STATE OF IDAHO
C. Ben Ross, Governor

IDAHO BUREAU OF MINES AND GEOLOGY
A. W. Fabrénwald, Director

A PRELIMINARY REPORT
ON THE GEOLOGY AND CHER DEPOSITS OF THE EASTERN PART OF THE YELLOW PINE DISTRICT, IDAHO

By
L. W. Currier

Prepared in cooperation with the United States Geological Survey

University of Idaho
Moscow, Idaho
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A PRELIMINARY REPORT
ON THE GEOLOGY AND THE DEPOSITS OF THE EASTERN
PART OF THE YELLOW PINE DISTRICT, IDAHO

By
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LOCATION AND ACCESSIBILITY OF AREA

The Yellow Pine mining district of central Idaho lies in the northcentral part of Valley County, east of Yellow Pine, a small settlement on a tributary of the South Fork of the Salmon River, and about 30 miles east of the town of McCall. The district is accessible by a good automobile road from Cascade, a lumber town on the McCall branch of the Oregon Short Line. The distance from Cascade to Yellow Pine is about 70 miles. The key map (Fig. 1) indicates the location of the area.

This preliminary report deals only with the eastern part of the Yellow Pine mining district, in the vicinity of the Meadow Creek mine of the Yellow Pine Co., and the cinnabar prospects to the north. This area is reached from Yellow Pine by an automobile road that follows the East Fork of the South Fork of the Salmon River for 12 miles to the mouth of Meadow Creek, where the Meadow Creek mine is located. The road from Cascade to Yellow Pine and from Yellow Pine to the mouth of Profile Creek, about 4 miles east of the settlement, was built and is maintained by the Forest Service; the part from Profile Creek to Meadow Creek was built by the Yellow Pine Co. The Forest Service also extended its road from the East Fork up Profile Creek for several miles and in the summer of 1932 continued construction toward the north, with the object of connecting with a similar highway that now extends from Mc Call through Warren to Edwardsburg. When completed, the road from Yellow Pine to Ed wardsburg will greatly aid the development of the mineral belt that extends northward from Meadow Creek to Ed wardsburg.

Landing fields at Yellow Pine and Meadow Creek make it possible to reach these points by airplane, and such service has been utilized for transportation of passengers, mail, and light supplies during the winter and spring since November 1930.

FIELD WORK AND SCOPE OF REPORT

This report is based upon field work done during a period of about 2 months in the summer of 1932. Lack of adequate and accurate base maps made it necessary to limit the geologic investigations of the field season to a preliminary survey over an area of about 30 square miles and to a study of the petrologic and mineralogic features of the area. Detailed structural and areal mapping was not attempted. This report presents, therefore, a rather generalized view of the geology of the area and a more detailed description of the petrology and types of mineralization, particularly with respect to the conditions at the Meadow Creek mine.

The preliminary geologic map (Fig. 2) offers a picture of the larger structural and stratigraphic features of the area but does not present the degree of structural detail that ultimately should be worked out for the area extending north and northwest from the Meadow Creek district to the Ed wardsburg district when an adequate topographic base map becomes available.
Fig. 1. Map of the State of Idaho, showing location of Yellow Pine and Thunder Mountain districts. (1) Yellow Pine district (shaded portion, area covered by this report). (2) Thunder Mountain district.
Numerous papers on the geology of central Idaho have been consulted and drawn upon for general and specific data, as well as several base maps by D. C. Livingston, A. O. Basor, and H. D. Bailey. The writer is also indebted to G. W. Worthington, mine superintendent at Meadow Creek, for permission to study the mine of the Yellow Pine Co.; to H. D. Bailey, engineer and geologist of the same company, for valuable help and information including mine maps showing certain structural details 2/; and to C. P. Ross, of the United States Geological Survey, for additional helpful facts and discussions.

The writer was capably assisted in the field by Harry N. Eaton and Roger H. McConnell.

SELECTED BIBLIOGRAPHY

Several brief reports on the Yellow Pine and Thunder Mountain districts have been published. The most useful of these are listed below:


2/ Since the preparation of this report, a brief article by H. D. Bailey, entitled "Ore genesis at Meadow Creek mine" has appeared in the Engineering and Mining Journal (vol. 135, no. 4, p. 162, April 1934). In this paper Bailey describes the structural relations of the ore bodies and the sequence of mineralization. Part of the structural data he gives were accumulated by him during the development period in the winter of 1932-33, after the writer's visit to the field, and he kindly furnished the writer with additional facts at that time. Still later development disclosed more data, and Bailey's paper should be consulted to augment and supplement the information contained in the present report.
TOPOGRAPHY

The maximum relief of the Yellow Pine district is about 4,200 feet, with altitudes above sea level ranging from about 4,800 feet at Yellow Pine to slightly above 2,000 feet on the crests of the highest peaks in the eastern part of the district. The area covered by Figure 2 has a relief of about 3,000 feet, the difference between the altitude of the peaks at the east (9,000 feet) and the mouth of Sugar Creek, tributary to the East Fork at the western edge of the area (about 6,000 feet).

Steep, rather smooth slopes, narrow V-shaped major valleys with tributary gorges, and rounded divides mark the youthful stage of topographic development of this region. The local master stream is the East Fork of the South Fork of the Salmon River, hereinafter called the "East Fork". Its valley at Sugar Creek shows a relief of 2,500 feet. Here the valley floor is narrow, but from a point about a mile above Sugar Creek the floor is fairly flat and gradually increases in width to about a quarter of a mile at the mouth of Meadow Creek. This relatively broad valley plain continues for about half a mile up Meadow Creek, but just above the mouth of Meadow Creek the valley of the East Fork becomes narrow and continues so for a distance of nearly a mile, above which it again displays a broad plain nearly to the limit of the mapped area. Much glacial debris is found at several places along the valley of the East Fork, and it is obvious that locally the configuration of the valley has been considerably influenced by valley glaciation.

The broad flat plain of lower Meadow Creek just above its junction with the East Fork provides an excellent landing field for airplane service to the Meadow Creek mine of the Yellow Pine Co.

Glacial cirques form the heads of several tributary valleys, notably those of Cinnabar and Fern Creeks, and low ridges of morainic deposits are found at places within these valleys and along the East Fork. At a few places, especially on upper Cinnabar Creek, deposits of landslide material merge into the glacial deposits. The thickest deposits of glacial till are found in the valley of the East Fork between Sugar and Meadow Creeks, and at one place on the north side a prospect tunnel, started in rock, passes through a small filled preglacial valley.

GENERAL GEOLOGY

GENERAL FEATURES

The Yellow Pine district lies almost in the center of the large area in which the granitic rocks of the Idaho batholith are exposed. At several places in central Idaho remnants of Paleozoic and earlier sedimentary formations constitute roof pendants within the batholithic area, and one mass of this type is present in this district. According to C. F. Ross 1/ this roof pendant is one of the largest known in the Idaho batholithic area. Numerous dikes, chiefly of intermediate to basic character, cut both granite and sedimentary rocks, and in addition narrow aplite veins are abundant at many places in the exposed granite.

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1/ Personal communication.
Fig. 2. Reconnaissance geologic map of the eastern part of the Yellow Pine mining district. Base from topographic maps by D. C. Livingston and claim map of Yellow Pine Co.
Along the eastern and northeastern borders of the district the granitic and sedimentary rocks are overlain by a thick series of Tertiary lavas which dip gently to the east and northeast. The western edge of the lava sheets has been beveled greatly by erosion. Doubtless the beds once covered a considerable part of the region to the west of their present exposures, possibly a large part of all of the mapped area. To the east the lava series increases greatly in thickness and constitutes the country rock of the adjoining Thunder Mountain district.

The sedimentary rocks occupy an area 15 miles long and probably 1 to 3 miles wide, extending in a direction northwest and north by west from the Fern Creek-Monumental Creek divide to the vicinity of Profile Gap, 6 miles southwest of Edwardsburg. The beds are variously and in some places considerably metamorphosed, in part by dynamic forces, in part by igneous action at and near contacts. Limestone beds of the series have been particularly affected. In the Fern Creek-Cinnabar Creek region the limestone beds contain deposits of cinnabar.

Although the sedimentary rocks cover a considerable area, the prevailing country rock of the Yellow Pine district is the granitic rock of the Idaho batholith. For the most part the material may be classified as quartz monzonite, but local facies are somewhat more calcic and less silicic.

SEDIMENTARY ROCKS

Lithology

The sedimentary rocks of the mapped area consist of a series of beds of quartzite, schist, and limestone that from the roof pendant. These rocks have been metamorphosed in varying degrees by both dynamic and contact metamorphism. Close folding with probably overturning and a lack of fossils or structural features that might serve in distinguishing and correlating individual beds make it impossible to state exactly their sequence and thickness. Pronounced metamorphism of the limestone and of the beds that were originally argillaceous has obscured lithologic continuity.

Quartzite and crystalline limestone constitute the major portion of the sedimentary rocks, but at several horizons mica schists, originally argillaceous sediments, are found either within thick quartzite or separating quartzite and marble.

The sedimentary rocks are exposed in a belt that trends northwest, following the general strike of the beds. This belt is 1 to 3 miles wide and about 6 miles long in the mapped area, but it is known to extend several miles farther to the northwest. At the southeast end, about three-quarters of a mile east of Fern Creek, the outcrop is terminated abruptly by the overlapping Tertiary lavas. Along Sugar Creek the belt is apparently narrowed by close folding and shearing, but north of this creek the outcrops of sedimentary rocks extend through a width of 3 miles. At several places small isolated exposures or cupolas of granite appear.

The prevailing dips of the sediments are 80°-85° NE., but lower and northwest dips are also common in many places. The maximum thickness is probably 4,000 to 6,000 feet in the Fern Creek area. In the general vicinity of the Fern Creek mine about 1,000 feet of quartzite and 500 to 600 feet of marble are exposed; the quartzite includes 200 to 300 feet of siliceous mica schist and 400 to 500 feet of quartzite conglomerate. The section along Sugar Creek
is incomplete; it shows 700 to 800 feet of quartzite (including a small amount of sericitic schist) and 550 to 600 feet of limestone. The quartzite and limestone beds are apparently repeated by close folding and faulting, as indicated by the sections in Figure 9. In general, the sedimentary column apparently consists in its lower part of thick quartzite (locally with schist beds near the top) and in its upper part of limestone (alternating with quartzite) and schist. The Fern Creek section differs from the Sugar Creek section chiefly in the conglomeratic character of part of the quartzite ("pebble quartzite"); it is possible that some of the quartzites of the Fern Creek section are different beds from those exposed along lower Sugar Creek, although they doubtless belong to the same series.

Clearly the sedimentary rocks of the area were originally (1) sandstone of a high degree of purity, (2) argillaceous sandstone and shale, and (3) limestone. These have been metamorphosed, respectively, into (1) quartzite, (2) sericitic quartzite and mica schist, and (3) crystalline limestone or marble. These transformations were doubtless brought about by both the dynamic effects of folding and shearing and by the thermal and silicifying effects of granitic intrusions. At some places hornfels facies were produced in narrow contact zones, and at others the limestones were considerably mineralized by contact metamorphism, though this type of change apparently produced no deposits of economic value.

The quartzites are white or light gray and display a vitreous luster and conchoidal fracture. The greater parts are massive, showing the original stratification planes faintly, but some contain thinner layers. Where the original sandstone contained clay material, sericitic schistose phases developed. In the upper Fern Creek area a considerable thickness of the quartzite is conglomeratic and contains abundant well-rounded and, in places, well-sorted quartz pebbles.

Locally, beds that were originally argillaceous sandstones and shales have become sericite and muscovite schists. Where affected by igneous intrusions as well as shearing, as in the vicinity of the Kennedy "mica ledge" prospect on Sugar Creek, biotite-muscovite schist and hornfels were formed.

The limestone beds are completely recrystallized, white to buff, and thin- to thick-bedded. They do not react readily with dilute acid and are doubtless highly dolomitic.

The age of the sedimentary rocks is not known, as they contain no fossils and are remote from other areas in which the age can be determined. Sediments that are highly metamorphosed and probably older occur in the Yellow Pine district just west of the mapped area. On the basis of their general similarity to rocks exposed in areas to the east and southeast and their striking difference from pre-Cambrian (?) beds in central Idaho, Ross suggests that the sediments of the Fern Creek-Sugar Creek belt are probably of lower Paleozoic age.1

Stratigraphy and structure of the sedimentary rocks

In general the sedimentary beds have been closely folded and in places overturned. This condition, combined with the absence of recognizable key beds within the series and the lack of continuity of exposures, renders it impossible to present a satisfactory structural cross section of the entire sedimentary

1/ Personal communication.
Fig. 3. Generalized cross sections along lines A-A' and B-B' in Figure 2 illustrating structural relations between roof pendent, granitic rocks of Idaho batholith, and Challis volcanics. The sections are interpretative only and do not indicate details of structure of the sedimentary rocks. Scale, same as map, Figure 2.
belt, though local structure is clearly observable in places.

On Sugar Creek the succession of beds as exposed from west to east is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Feet</th>
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<tbody>
<tr>
<td>Quartzite</td>
<td>100</td>
</tr>
<tr>
<td>Limestone</td>
<td>75</td>
</tr>
<tr>
<td>Quartzite</td>
<td>250-350</td>
</tr>
<tr>
<td>Limestone</td>
<td>350-400</td>
</tr>
<tr>
<td>Quartzite</td>
<td>100-150</td>
</tr>
<tr>
<td>Limestone</td>
<td>100+</td>
</tr>
<tr>
<td>Quartzite beds repeated by folding</td>
<td>800+</td>
</tr>
<tr>
<td>Limestone</td>
<td>100+</td>
</tr>
<tr>
<td>Quartzite</td>
<td></td>
</tr>
</tbody>
</table>

The quartzite contains some siliceous mica schist.

Along Fern Creek to the divide between Fern and Cinnabar Creeks the following succession of beds from southwest to northeast is noted:

1. Quartzite (in contact with granodiorite). Feet
2. Granodiorite cupola 200+
3. Limestone (probably same as 2) 200+
4. Quartzite, conglomeratic
5. Quartzite 2,000
6. Quartzite, conglomeratic (may be same as bed 4, repeated by folding)
7. Limestone (contains cinnabar at Fern mine) 500+
8. Thin calcareous schist 50?
9. Quartzite, conglomeratic in part (repeated by local folding) 1,500+
10. Limestone (contains cinnabar at Hermes mine) 200
11. Quartzite and schist 200
12. Limestone, quartzite, and schist series 1,000+

Reversal of dip in beds 6 and 9 suggest the presence of close folds and consequently considerable repetition of beds in the series.

The generalized sections in Figure 4 indicate the structural relations between the igneous and sedimentary masses. On account of the impossibility of correlating individual sedimentary beds and of determining the true stratigraphic sequence, the details of structure in the sedimentary area cannot be accurately expressed.

Igneous metamorphism of limestone

At and near contacts with the quartz-monzonite the limestone has undergone alteration with the development of minerals that are characteristic of igneous (contact) metamorphism. Commonly the zones of alteration are comparatively narrow, and no deposits of economic value have been found in them. The local contact zones carry diopside, garnet, an amphibole, and a scapolite in abundance, besides other minerals. The mineral associations described in the following paragraphs are typical of igneous metamorphism of limestone. The principal occurrences are described in the following paragraphs.
Fern mine

Surface exposures on the property of the Fern mine adjacent to the cinnabar deposits show an abundance of tremolite with sparse copper minerals. In this locality there has been also considerable silicification of the limestone, but this alteration was largely a phenomenon of later and lower temperature processes, connected with the development of epithermal cinnabar deposits.

Garnet Creek prospect

On Garnet Creek 3,000 feet east of the East Fork a prospect cut in rock of an igneous metamorphic zone adjacent to a contact between the limestone and granodiorite shows a complete replacement of limestone by garnet (almandite), epidote, hastingsite, and quartz; and limestone exposed a few hundred feet farther from the contact contains scaly antigorite and tremolite.

Hermes mine

Limestone in the vicinity of the Hermes mine, at the head of Cinnabar Creek, is well banded, and the bands are selectively replaced by epidote and other minerals. A thin section shows the following association of metasomatic minerals: Epidote, hornblende, scapolite (mizzonite of Winchell’s classification), a pyroxene (near diopside), abundant titanite, tourmaline, and a little biotite.

Midnight Creek

About half a mile east of the East Fork, on Midnight Creek, banded limestone carries abundant scapolite (dipyre of Winchell’s classification) and phlogopite.

IGNEOUS ROCKS

Granitic rocks

General character and age

Granitic rocks of the Idaho batholith constitute the prevailing country rock of the area. Most of the material may be classed as biotite-quartz monzonite, but in places there are border facies that have the composition of granodiorite and quartz diorite. In general the several facies are similar to those that occur throughout the large area of batholithic rocks exposed in central and south-central Idaho. In parts of the Yellow Pine district the granitic rocks are not only of varied composition but contain an abundance of narrow aplite veins in the localities where shearing and mineralization are most prominent. Pegmatite veins, however, are remarkably few.

The quartz monzonite, which appears to be the prevailing granitic rock, is fairly light in color and is composed largely of white and light-gray feldspar and quartz. Biotite is the general ferromagnesian component but is very subordinate in amount. The granodiorite and quartz diorite border facies are considerably darker because of a greater content of biotite of hornblende or both.

The age of the Idaho batholith is considered by Ross to be late Jurassic or early Cretaceous.\(^1\) So far as the Yellow Pine area is concerned no evidence

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\(^1\) Ross, C. E., Mesozoic and Tertiary granitic rocks in Idaho; Jour. Geology, vol. 36, no. 8, pp. 673-693, 1928.
is available that would supplement or modify Ross's conclusions. In this area
the granite intrudes sedimentary rocks of lower Paleozoic (?) age and is defin-
itely earlier than the Challis volcanics (early Miocene or late Oligocene) of
Ross, which overlap the eastern border of the Yellow Pine district. Other
writers consider the age of the batholith to be late Cretaceous or Eocene.
Ross's paper on the Mesozoic and Tertiary granitic rocks in Idaho summarizes the
evidence and cites references to the work of others.

Petrographic descriptions

The following detailed petrographic descriptions of the several facies of
the granite rocks, though highly technical and not essential to an understanding of
the broader geologic aspects of the area, are presented as a matter of scien-
tific record and because of the close genetic relationship that is believed to
exist between the batholithic mass and the gold-arsenopyrite lodes.

A study of several thin sections reveals that in the late stages of igneous
activity deuteric 2/ and high-temperature hydrothermal processes modified the
original rock partly by the addition of silica and potash which resulted in the
formation of a considerable amount of microcline and some muscovite. Both of
these minerals replace original plagioclase. Thus some or much of the quartz
monzonite may have been originally of dioritic or granodioritic composition.
The rocks were modified further by hydrothermal alteration, during which quartz,
muscovite, sericite, titanite, apatite, mica, and pyrite were deposited. It is
difficult to discriminate closely between alteration of probably deuteric origin and mineralization during an immediately succeeding high-temperature
hydrothermal stage. There was probably a continuous process of alteration and
mineralization that started in the late stages of solidification and continued
for some time as typical hydrothermal alteration through the stage of gold-
quartz mineralization.

Quartz monzonite facies. The typical quartz monzonite is a light- to
medium-gray medium-grained rock and displays a faint to distinct gneissic struc-
ture. In two sections examined the average size of grain, exclusive of a few
large phenocrysts, was 1 millimeter and the range from 0.02 to 3 millimeters.

Analyses of typical quartz monzonite from various parts of central Idaho
cited by Ross 2/ show the following general range of composition: Quartz, 25
to 30 per cent; potash feldspar, 16 to 35 per cent; plagioclase, 20 to 45 per
cent; biotite, 1 to 10 per cent. Ross states that there is usually 20 to 30
per cent of quartz, about 20 per cent of potash feldspar, and a little more
than 40 per cent of plagioclase, which varies in composition from oligoclase to
andesine.

1/ Ross, C. P., Geology and ore deposits of the Seafoam, Alder Creek, Little
Smoky and Willow Creek mining districts: Idaho Bur. Mines and Geology
Pamphlet 33, 1930; Geology and ore deposits of the Canto quadrangle, Idaho;
U.S. Geol. Survey Bull. 584, p. 45, 1935; The Thunder Mountain mining dis-
2/ As used herein, the term "deuteric" is applied to late reactions in igneous
rocks during and in direct continuation of the consolidation of the rock;
the effects are essentially those due to reactions between materials already
present in the cooling magma. In some instances the stage of deuteric alter-
ations doubtless overlaps the stage of high-temperature alterations
brought about by emanations rising from lower parts of the magmatic reser-
voir, so that the effects of the two processes are not always distinguishable.
3/ Ross, C. P., manuscript.
A common and characteristic phenomenon of Idaho batholith material is the myrmekitic intergrowth of quartz and feldspar. This is evident in thin sections of material from the Meadow Creek-Sugar Creek area and is apparently a feature chiefly of plagioclase grains that are in contact with grains of microcline and quartz. Many of the plagioclase grains show marked reaction rims at the contacts with microcline, as well as textures that indicate clearly the replacement of plagioclase by both microcline and quartz. The myrmekitic quartz is considered to be of metasomatic origin. The reaction rims are more silicic zones partly or entirely surrounding the plagioclase grains and are sharply demarcated; the interior of the plagioclase grains shows relatively faint zoning of the common type. These relations, together with the penetration of plagioclase along its crystal directions by microcline and quartz and the surrounding of some plagioclase grains by microcline, indicate the introduction of some quartz and at least some of the potash feldspar in a late magmatic stage in which deuteric reactions were very marked. The microcline and much of the quartz were apparently contemporaneous. In a slightly later stage fracturing took place, and muscovite and more quartz were deposited.

The most abundant accessory minerals are apatite and zircon. These minerals show in general euhedral and subhedral shapes. Some of the smaller crystals are situated within minerals of early development, but the larger grains are prominently concentrated along fractures and between grains, in such positions as to show clearly that they are of relatively late origin probably deuteric or early hydrothermal. The apatite and zircon are associated with quartz, biotite, and pyrite. The position of the biotite in the paragenetic sequence is not obvious, inasmuch as it constitutes the principal and widely distributed accessory mineral of the primary rock, but the late stage and metasomatic relations of much of the zircon and apatite seem definite. