other geologic data were taken wherever such would prove diagnostic.

The work underground consisted of a limited amount of detailed mapping and a general reconnaissance to obtain an idea of the broader underground relationships of veins and structures. Representative folds, faults, and mineral occurrences were photographed, and samples were taken from significant points.

It is a pleasure to acknowledge the kind cooperation shown by the Jardine Mining and Milling Company during the course of the survey. The author is deeply indebted to Dr. Seager for his guidance throughout the pursuit of this thesis, and to Dr. E.S. Perry for his many helpful suggestions. Credit is due to D.H. Swank for the col-
GENERALIZED GEOLOGIC MAP
of the
SOUTHERN PART
of
PARK COUNTY

Legend
GaI Cenozoic - undifferentiated alluvium
M Mesozoic sandstones 
and shales
P Paleozoic shales 
and limestone
R Metamorphics
Tv Volcanics

Scale - 1 in = 8 mi
lection of many of the specimens used during the study.

GEOGRAPHY

Location.—The Jardine mining district includes all mineral bearing country within a mile of the town of Jardine. The town of Jardine is in the extreme southern end of Park County, about 4 miles north of the Yellowstone National Park—Montana boundary line, and about 5.4 miles by road from the town of Gardiner, at the entrance of Yellowstone Park. The nearest railway is the branch line of the Northern Pacific running from Livingston, Montana to Gardiner. The U.S. Highway No. 89 also is laid through Gardiner. Jardine is accessible by means of a dirt road, maintained by the county, and leading to Crevass Mountain.

Physical Features of the Region.—The southern part of the west boundary of Park County is determined by the Gallatin Range. The main range of the Snowy Mountains lies approximately in a north and south position, and averages about 10 miles from the eastern border of Park County. Yellowstone River enters the county through the southern end and flows nearly parallel to the Gallatin Range, finally passing out of the county at approximately the central portion of the eastern boundary.
The Gallatin Range is composed in a large part of Archean gneisses over which occurs a series of sandstones, limestones, and shales, representing all of the periods included in the Paleozoic and Mesozoic eras. Associated with these sedimentary beds, are large masses of intrusive rocks, which have played an important part in bringing about the present structural features of the range. The igneous rocks are essentially of the diorite variety, and are composed principally of the minerals plagioclase feldspar, hornblende, and mica. Dikes and sills of this material cut the overlying sedimentary rocks.

The Snowy Range consists largely of granites, gneisses and schists, of pre-Cambrian age, and is rough and rugged in topography.

The Yellowstone river is the main drainage course for the area. The Yellowstone Valley is a broad valley lying between the Gallatin Range and the Snowy Range.

A major geological feature of this region is the Gardiner Thrust Fault.

One and one-half miles upstream from Gardiner, Bear Creek enters the Yellowstone River. The Bear Creek valley shows very definite signs of glaciation. Various parts of the brink of the valley is seen to be covered by post-Tertiary basalts and acid extrusives.
Jointing is characteristic of much of the basalt. Andesite and rhyolite flows cap the lower hills surrounding Jardine. These flows are quite definitely pre-glacial, as fragments of the rock are seen strewn over the valley floor.

Peculiar phenomena of the valley of Bear Creek are the low, level-topped ridges and mounds lying parallel to the sides of the valley. These are apparently lateral moraines composed of debris gathered by the valley glacier which once occupied this region. An unusual feature of one of these moraines is that it forms a channel between itself and the side of the valley. This is probably the result of the high angle of repose of the material of which the moraine is composed.

The rounded and timbered surface of Crevass Mountain lies about 5.5 miles southeast of Jardine. It is composed of a complex series of metamorphics of pre-Cambrian period, the principal rock type being a biotite quartz schist.

Its surface has been glaciated by probably the same mass of glacial ice which once covered Yellowstone National Park. The great height of the Yellowstone glacier, as evidenced by the large granite erratic found on the brink of the Grand Canyon of the Yellow-
stone, where the elevation is about 7500 feet, lends foundation to this suggestion.

PETROGRAPHY

The great bulk of the rocks of the Jardine district consist of crumpled and folded pre-Cambrian schists. The series may be divided into three main rock types. These are namely, a biotite quartz schist, a muscovite biotite quartz schist, and a quartz amphibole variety which approaches an amphibolite in homogeneity. From the surface work to date, no definite relationship can be established between the various types other than their relative positions.

