5-1939

Igneous Rocks of the Jardine and Crevasse Mountain Mining Districts.

Ray E. Gilbert

Follow this and additional works at: http://digitalcommons.mtech.edu/bach_theses

Part of the Ceramic Materials Commons, Environmental Engineering Commons, Geology Commons, Geophysics and Seismology Commons, Metallurgy Commons, Other Engineering Commons, and the Other Materials Science and Engineering Commons

Recommended Citation
http://digitalcommons.mtech.edu/bach_theses/91

This Bachelors Thesis is brought to you for free and open access by the Student Scholarship at Digital Commons @ Montana Tech. It has been accepted for inclusion in Bachelors Theses and Reports, 1928 - 1970 by an authorized administrator of Digital Commons @ Montana Tech. For more information, please contact sjuskiewicz@mtech.edu.
IGNEOUS ROCKS OF THE JARDINE AND Crevasse Mountain Mining Districts

by

Ray E. Gilbert

A thesis, submitted as partial fulfillment of the requirements for a Bachelor of Science degree in Geological Engineering.

May 1939
IGNEOUS ROCKS OF THE JARDINE AND
CREVASCSE MOUNTAIN MINING DISTRICTS

by

Ray E. Gilbert

A thesis, submitted as partial fulfillment of the requirements of a Bachelor of Science degree in Geological Engineering.

May 1939
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Geography</td>
<td>3</td>
</tr>
<tr>
<td>General geology</td>
<td>5</td>
</tr>
<tr>
<td>Economic geology</td>
<td>9</td>
</tr>
<tr>
<td>Extrusive rocks</td>
<td>10</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>10</td>
</tr>
<tr>
<td>Latite</td>
<td>13</td>
</tr>
<tr>
<td>Andesite</td>
<td>16</td>
</tr>
<tr>
<td>Basalt</td>
<td>18</td>
</tr>
<tr>
<td>Age relationships</td>
<td>20</td>
</tr>
<tr>
<td>Intrusive rocks</td>
<td>21</td>
</tr>
<tr>
<td>Granite</td>
<td>21</td>
</tr>
<tr>
<td>Granite pegmatite</td>
<td>24</td>
</tr>
<tr>
<td>Diorite</td>
<td>26</td>
</tr>
<tr>
<td>Age relationships</td>
<td>32</td>
</tr>
<tr>
<td>Conclusion</td>
<td>33</td>
</tr>
<tr>
<td>Bibliography</td>
<td>35</td>
</tr>
<tr>
<td>Plate</td>
<td>Illustration Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Index map of Montana</td>
</tr>
<tr>
<td>2</td>
<td>Map of Jardine &amp; Crevasse Mt. mining districts</td>
</tr>
<tr>
<td>3-A</td>
<td>View of Decker Flat</td>
</tr>
<tr>
<td>-B</td>
<td>View up Palmer Creek</td>
</tr>
<tr>
<td>4-A</td>
<td>Blocky rhyolite at top of Palmer Mt.</td>
</tr>
<tr>
<td>-B</td>
<td>Rhyolite dike below Decker Flat</td>
</tr>
<tr>
<td>5-A</td>
<td>East side of Mt. Baldy, showing</td>
</tr>
<tr>
<td></td>
<td>position of andesite</td>
</tr>
<tr>
<td>-B</td>
<td>Hand specimen of Baldy andesite</td>
</tr>
<tr>
<td>6-A</td>
<td>Basalt-gravel contact</td>
</tr>
<tr>
<td>-B</td>
<td>Hand specimen of basalt</td>
</tr>
<tr>
<td>7-A</td>
<td>Spherulites in basalt (45X)</td>
</tr>
<tr>
<td>-B</td>
<td>A between crossed nicols</td>
</tr>
<tr>
<td>8-A</td>
<td>Section showing relation between</td>
</tr>
<tr>
<td></td>
<td>basalt and Gardiner thrust</td>
</tr>
<tr>
<td>-B</td>
<td>Outcrop of basalt at point where</td>
</tr>
<tr>
<td>9-A</td>
<td>Hand specimen of large granite mass</td>
</tr>
<tr>
<td>-B</td>
<td>Pegmatite dike cutting schist</td>
</tr>
<tr>
<td>10-A</td>
<td>Hand specimen of porphyritic</td>
</tr>
<tr>
<td></td>
<td>diorite</td>
</tr>
<tr>
<td>-B</td>
<td>Feldspar phenocrysts weathered out of diorite</td>
</tr>
<tr>
<td>Plate</td>
<td>Between pages</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
</tr>
<tr>
<td>11-A</td>
<td>Magnetite needles in diorite ...... 31-32</td>
</tr>
<tr>
<td></td>
<td>B Hand specimen of diorite gneiss</td>
</tr>
</tbody>
</table>
IGNEOUS ROCKS OF THE JARDINE AND CREVASSE MOUNTAIN MINING DISTRICTS

by

Ray E. Gilbert

INTRODUCTION

It is surprising to learn that so large a variety of igneous rocks is present in the Jardine and Crevasse Mountain mining districts, a region that is generally thought of as consisting principally of schists. Particularly is this true when one considers that the district is old, easily accessible, and fairly well known. Of course, its nearness to an area of such extensive lava flows as are found in Yellowstone National Park, would lead one to suspect the presence of at least some extrusives; but in addition to these, there are also many intrusive bodies, as well as several interesting metamorphic rocks that are possibly of igneous origin.

During the summer of 1938 the writer had the opportunity to become acquainted with these rocks, while working for the Montana Bureau of Mines and Geology as field assistant to Dr. G. F. Seager, who was mapping the areal geology in the vicinity of Jardine. It was because of that work that this report was made possible, and the
Index Map of Montana Showing Location of Jardine, Montana
writer wishes to express his gratitude to the Bureau of Mines and to Dr. Seager, not only for giving him free access to hand specimens, thin sections, photographs, and field notes, as well as permission to use the preliminary map made during the summer, but also for the many helpful suggestions given during the laboratory study of the specimens. To Dr. L. I. Sloss goes the credit for the success of the photomicrographs of thin sections and the photographs of hand specimens, and thanks is due Dr. E. S. Perry for his help in pointing out a suitable attack of the problem. Both Dr. Perry and Dr. Seager offered helpful criticism of this manuscript.

The geology in the immediate vicinity of Jardine was mapped during the summer of 1937 by Dr. Seager and Walter Duykers, his field assistant. Their work is incorporated in the map accompanying this report.

A total area of approximately 20 square miles was mapped during the summers of 1937 and 1938 (see map at end of report). Most of the mapping was done with telescopic alidade and plane table, although some was done with Brunton compass and pacing traverses after control points had been established with the plane table. A base map showing patented claim corners and section corners provided a check on the accuracy of the work. Most of the roads and streams were mapped as the
traverses were carried along.

GEOGRAPHY

The Jardine and Crevasse Mountain mining districts are in the southern part of Park County, Montana, in Township 9 South, Range 9 East, along the northern border of Yellowstone National Park, a few miles east and northeast of Gardiner, (plates 1 and 2). The town of Jardine is six miles northeast of Gardiner at the end of a well graded road, while Crevasse Mountain is about 2\(\frac{1}{2}\) miles southeast of Jardine. The Crevasse Mountain district is accessible by a dirt automobile road that runs thru Jardine. A logging road provides a dubious means of automobile access to the Pine Creek area northeast of Jardine.

Steep mountain slopes and deep, narrow valleys characterize the Jardine and Crevasse Mountain area. Within a distance of four miles, elevations differ by 4,000 feet between the top of Palmer Mountain, in the east central part of the district, and Yellowstone River, which marks the lowest point in the region (5,400 feet above sea level). Southward from the map area, the Yellowstone has cut a deep canyon, where it flows out of Yellowstone Park, to be joined by the deep Bear Creek Gulch, which forms a southwestward trending gash across
A - View of Decker Flat, looking west toward Bear Creek. Basalt cliffs in foreground.

B - Looking east up Palmer Creek. Bear Gulch in left foreground.
the district. At the junction of these two, the Yellowstone bends back into the Park, only to emerge again at Gardiner and resume its northward course. Northeast of the junction and 600 feet higher, is a huge grassy flat covering nearly a square mile, bordered on the Bear Creek and Yellowstone River sides by an outstanding rim of basalt. This flat, known as Decker Flat, merges on the east into very steep, grass covered slopes, which in turn rise to form Buffalo Mountains and heavily timbered Crevasse and Oregon Mountains in the southeastern part of the district. Between these last two mountains and talus capped Palmer Mountain, north of them, is the head of Palmer Creek, a small stream that runs west into Bear Creek. West of Palmer Mountain, and separated from its timbered slopes by a low saddle, is the bare knob of Mount Baldy, which slopes down to Palmer Creek on the south, and to Bear Gulch on the west, while it is bounded on the north by the rather broad timbered valley of Pine Creek, another westward flowing stream joining Bear Gulch just above Jardine. Opposite Pine Creek is the canyon cut by the North Fork of Bear Creek, which joins the Main Fork at Jardine. Between North Fork and Pole Creek, a small east flowing stream to the south, is Hanlon Hill, which rises abruptly from the Jardine road to form part of the west side of Bear Gulch. Below Pole Creek a similar slope gradually swings away from the
Gulch, leaving a flatter area roughly equivalent to Decker Flat on the other side of Bear Creek.

**GENERAL GEOLOGY**

Pre-Cambrian schists, intruded by granite and diorite, have been thrown up against Paleozoic sediments along the Gardiner thrust, a huge fault in the southwestern part of the Jardine and Crevasse Mountain districts, and have been exposed by the erosion of overlying rocks. Several lava flows, during Tertiary time, again covered part of these exposed pre-Cambrian rocks, as did a still later Pleistocene basalt flow. Pleistocene glaciers cut deep valleys down thru these lavas and the underlying schists, and dumped their debris over the region. Much glacial material lies high on the mountain slopes. In a lake, formed by damming of Bear Gulch, possibly by a glacier in Yellowstone Valley, gravel, sand and clay sediments accumulated. These may now be observed in terraces at several levels in Bear Gulch. When the dam was removed, Bear Creek cut its present channel down thru the deposits, leaving remnants hanging along the sides of the gulch. Solutions moving along the plane of the Gardiner thrust deposited, and are still depositing, travertine along the fault outcrop.

The schists, which form the predominant rock of this
region, are of two general types, a gray biotite-quartz schist, and a darker quartz-amphibole schist, both of which are believed to be of sedimentary origin. Locally, thin zones of sugary white quartzite are found in the schist, and are probably caused by differences in the lithology of the original sedimentary strata. Very complex minor folding makes it exceedingly difficult, if not impossible, to determine the regional structure of these rocks.

In the southern part of the district, the schist is cut by a large granite mass, which is more or less gneissic, and near which are found several granite pegmatites that often grade into glassy quartz veins.

Scattered thru the district are many dikes and sills of diorite cutting the schist. These small masses are in some places quite gneissic, and in others appear to be unaltered. Locally, they contain large phenocrysts of feldspar. The largest bodies of diorite occur on Crevasse and Oregon Mountains, but there are also several prominent masses cropping out on both sides of Bear Gulch.

Interesting amphibolite zones, of minor areal extent, are found on Buffalo Mountain and on the slopes of Pine Creek Valley. The question of whether these zones represent severely metamorphosed igneous sills, or original sedimentary bedding, has yet to be settled.
Of the several extrusives in the district, that which occupies the largest area is a biotite rhyolite porphyry, hereafter referred to as the Palmer Mountain rhyolite. It covers the northeastern part of the map, and forms Palmer Mountain. Just how far beyond the limits of the map this rhyolite extends is not known.

Other rhyolite flows are found underlying an andesite flow on Mt. Baldy, and capping a small hill in the southeast corner of the map. One intrusive rhyolite dike was seen near the mouth of Bear Creek. The rhyolites differ from one another somewhat, chiefly in color, and in size and quantity of phenocrysts. Some show poor flow structure, others exhibit tuffaceous phases.

Next in areal importance to the Palmer Mountain rhyolite is a quartz latite porphyry that covers the hills along the west side of Bear Gulch, south of the North Fork. Another occurrence is found north of Pine Creek, bordering the western edge of the Palmer Mountain rhyolite. In one place at least, there is a thin vitrophyric member, while the flow capping Hanlon Hill is in part tuffaceous. The rock changes in color and texture as one follows it south, and it may be that there are two separate flows, though no distinct division is evident.

The only andesite found, with the exception of one
small area near the northwest corner of section 3, was
on Mt. Baldy. The Baldy andesite occupies the top of the
mountain as well as the saddle between Baldy and Palmer
Mountain.

Columnar basalts underlie Decker Flat and the area on
the opposite side of Bear Gulch. These represent the
latest flows, and rest unconformably upon schist, granite,
and ancient river gravels.

In the southwest corner of the area, on the footwall
side of the Gardiner thrust, are overturned strata of the
Madison formation, of lower Mississippian age. These
strata consist almost entirely of massive gray limestone.

Just west of the mouth of Bear Creek, this limestone,
as well as the schist on the other side of the fault,
is covered by a deposit of white to buff colored travertine.

Terrace gravels and clays are found along both sides
of Bear Gulch, and glacial drift is distributed over
nearly all parts of the district, excepting on the high
mountain tops. The rocks in this drift are nearly all
granite, and many large granite erratics can be seen in
the southern half of the region.
Economic Geology

Some of the gravels along Bear Gulch, below Jardine, were sluiced for gold as early as 1866, when placer gold was first discovered in the district, at the mouth of the gulch, and it was not until several years later that mining of the Jardine vein ores was begun. No placer gold is being produced at the present time, although Alex McDonald is driving prospect tunnels in an effort to reach pay dirt in the ancient Bear Creek channel that has been buried under basalt flows.

Ore minerals in the Jardine and Crevasse area, in the order of their economic importance, are gold, arsenopyrite, and scheelite, which occur in lenses or pods in mineralized shear zones in the folded pre-cambrian schists (9'). Most of the mining in the district has been done along the hill just east of Jardine, where three types of ore occur: 1) Large masses of decomposed iron-stained schist, carrying small particles of arsenopyrite and gold, 2) high grade arsenical ore, with large crystals of arsenopyrite imbedded in the hard quartz-biotite schist, which also carries gold, and 3) siliceous ore, largely quartz, containing payable quantities of gold, especially where it is fractured and iron stained. Similar smaller, and less

'Numbers in parenthesis refer to number of reference in bibliography.
economically important, deposits are found in the area Crevasse Mountain, where some small scale mining and prospecting is being done at the present time.

EXTRUSIVE ROCKS

Because the extrusives of the Jardine and Crevasse Mountain districts have a greater areal extent than do the intrusives, they will be described first. For descriptive purposes, it will be convenient to group all of those belonging to the same class together, irrespective of their areal or time relationship. That is, all rhyolites will be considered first, then the latites, and so on, to the more basic rocks, ending with basalts. The classification of the rhyolites and latites is a megascopic one, and may be subject to revision when thin sections of the rocks are studied.

Rhyolite

The largest rhyolite flow is in the northeastern part of the district, extending south to the head of Palmer Creek, making up Palmer Mountain, and swinging north across Pine Creek, to cover a total area of three square miles (Plate 3). On Palmer Mountain, and on the peaks north of Pine Creek this rock shows in blocky outcrops and prominent talus slopes, while its presence in
A - Top of Palmer Mountain, looking west. Shows blocky outcrops and talus of rhyolite.

B - Rhyolite dike below Decker Flat rimrock on eastern side of Bear Gulch.
the timbered and soil covered valley between can only be inferred from the float, which is practically all rhyolite. The outcrops generally show very irregular jointing, although some regular hexagonal jointing was seen on the eastern side of Palmer Mountain. On a peak in the northeastern part of section 3, the rhyolite has a remarkable slab structure, with plates breaking from an inch to several inches thick and up to two feet across. No evidence of flow structure, other than this jointing, was observed.

Cathcart, in an unpublished U. S. Geological Survey report, classified the Palmer Mountain rock as intrusive, but evidence for this is lacking in the mapped area.

The rock has a light gray to white, aphanitic groundmass, with tiny black specks of biotite and hornblende scattered thru it. The number and size of these small phenocrysts vary somewhat in different parts of the flow, but two specimens taken on opposite sides of Pine Creek, about 1½ miles apart, are almost identical. On the eastern peak of Palmer Mountain, however, is a 25 foot zone of purplish-gray, fine to medium grained, non-porphyritic rhyolite that furnishes the only marked variation from the typical Palmer Mountain rhyolite. A less noticeable variation is the presence of a few brownish bands that are suggestive of tuffaceous origin in part, although no pyroclastics are present.
Underlying the Palmer Mountain rhyolite near the head of Palmer Creek, is a darker rhyolite of undetermined thickness and extent. In most places it is buried under talus, so that nothing definite could be learned about it. However, the same rock is also found under the andesite flow on the eastern slope of Mt. Baldy, and its thickness there is indicated by float to be about 100 feet. This rhyolite, then, is older than both the Baldy andesite and the Palmer Mountain rhyolite.

This rock has a dark gray to purple, aphanitic groundmass, that is mottled by white blotches and streaks which locally indicate flow structure. Small feldspar phenocrysts, tiny needle-like crystals of hornblende, and fine grained biotite give the rock a porphyritic texture.

In the north central part of section 15, bordering the north side of Palmer Creek for about ½ mile, is a still different type of rhyolite porphyry. There are no prominent outcrops and the extent of the flow could be only roughly determined by float. It appears to be about 2500 feet long and between 300 and 500 feet wide, and is at a lower elevation than either of the other rhyolites described. Evidence of its age relationship to them is completely lacking.

No fresh specimen could be obtained, but greatly weathered specimens show a reddish-brown, aphanitic groundmass with quartz and feldspar phenocrysts all less than 1/8 inch across.
The only other rhyolite found in the mapped area occurs as a dike on the east side of Bear Gulch, a half a mile above the mouth of Bear Creek. The dike forms a prominent light brown wall, 50 feet wide and over 250 feet long, running down the steep side of the gulch, below the Decker Flat rimrock. Along the south side of this dike is a 30 foot zone of greatly sheared rhyolite, which may represent an earlier intrusion along the same vent, or which may simply be a sheared portion of the wall forming rock.

The resistant part is a light gray, phaneric rock, with grain size varying from very fine to medium. Feldspar, quartz, hornblende, and biotite can be identified megascopically. A yellowish alteration product of the feldspar is present, and the entire rock weathers to a brown surface.

Latite

Covering the hills west of Bear Gulch, below Jardine, is a large flow of latite porphyry, which varies somewhat in color and texture from point to point. The eastern contact of this flow with the underlying schist roughly parallels, and stays above, the Gardiner-Jardine road, while its western boundary is undetermined. The eastern contact swings away from Bear Gulch to follow Pole Creek north, and apparently never crosses the creek.
though coming almost down to it. The flow thus covers at least 3½ square miles, and probably extends a considerable distance to the north and west of the mapped area.

The latite forms prominent brown cliffs in places along the hillsides, some of which show good flow structure.

One vitrophyric member, about four feet thick, occurs in the lower part of the flow. Because of its being so low, however, it is generally hidden under talus or soil.

While the latite varies in color, specimens from different points all show nearly equal amounts of feldspar phenocrysts. Oligoclase, orthoclase, and minor quantities of hornblende and quartz are present as phenocrysts. The feldspar phenocrysts are up to 1/8 inch long, while the hornblende is in tiny needles. At some points, nothing but green blotches is left to furnish evidence of the former presence of hornblende. The aphanitic groundmass may be dark gray, a mottled gray and white, or even a light pink, in different localities.

The vitrophyric member has a shiny, black, glassy groundmass in which are white phenocrysts of oligoclase and orthoclase, usually less than 1/8 inch long. These phenocrysts make up nearly a third of the rock.

A small body of quartz latite porphyry, about 1/8 of a square mile in area, that caps Hanlon Hill, west
of Jardine, resembles the large flow south of Pole Creek closely enough in color and texture to be considered a part of that flow. Although the prominent cliffs that are seen farther south are absent, the outcrops along Hanlon Hill are the same brown color as those cliffs.

The approximate contact of the latite with the underlying schist can be seen, even from the opposite side of Bear Gulch, as a marked change in color from the reddish soil of the weathered lava to the grayish soil produced by the schist.

Some tuffaceous material was found on the dump of a tunnel just below the schist-latite contact, on the east side of the hill. The tunnel was caved, so that it was not possible to ascertain the relationship between the latite porphyry and its tuffaceous phase.

The Hanlon Hill latite has a dark gray, aphanitic groundmass, that is flecked with white phenocrysts of feldspar, much of which has been altered to kaolin, up to 1/8 inch long. The rock weathers to a reddish-brown, which accounts for the color of its outcrops.

Rock identical to the Hanlon Hill latite is found north of Pine Creek, where it is on an average 500 feet higher than that on Hanlon Hill. It occupies most of the northern half of section 3, and touches the western edge of the Palmer Mountain rhyolite, though the contact
is hidden under talus slopes, so that the relationship between the two can not be discerned. No remnants of the flow could be found between this northern occurrence and the Hanlon Hill rock.

A tuff is found in the southeast corner of the district, on a southward trending spur of Oregon Mountain. This rock forms slight cliffs that appear dark brown from a distance, and exhibits prominent jointing that dips steeply to the east. There are two small patches of the tuff, each about 600 feet in diameter, the northernmost and highest of which has a much more platy structure than the other, and is less resistant to weathering.

The rock has a dark, reddish-purple, glassy matrix containing lighter purple fragments of aphanitic material, as well as a few scattered sandine grains. These fragments, which vary from tiny specks to 4 inch in diameter, compose nearly fifty per cent of the rock.

Andesite

The principal andesite occurrence is that on top of Mt. Baldy, and in the saddle between Baldy and Palmer Mountain, in the southwest corner of section 10. That on the north peak of Baldy forms a cliff in a well bedded, slabby to blocky outcrop which dips between 40 and 60 degrees to the northeast. The andesite in the saddle
Plate 5

A - East side of Mt. Baldy, showing approximate limits of its andesite capping.

B - Andesite porphyry from Mt. Baldy.
seems to be the same flow as that on the peak, although its outcrops are less prominent. The flow has an areal extent of 1/7 of a square mile, and overlies a rhyolite flow that has already been described (page 12).

The fresh rock is a dark porphyry, with a grayish-black, aphanitic groundmass, in which there are many phenocrysts of shiny dark andesine, as well as few scattered pyroxene phenocrysts. These range up to 6 mm. long and from 1/5 to 1/6 as wide. The andesite weathers to a purplish-black, with some yellow limonite stains.

Microscopically, the rock consists of andesine and augite phenocrysts in a microcrystalline groundmass of plagioclase, with small subhedral grains of magnetite, and a scattering of secondary calcite, chlorite, and a highly birefringent, micaceous mineral, generally associated with the magnetite grains. The maximum extinction angle of the feldspar, which makes up $\frac{1}{3}$ of the rock, is 22 degrees to the albite twins, classing it as andesine ($\text{Ab}_6\text{An}_4$).

In the high country north of Pine Creek, just south of the northwest corner of section 3, is a small body of andesite porphyry not more than 150 feet by 450 feet in dimension. This porphyry appears to be the same rock as the Baldy andesite, and possibly belongs to the same flow. It is from 1,000 to 1,500 feet lower in elevation than the Baldy rock.
Basalt

The latest flow rocks are the basalts in the southwestern part of the district, on both sides of the lower end of Bear Gulch. The flow on the east side of the gulch forms Decker Flat, and covers an area of half a square mile, while that on the west side of the gulch, at about the same elevation, covers an unknown area, since only its eastern edge was mapped. The comparatively thin flows show remarkable columnar jointing, with the hexagonal columns as much as two feet across. This has resulted in an outstanding rimrock wall along the edge of Decker Flat, with a plainly visible contact at its foot with schist, granite, or old river gravels buried under the flows. Their approximate thickness was obtained by measuring the height of the rimrock, which was 160 feet near its eastern limit.

The basalt is generally porphyritic, with a black, very fine grained groundmass, and phenocrysts of plagioclase and sometimes of pyroxene, as well as some fine grained olivene. The plagioclase crystals vary in size from tiny needles up to euhedral crystals half an inch in length, while the pyroxene phenocrysts are nearly always less than 1/8 of an inch long. Locally, the rock may be quite vesicular and anygduloidal, with anygdules of calcite and limonite.
A - Gravels buried under Decker Flat basalt. Note columnar jointing in basalt, tunnels in gravel.

B - Hand specimen of the basalt.
Plate 7

A - Spherulites in basalt (45X).

B - Same field as A, between crossed nicols.
A microscope reveals olivene phenocrysts 1/3 of a millimeter in length in a groundmass of small, lath-like labradorite crystals and irregular grains of olivene andaugite, together with small, subhedral grains of magnetite. There is also some glass present, which forms small spherulites. Labradorite (Ab₄An₆) was proven by a maximum extinction angle on the feldspar of 35 degrees.

The basalts were extruded at a time when the topography was not much different than it is at present, and seem to have come up along the plane of the Gardiner thrust. Wilson (10) gives the following reasons for believing the basalts to have been extruded from the fault plane:

1. Their distribution is in an elongate belt along the outcrop of the fault plane.

2. The margins of the flows characteristically end flush along the outcrop of the fault. At some localities the basalt flowed to the southwest, and at others northeast, the direction of flow being wholly dependent upon the direction of slope of the topography with relation to the fault at the time of extrusion.

3. At several localities, notably a mile east of Gardiner, on the road to Jardine, the flows merge with the dikes that fed them. This is shown in the change from vertical columnar jointing in the flows to oblique
A - Diagrammatic cross-section across the fault zone one mile east of Gardiner showing the postulated relation between the basalt and the Gardiner thrust.

From Wilson (10, p. 659)

B - Basalt outcrop at point where section was taken, looking east.
jointing in the dikes (plate 8). These dikes occur in the fault plane, and have the same strike and dip as the fault plane.

**Age Relationships**

Evidence to establish the relative ages of the lavas is lacking in the comparatively small area mapped, and efforts to correlate the flows with those in the surrounding region, as described in the Livingston and Yellowstone Park folios (8,9) of the U. S. Geological Survey, are rather unsatisfactory. A tentative correlation based on Weed's work in the Livingston folio indicates the andesites to be the oldest, followed in order by the latites, the rhyolites, and last of all, the basalts.

These flows are all of Tertiary age, with the possible exception of the basalt, which may belong to pre-glacial Pleistocene.
INTRUSIVE ROCKS

Most of the intrusives of the Jardine and Crevasse Mountain district can be classed as either granite or diorite. A few, however, fall under related classes such as granite pegmatite and dolerite. The granite, since it composes the largest single intrusive mass in the district, will be described first.

Granite

A large body of granite has intruded the schists in the southern part of the mapped area. This granite covers at least a square mile, and probably represents only the northern edge of a much larger mass. Outcrops of the rock are few and obscure, because it is covered in most places by glacial drift. Granite erratics in the drift make it almost impossible to determine the granite-schist contact by examination of float.

A typical specimen of the granite appears light gray at a distance, but is revealed by closer inspection to be a mottled gray, white, and buff. It contains medium to coarse grained feldspar, quartz, and biotite, with alteration products of the biotite giving the rock its peculiar buff tint. The grains have a rough, hardly discernable orientation, that produces a slight gneissic appearance.
Locally, the rock contains no mafic minerals, but is composed entirely of feldspar, quartz, and muscovite. As such, it can be classed as an alaskite, or alaskite gneiss, since it generally has a noticeable orientation of mineral grains. The alaskite is a white, medium grained rock, with brown stains along its numerous joint surfaces.

Granite pegmatite dikes are found closely associated with this intrusive mass, and will be described later under that subhead.

Several smaller bodies of granite and granite gneiss are found in the southern part of the district. Among these is one that forms a small rounded knoll at the edge of Decker Flat, near the center of section 20. This granitite, which resembles the rock of the larger mass, is less than 400 feet across, and is almost hidden under glacial debris.

Still farther west, and below the Decker Flat rim-rock, is an elongate zone of granite or alaskite gneiss, that forms a prominent pink outcrop. This band, which is less than 100 feet wide, parallels the rimrock for more than 1,000 feet.

The rock is a pinkish-gray, coarse grained gneiss, composed of orthoclase, quartz, and muscovite. The musco-
covite is streaked out in glistening planes parallel to the gneissic structure.

A short distance west of this last granite is a granite dike, on the eastern side of Bear Gulch. The dike is not over 50 feet wide by about 400 feet long, and runs down the side of the gulch nearly at right angles to the rimrock at the top of the slope. The granite is almost buried by talus, and one could pass within a short distance of it without realizing that he was near a dike.

The granite is a light bluish-gray, medium to coarse grained rock, consisting of feldspar, quartz, and biotite. About 15 per cent of the rock is biotite. There is no orientation of the grains, nor any other evidence of shearing.

In a diorite body near the top of Crevasse Mountain is a granitic segregation, or dike-like zone, which has no sharp, clear cut boundaries, but which does appear to be a granite dike cutting the more basic rock. If so, it is indicative of the later age of the granites in the area.

This rock is a yellowish-gray, coarse grained intrusive, with subhedral crystals of feldspar, quartz, and biotite, and needle-like hornblende crystals. The feldspar is stained yellow to orange. Dark minerals compose nearly a third of the rock.

-23-
A - Typical specimen of the large granite mass in the southern part of the district.

B - Pegmatite dike cutting schist on south side of Crevasse Mountain.
Granite pegmatite

Along the borders of the large granite intrusion are found many pegmatite dikes cutting the surrounding schists. In addition to these, others are found as far as 2 1/2 miles away from the mapped granite-schist contact. Three of the pegmatites are exposed in small prospect cuts near the head of Palmer Creek, in the central part of section 14. Another one is similarly exposed near the trail at the head of Pine Creek, and yet another is found on the high point between North Fork and Bear Creek. This last one cuts a prominent diorite outcrop, and is therefore younger than the diorite. In the north central part of section 19, on the west side of Bear Gulch is a comparatively large dike, about 50 feet wide by over 100 feet long in the outcrop. The longest dike mapped, however, is much nearer the granite contact, in the southeastern part of section 22. This dike, though only a few feet wide, can be traced for 500 feet along its strike.

The pegmatites vary in width from several feet down to fractions of an inch. Small ones occur as thin lith-par-lit injections in schist, generally along the borders of wider dikes. No prominent outcrops are formed by the pegmatites; rather, one could pass over many of them without realizing it, if they had not been exposed by prospect cuts or trenches. The pegmatites are in general parallel
to the schistosity of the adjacent rock, and are themselves more or less gneissic.

The mineralogy of all of the pegmatites in the district is quite uniform, although percentages of different minerals may vary considerably. Glassy quartz and white feldspar are predominant, while muscovite, biotite, garnet, and tourmaline may be present in minor quantities. Specimens show gradations from practically all feldspar with small, scattered quartz lenses, to glassy quartz veins with feldspar completely absent. In fact, this very thing can be seen in a hand specimen of a four inch dike or vein, in which a central zone nearly 100 per cent quartz is bordered on each side by an inch zone of feldspar containing a few intergrown quartz crystals.

The pegmatitic quartz is milky to smoky, and sometimes badly sheared, with yellow stains along the joints. The smoky quartz looks exactly like typical Jardine vein quartz. Feldspar in the dikes is usually coarse grained and intergrown with the quartz, but when it makes up most of the dike it may have a fine grained, sugary texture. Both albite and orthoclase are present. Muscovite occurs in small segregated masses as coarse, platy, hexagonal crystals, or along the shear planes of the gneissic facies, or as a thin layer along the pegmatite-schist contact.
Biotite, when present, is medium grained, and is associated with quartz, or is along the borders of the dikes. Small, euhedral to subhedral, brownish-pink garnets, either almandite or spessartite, are sometimes associated with the quartz and biotite. Tourmaline is rare, and when present is in tiny black needles usually less than 3 mm. long.

Schist intruded by the pegmatites often shows no alteration, but at times it is so changed along the contact that megascopically it resembles a diorite. Near the dike on the west side of Bear Gulch are lit-par-lit injections of pegmatite in schist, that have produced long radiating amphiboles along the borders.

Diorite

In this paper, some rocks that might be called dolerites in a strict classification, will be grouped under diorites, because after all, a dolerite is nothing more than a textural variety of the diorite clan (2,p.89).

The diorites occur as dikes, sills, and irregular masses, distributed widely thru the district. The largest masses are on the near Crevasse Mountain and along the sides of Bear Gulch. Being more resistant to weathering than the schists in which they are found, the gener-
ally form dark massive outcrops that sometimes stand out
as rounded knolls or as cliffs that rise in steps. Al-
though the diorites vary in grain size, and are locally
porphyritic and sometimes rather schistose, they all have
the same greenish-black color, and their outcrops always
look about the same. In several places they are cut by
quartz veins, some of which resemble the typical Jardine
vein quartz.

The top of Crevasse Mountain is formed by part of an
elongate mass of diorite which is nearly 2,000 feet long
and between 200 and 500 feet wide. The long axis of this
body lies nearly due north and south. Separated from this
diorite by only 200 feet of schist is a much larger mass
that extends down the northeast slope of Crevasse Mountain.
It has an area of over a tenth of a square mile. A com-
paratively small diorite dike, with an east-west trend,
crops out on the western side of Crevasse Mountain, not
over 100 feet away from the diorite that forms the top
of the mountain. This outcrop is 300 feet long, and only
about 75 feet wide. Not a very great distance east of these
bodies is another diorite mass, on the north side of
Oregon Mountain. A precipitous slope is formed by this
A - Hand specimen of porphyritic diorite, showing one feldspar phenocryst.

B - Large feldspar phenocrysts that have weathered out of the diorite.
diorite, which is nearly 300 feet wide and 1,500 feet long, with a northeasterly trend. Two small dikes, a few feet in width, are found between this and the Crevasse Mountain diorites. Farther south, on a spur running down from Oregon Mountain, in the northeast quarter of section 23, is still another patch of diorite, about 300 feet across.

It is not hard to imagine a single large diorite body underlying all of thesecroppings at no great depth, with its irregular top exposed in places that are separated by remnants of the schist roof.

A somewhat similar condition is found on the western edge of Bear Gulch, where a zone of diorite outcrops extends from the north central part of section 19, across the southeast quarter of section 18, to the west central side of section 17. The two largest outcrops in this zone form low, rounded knolls; one just south of the northern quarter corner of section 19, the other on the eastern side of the Jardine reservoir along the Gardiner-Jardine road. The one near the reservoir is over 1,200 feet long and as much as 300 feet wide, while the other is 500 feet by 200 feet in dimension. In line with, and northeast of, these two are several small outcrops of diorite, seldom more than 100 feet in diameter. Gravelstseparate thecroppings, which are 100 to 500 feet apart, so that it cannot
be seen whether they represent isolated patches in the schist, or one mass with only the higher points sticking through the gravels. In any event, it is very probable that this entire zone of outcrops is indicative of the upper part of a wide north-easterly dike, nearly a mile long. It is interesting to note that if the trend of this zone was extended, it would pass thru the Jardine Hill, approximately parallel to a large fault that has cut off the ore deposits. Could this large dike represent a weak zone along which branch faulting occurred at the time of the Gardiner thrust faulting? The very schistose appearance of some of this diorite, as well as the presence, in one place, of a four inch band of travertine along the diorite schist contact, suggest the possibility of this.

A smaller group of dioritecroppings is found on the point between Bear Creek and Palmer Creek, in the central part of section 17. The largest one of these is less than 1,000 feet long by 250 feet wide, and forms a prominent black outcrop plainly visible from the Jardine road on the opposite side of the gulch. A short distance north-east of this is a greatly sheared diorite less than 100 feet across. On the Palmer Creek side of the point is still another small irregular body of diorite, which is probably nothing more than another outcrop of the larger body.
Besides these groups of diorite bodies, there are also several isolated masses and dikes in the district. The largest of these is on the northern side of Pine Creek, just southwest of the center of section 3. It has a roughly circular shape and is about 500 feet in diameter. A mass about half that size outcrops high on the point between North Fork and Bear Creek. The prominent black cropping can be plainly seen from Jardine, and from even farther down the gulch.

Small diorite dikes are found on the Jardine Hill, where they seem to be associated with, and are very probably responsible for, the ore deposits. Another dike is just north of the Hanlon Hill latite, and still another crops out on a point of the ridge between North Fork and Pole Creek, in the north central part of section 5. Diorite dikes occur near the top of Mt. Baldy, and one about 30 feet wide appears far down the south slope of the mountain. Below the Decker Flat rimrock, in the southeast quarter of section 19, is an outcrop of a north-south diorite dike.

The diorites are all about the same greenish-black color, though they may acquire a reddish tinge on weathering. They are usually fine to medium grained, and rare-
Besides these groups of diorite bodies, there are also several isolated masses and dikes in the district. The largest of these is on the northern side of Pine Creek, just southwest of the center of section 3. It has a roughly circular shape and is about 500 feet in diameter. A mass about half that size outcrops high on the point between North Fork and Bear Creek. The prominent black cropping can be plainly seen from Jardine, and from even farther down the gulch.

Small diorite dikes are found on the Jardine Hill, where they seem to be associated with, and are very probably responsible for, the ore deposits. Another dike is just north of the Hanlon Hill latite, and still another crops out on a point of the ridge between North Fork and Pole Creek, in the north central part of section 5. Diorite dikes occur near the top of Mt. Baldy, and one about 30 feet wide appears far down the south slope of the mountain. Below the Decker Flat rimrock, in the southeast quarter of section 19, is an outcrop of a north-south diorite dike.

The diorites are all about the same greenish-black color, though they may acquire a reddish tinge on weathering. They are usually fine to medium grained, and rare-
ly coarse grained. Porphyritic facies have a groundmass that can not be distinguished from the non-porphyritic diorites, and contain large subhedral to euhedral phenocrysts of light gray plagioclase. Some of the diorites show no orientation of mineral grains, others can hardly be told from the typical quartz-amphibole schist of the district, while still others exhibit gradations between the two.

Microscopically the diorites are composed of nearly equal amounts of andesine and hornblende. In addition, there is some biotite, that seems to be an alteration product of the amphibole, and varying amounts of other secondary minerals, such as chlorite and calcite. A very small percentage of quartz is usually present, and an opaque mineral, probably magnetite or ilmenite, is found in irregular grains or in peculiar intergrowths of spindle-like crystals (Plate II). The maximum extinction angle on the feldspar varied from 13 to 23 degrees in different specimens, all being within the range of andesine (Ab$_7$An$_3$ to Ab$_6$An$_4$). The amphibole is strongly pleochroic from light to dark green.

The Oregon and Crevasse Mountain diorite is medium to coarse grained, with slender, needle-like crystals of amphibole. It is locally porphyritic, with widely scat-
A - Magnetite needles in diorite (45x).

B - Specimen of sheared diorite from west side of Bear Gulch.
tered plagioclase phenocrysts that range up to three inches in length. On the north side of Crevasse Mountain, a fine grained slightly schistose facies was observed.

The Bear Gulch diorites resemble this fine grained facies somewhat, but they are generally much more schistose. One of the small bodies consists of a very porphyritic diorite in which plagioclase phenocrysts make up nearly half of the rock. The phenocrysts are between 5 and 25 mm. long, and are often irregular, broken, and augen shaped, and at times are nothing more than streaks. The groundmass has a micaceous, schistose appearance. Quartz seams in the diorite are definitely later than the phenocrysts, since the seams either deflect around the phenocrysts, or thin where they pass. Evidently the rock was originally a porphyry, and the phenocrysts have simply been shattered by later shearing forces acting on the rock.

Other diorites of the district closely resemble either the Bear Gulch or the Oregon and Crevasse Mountain diorites, with perhaps the exception of the diorite north of Pine Creek, which differs from the others in that it has a medium grained, diabasic texture.

Age Relationships

Since granite and pegmatite have been found cutting
the diorite in a few places, and since glassy quartz, which is often associated with the pegmatites, has been found cutting the diorite in several places, it seems logical to conclude that the diorite is earlier than the granite and its satellitic dikes. Also, since all of the intrusives show more or less evidence of having been subjected to shearing forces, it is probable that they were intruded at least before metamorphism of the country rock was completed.

CONCLUSION

The sequence of igneous activity in the Jardine and Crevasse Mountain district was, first, the intrusion of large masses of diorite, followed by the intrusion of granite and the emanation from it of pegmatitic segregations -- all in pre-Cambrian time. These intrusives were exposed by erosion, and not until Tertiary time was the first flow rock, an andesite extruded. This flow was followed, in order, by latite, rhyolite, and finally basalt, flows.

Future work suggested by the study of these igneous rocks is the definite classification of the so-called quartz latite by microscopic examination of thin sections;
the reconnaissance of a wider area to correlate the lavas with those in Yellowstone Park, if possible; a detailed microscopic study of the garnet amphibolites of the district in an effort to ascertain their origin; and a careful study of the ore deposits with the hope of proving their association with the diorites.
EXPLANATION

SEDIMENTARY ROCKS
- Travertine
- Alluvium and glacial deposits (gravels, sands, and clay)
- Madison formation (massive gray limestone)

METAMORPHIC ROCKS
- Schists and quartzites (biotite-quartz and quartz-amphibole schists, locally garnetiferous; biotite quartzites)
- Amphibolite (garnetiferous)

EXTRUSIVE ROCKS
- Basalt (locally porphyritic, vesicular, and amygdaloidal)
- Quartz latite porphyry (includes vitrophyre and tuffs)
- Biotite rhyolite porphyry
- Andesite (includes porphyries and treads)

INTRUSIVE ROCKS
- Granite and granite pegmatite (batholith, dikes, gneissic)
- Diabase (irregular masses, dikes; locally gneissic, porphyritic)
- Dolerite (small irregular masses, dikes; locally amphibolitic)