The quartz biotite schist is found in the main part of the workings and is the most abundant rock type. The muscovite biotite quartz schist is seen in the cuts and adits in the extreme southern end of the property and grades into the biotite quartz schist. The quartz amphibole rock is encountered both in the central part of the workings and in the south workings.

The amphibole rock, because it is frequently more or less massive and "igneous appearing", is sometimes referred to locally as "diorite", but occasional, though definite, bands of garnet imply that the original rock was sedimentary.
The series is cut at the northern end by a diabase
dike, which varies in width from twenty feet to forty-
five feet. The genetic relation between this dike and
the ore deposits is not yet evident. It is, however,
of sufficient extent to warrant discussion.

Biotite Quartz Schist. — Megascopically this rock can
be seen to be composed mainly of quartz and biotite. It
varies texturally from a schistosity that controls the
fracture to a schistosity that is barely noticeable. The
quartz is approximately three times as plentiful as the
biotite. Under the microscope, the quartz is seen to
have an undulating or wavy extinction characteristic of
quartz which has been subjected to dynamic stresses. The
quartz grains average about 0.25 mm. in diameter. Plagioclase occurs very sparingly in the rock. Those grains
that were encountered appeared to have an extinction
corresponding to a composition of oligocene or andesine.

Some varieties of the rock are garnetiferous. The
garnets occur in grains nearly 1 cm. in diameter. The
color is usually dark red. Studied in thin section the
garnets are seen to be highly fractured suggesting a con-
tinuance of dynamic stress after the crystal had lost
its power of recuperation. The intense fracturing of the
garnets made recognition inaccurate.
Muscovite Biotite Quartz Schist.—The characteristics of this group vary widely, the types being placed under one heading more because of similarities in texture rather than in composition. These rocks are all highly schistose and less dense than the other metamorphosed rocks. The composition is mainly quartz, biotite, muscovite, and chlorite, with varying quantities of zircon, apatite, and opaque accessories, the latter being mainly arsenopyrite. The color of this rock varies from light tan and brown to dark green and gray, eventually grading into the quartz biotite schist described previously. The change in color is an index of the change in composition. The lighter color rocks being nearly pure muscovite quartz schists. The darker varieties contain increasing quantities of chlorite and biotite. Small amounts of plagioclase felspars were present.

The grain sizes in this type are generally smaller than in the other metamorphosed rocks of this area. The zoning of the minerals within the rocks is also more pronounced than in the related types farther north in the area. These facts attended by the more frequent foliation than was seen in the others, suggests that these rocks have been subjected to greater metamorphism than have the others. However, the series might originally
have consisted of sediments composed mainly of argillaceous beds varying somewhat in composition, thus accounting for both the differences in texture and the differences in composition. Further study of this area may prove possible its division into zones of metamorphism such as was done by Barrow* in the Highlands of Scotland.

Quartz Amphibole Schist.—This rock is usually fine-grained, dense, and dark. It sometimes shows a tendency toward schistosity but is more often massive. The main constituents are amphibole and quartz, the former being about three times as plentiful as the latter. Plagioclase has not been observed in this rock. Biotite forms a small fraction of the dark constituents of this rock and is occasionally chloritized, as is also the hornblende.

The amphibole, which is of the hornblende variety, has an extinction angle which varies from 16 to 22 degrees and is therefore classed as having a positive crystal elongation. It has a birefringence of 0.0243.

Diabase.—Megascopically this rock is medium grained and dark. It can be seen to be composed of about one-half dark constituents and one-half light constituents. Under the microscope the former are seen to be altered pyroxenes, amphiboles, and biotite, with the pyroxenes predominating. About one-fourth of the pyroxenes are al-

---

*Metamorphism — Alfred Harker
tered to chlorite. The lighter constituents are feldspars, one-half of which are plagioclase. The latter have an extinction which corresponds to the composition of andesine.

THE ORE DEPOSITS OF JARDINE

Historical Notes

The mining industry in Jardine had its beginning in 1866 when a gold placer deposit was found near the mouth of Bear Gulch, a few miles below the present townsite of Jardine. Active placering of all the bars and gravels along the creek soon followed.

With the growth of placer mining activities, curiosity was aroused as to the origin of the gold. It was traced to a mineral belt with a northwesterly trend which passed through the top of Crevass Mountain and the junction of North Fork and Bear Creek.

In 1884 the first operations on the vein deposit began. At this time, a man Major Eaton installed a large hydraulic plant which utilized 400 feet of head on Bear Gulch Creek. With the power from this plant, he operated a 5 stamp gold mill and also a saw mill.

Shutdowns were frequent and the ownership changed hands many times. The town of Jardine was named after A.C. Jardine, who, during the year 1900, was superinten-
dent of the property and represented Canadian interests.

In 1914, through a bondholder's foreclosure, the Jardine Mining and Milling Co. took over the properties. Activities were brought to a standstill by judicial contests which followed one another in rapid succession.

In 1916, Harry Bacorn took over the duties as manager of the property. Later, he was joined by his brother F.W. Bacorn. Under the combined effect of Bacorn's efficient management and the availability of outside capital, the mine prospered.

In 1934, the company ownership again change hands to become the property of the Case Pomeroy & Co. of New York. The company retained the name of Jardine Mining and Milling Company, and has been subject to no change in ownership up to the year of 1938.

Description of the Deposits

On the top of Crevass Mountain the mineral belts is over a thousand feet wide and crops out for a distance of one mile. Near Jardine, the mineralized zone is for the most part covered by timber and sod. Both near Jardine and Crevass Mountain the country rock is principally a biotite quartz schist described previously in this report.

At Jardine the mineralization has taken place along a system of four fissure veins or shear zones. They have been assigned numbers, with number one as the most wes-
terly. All of the veins have several branching satellites. The first three veins are quite narrow, varying from a few inches in width to a few feet. But the fourth is sixty feet wide in places and averages about twenty feet. This vein varies in dip from 55 to 60 degrees, the others have a flatter dip. The veins strike north and south throughout most of their length excepting veins one and two which at the middle change in strike from north to northwest. The mine has been divided into north and south territories. The vein structure in the south workings have been subjected to such intense folding that recognition of a definite system becomes nearly impossible. In the north workings, the veins can be seen to cut schistosity, locally, however, they will sometimes tend to follow the bedding and schistosity.

The actual mineralization has taken place in several very definite stages. The form of mineral occurrences varies from massive crystal aggregates, in which form the arsenopyrite occurs, to submicroscopic grains, in which form most of the gold occurs.

There is no oxidation zone in Jardine, the glacial erosion having been so severe, that any oxidized products as might have been formed would have been completely scraped away.
A prominent geological feature of the district is the Bear Gulch fault. It has a strike of N 20° E and varies in dip from 40 to 50 degrees westward. This has sometimes been thought to be part of the fault structure which determined Bear Gulch. No mineralization has taken place along the fault but in places it is filled with a chalcedonic quartz. Most of the mine workings lie to the west of the fault.
MINERALOGY

Quartz occurs as massive "kidneys" and lenses in the fissures. It is always granulated and fractured when found in such bodies. The chain-like arrangement of the lenses suggests a former continuous quartz vein of more or less uniform width which has been subjected to a squeezing that resulted in the segregation of the vein into bodies of the ofrm and shape described. The possibility of folding prior to injection, is, however, not necessarily eliminated.

Chalcedony occurs as a vein filling in the Bear Gulch fault. It is usually highly fractured and is never found in especially large bodies.

Arsenopyrite occurs as euhedral crystal replacements in the quartz biotite schist and in the quartz amphibole schist. However, while this is the most common form of occurrence of the mineral, a certain amount of it also occurs in the vein quartz. Perfect octahedral crystals of this mineral can be removed with ease from the matrix wherever the latter occur in the decomposed variety of the schist. It also occurs as irregular crystalline masses. The arsenopyrite was not considered as ore during the early part of the mine history. The main objection to its extraction was the fact that it was a base ore. Under the more recent management, however, those parts of the mine in which the arsenopyrite had been passed through without any development whatever, were mined out. Gold is al-
Arsenopyrite in Biotite Quartz Schist

PLATE II
most always associated with the arsenopyrite. The ore thus serves two markets, one for gold and one for arsenic.

The arsenopyrite is roasted and reduced to white arsenic ($\text{As}_2\text{O}_3$), which, when the price is high enough, serves as a valuable by-product.

Gold occurs both as free-milling ore in and around quartz veins and associated with arsenopyrite and pyrite in which form it requires special treatment. The quartz gold was formerly the only object of the mining operations. As a rule it is found in the contact between the quartz vein and the schist. It also occurs in the massive quartz and quite often in the schist around the vein, seeming to favor those schists which are iron-stained. In those parts of the vein where the quartz has apparently torn fragments of schist from the wall of the vein, the gold values seem to be higher than at other places. Apparently the fragments of schist, or at least certain constituents of the schist, act as precipitants for the gold. Not infrequently the gold occurs as meagascopic grains in small cavities in the quartz. (see figure) Examination of such occurrences under the binocular microscope suggests that the gold may have been precipitated from a gold-bearing solution which became trapped in the cavity.

The exact form of the gold in the schist is not known
Gold in Quartz

The gold lies in a small cavity in the quartz.

PLATE III
Two figures showing the association of gold and quartz. In the lower illustration only a small amount of quartz is visible but the specimen contains a large amount of quartz.

PLATE IV
A specimen showing the association of gold, quartz, and scheelite. The portion encircled with red is scheelite.

Note the granulation of the quartz.

PLATE V
It has been suggested that those parts of the schist which carry gold values also are cut by submicroscopic veinlets of quartz, in which case the gold would be associated with quartz and not the result of secondary hypogene enrichment as such an occurrence might suggest.

Gold is so frequently associated with arsenopyrite and pyrite, that an attempt has been made to explain the presence of the gold as a sulfide.*

Scheelite is very irregular in distribution. The mineral is found in pockets and pipes. The variety that is found in Jardine is a rather brown to "honey colored" translucent variety. It is found for the most part in vein four. Occasional crystal faces of the pyramidal type can be seen, but usually, the mineral is massive and fractured to the extent that makes crystal recognition nearly impossible.

The scheelite is hand sorted in the mine from the rest of the ore whenever encountered and stored until the amount collected is sufficient to justify the special treatment which it is necessary to give it. The high specific gravity of scheelite permits separation by panning, which practice is resorted to on the smaller properties in the area. In Jardine, scheelite is concentrated on Wilfley tables.

Pyrite often occurs as fillings in the interstices of arsenopyrite crystal aggregates but is more commonly found

*Clarke's Data on Geochemistry    G.S.A. Bul 770
Scheelite (dark gray) in Quartz (light gray)
This particular specimen contains about 53% scheelite.

PLATE VI
as replacement veinlets in the quartz biotite schist and the quartz amphibole schist. A certain amount of the gold is found with the pyrite. The examination of the replacement masses of pyrite in the schist shows the pyrite with a schistose structure. This is apparently due to the greater ease of replaceability of certain parts of the rock.

Marcasite is distributed very sparsely throughout the deposit. It was quite probably formed from percolating waters, which, while in an acid state, had come in contact with pyrite. It is not an important mineral constituent of the ores and is found very infrequently.

Galena occurs in pockets throughout the mineralized zone and takes no special form of deposition other than characteristic cubical crystals. Silver is always associated with the galena. The silver content of the galena is not visible and may be present in the form of argentite. The galena is quite definitely primary. Gold is also found with the galena.

Calcite occurs in small quantities and is frequently found with the galena. It is usually quite pure.

Limonite has been derived from two general sources: one is the iron content of the basic constituents of the country rock; the other is the iron content of the sulfide ores, arsenopyrite and pyrite. In the former case the limonite is found on the weathered surfaces of the
rocks. In the latter case, the limonite is found in the interstices of the sulfide veins where these have been subjected to the action of meteoric waters.

**Aluminum and Iron Sulfate (hydrates)** are found in a large open cut excavation in the southern part of the property. Here the flow of the meteoric waters has resulted in the deposition of a form of copperas and alum. They occur as mammilary shells and incrustations around joints and veins. The color of the incrustations varies from white and yellow to green and dark blue. The darker variety contains more iron than the lighter.

The probable course of events that resulted in this deposit was the formation of sulfuric acid from percolating ground waters which reacted with pyrite, followed by the attack of the alumina in the schists and shales, the resulting product being alum and ferrous sulfate.

**Sulfur** has formed from the decomposition of sulfides through the action of acid surface waters. It has been deposited in thin layers on the surfaces of rocks near the sulfide veins.

**Anglesite**, sulfate of lead, is found in tiny veinlets around galena deposits where the latter occurs in a more or less porous rock. The latter was essential to the flow of ground water solutions.
PARAGENESIS

Polished sections were made of all the primary ores in the district. In many cases, however, the granularity of both the pyrite and the arsenopyrite resulted in such poor surfaces that the examination had to be made megascopically.

Galena was found to replace both sulfide and gangue minerals. Veinlets of this mineral were found cutting arsenopyrite, pyrite, scheelite, and quartz. The quartz showed evidence of having been contemporaneous with these sulfides and also appears to have fractured the scheelite. Fragments of scheelite were found seemingly "floating" in the quartz.

Nearly all the specimens agreed as to paragenesis. The sequence is given below.

quartz ___________________________
arsenopyrite _______
pyrite _______
scheelite _______
calcite _______
galena _______

-19-
The mineral deposits at Jardine present an interesting problem which involves their localization, the origin of the metallizing solutions, temperature of formation, and their age.

The shear zones along which mineralization has taken place in a large part follow the bedding planes but a close examination shows that this has not always been the case. Several examples have been found where the shear zones cut directly across the bedding planes.

The type of deposition seems to be a result of both fissure filling and of replacement, the latter being the most important. The fact that the veins have followed what were apparently pre-existing shear zones necessitates a certain amount of fissure filling while suspended fragments of vein schist near the middle of relatively large quartz lenses implies that a considerable amount of replacement must have taken place. Further, the dissemination of arsenopyrite throughout the country rock allude to mineralization by replacement.

A study of the minerals suggests that they must have been deposited under relatively high temperatures both arsenopyrite and scheelite being indicative of such a condition. The cooler temperatures of the later stages of min-
eralization are indicated by the presence of galena.

No definite evidence has been found regarding the origin of the mineral solutions which were responsible for the Jardine deposits. An outcrop of gneissic granite has been reported however, on the south slope of Crevass Mountain. This may possibly be related to the igneous mass from which the solutions emanated. The diabasic dike mentioned previously in this report is also suggestive of the proximity of an igneous mass.

The deposit can not be classified as a contact deposit since no absolute proof of such a relationship has yet been found, the minerals are chiefly primary and the implacement has been metamorphic. The deposit is thus best called "hypothermal".

Conclusions on Origin.—The events incident to and following the vein formation in the Jardine and Crevass Mountain districts are by no means entirely clear. However, certain field and laboratory observations prompt the writer to advance what appears to be at least a plausible genetic history of these deposits. It is not to be regarded as final. Beginning with the oldest, the events in the history of the veins appear to have been as follows:

(1) Deposition of impure ferruginous and argillaceous sandstones in Pre-Cambrian time, probably early Pre-Cambrian.
(2) Deformation and probable granitic intrusion of the sedimentary series. Presumably as an effect of the compressive forces a rather well-defined set of shear zones formed. These now commonly transgress the "grain" of the well quartz schist, and presumably also transgress the original bedding. Along these shear zones the high-temperature solutions which emanated from the deep-seated igneous mass deposited their load, forming the veins. In the vicinity of the larger veins occupying shear zones, the quartz appears to have locally followed the bedding planes of the rocks.

The dating of the metamorphism with regard to the vein formation is conjectural. It is possible that the impure sandstones were subjected to some load metamorphism prior to their folding, and entirely possible, if not probable, that they were appreciably dynamically metamorphosed prior to shearing and introduction of the veins. It seems clear, however, that the veins themselves have been involved in compressive forces which affected veins and enclosing wall rocks alike. The evidence for the post-mineral deformation is (a) the structure and distribution of the veins, there being clear evidence of folding, (b) the conformity of the quartz veins
and lenses to the intricate foldings of the schists, suggestive that the schistose rocks with the stringers and lenticles of quartz parallel to the schistosity have been involved in the folding, (c) the folding and small scale faulting of the quartz seams show close relationship with the fracture cleavage of the schist, and (d) the drawing out and granulation of the quartz.

No trace or remnant of a pre-existing easily replaceable bed exists, such as would suggest a possible alternative explanation for the faithful conformity in many instances of the quartz seams to the schist. The conclusion seems inevitable, therefore, that at least some deformation is post-quartz.

(3) Whether or not the post-mineralization folding was epi-genetic in the sense of belonging to the same orogenic epoch as that which accompanied the vein formation, or of a later date is questionable. If later, the writer is inclined to regard it as Pre-Cambrian, and probably Pre-Belt, rather than of later date. Deformation during Laramide time did not produce, as far as is known, folding of the type exhibited in the Jardine-Crevass districts.
(4) Deep burial by Paleozoic and Mesozoic strata with possible further metamorphism.

(5) Probable faulting during Laramide time along faults subsidiary to the Gardiner thrust fault which is a fault of some magnitude. Unquestionably adjustments occurred in the Jardine deposits and in the Crevass region which lies immediately to the east of the Gardiner thrust.

(6) Removal of sedimentary strata which covered the deposits and oxidation of the minerals, especially in the upper parts, with production of an iron-stained schist from the original disseminated arsenopyrite rock.
CONCLUSIONS

During the relatively short period of time spent on the study of the Jardine deposits the following points were established. (1) The mineralization is probably the oldest in Montana. (2) The Jardine deposits and the Crevass Mountain deposits are part of the same mineral belt. (3) Secondary enrichment will never be important. Since the leached zone would have been scraped away by the strong glacial action to which the district was subjected, the present workings should lie in the enriched zone. No sign of such re-mineralization is present. (4) The deposit might, at depth, prove to be a contact metamorphic type. Though, as previously explained, no igneous mass has yet been encountered that could be definitely traced to the vein deposits, the reported gneissic granite on Crevass Mountain and the diabasic dikes to the north of the deposits might prove to be a stock and differentiate, respectively, of the igneous mass from which the solutions emanated.

The scheelite content of the ore has, very likely, not yet been fully appreciated. The justification of this statement lies in the difficulty of recognition of this mineral. In many instances it is difficult to distinguish from the quartz in which it lies. An aid in its detection will be given further on.

The question of the origin of the gold in the schist
is not yet clear. The high values in the iron-stained schist is somewhat suggestive of secondary enrichment. No evidence has been uncovered so far that would either prove or disprove such a theory. A method of attack of such a problem would be to prepare and carefully study a great number of assay maps, noting the relation between what is definitely known to be primary enrichment and that part which is not definitely known to be such. The crumbly nature of the material to be handled would again prove a hindrance to microscopic study.

There is a great amount of faulting, especially in the southern end of the Jardine district, which has not yet been adequately worked out. A detailed study of these faults and their relation to the Bear Gulch fault would be a great asset in the determination of the extent of the movements which have taken place in the region.
SCHEELITE EXPLORATION

Mention was made in the conclusions of this paper regarding the scheelite content of the ore. Following is a brief description of an apparatus which might prove a definite aid in its exploration both for study of occurrence and distribution and for mining as an ore.

In an enlightening explanation of the applicability of the ultra violet ray to the detection of scheelite, William O. Vandenburg* pointed out the essential features of such a machine which has been used successfully by the Nevada Massachusetts Company Inc. These features are as follows:

1. A small transformer that steps up 110-120 volts A.C. to 4,500 volts.

2. A mica condenser that has a capacity of 0.004 micro farads at 3,500 volts.

3. A spark gap with adjustable and replaceable iron electrodes.

The effect of the scheelite is to shorten the wavelength of the light coming from the ultra-violet ray machine thus rendering the rays visible and revealing the presence of the scheelite.

Since many of the drifts in the Jardine workings are not equipped with A.C. current it would be necessary

to include the following additions with the apparatus:

1. A 2.4 volt storage battery
2. A D.C. motor
3. One A.C. generator

The D.C. motor run by the battery would be coupled with the A.C. generator to produce the necessary alternating current.

It is to be understood that the above is merely a rough outline and that a certain amount of experimenting would be necessary in order to determine the manipulation which would give the best results.

The outfit described by Vandenburg weighed about eighteen pounds and could be carried around conveniently by one man but the added weight of the battery and motors would necessitate the use of a small car to facilitate transportation.
BIBLIOGRAPHY

Sahinen, U.M.
Mining Districts of Montana
Master of Science Thesis
Montana School of Mines 1935

Harker, A.
Metamorphism
Methuen & Co. Ltd. 1932

Powell, J.W.
U.S. Geological Survey Folio No.1 1894

Robie, E.H.
Arsenic Mining in Jardine
Engineering and Mining Journal Press Nov. 14, 1925
Vol. 120

Vandenburg, W.O.
A Note on the Use of Ultra Violet Lamps in Mines for
Rapid Detection of Scheelite in Ores by Fluorescence
U.S. Bureau of Mines Information Circular 6873
Dec. 1935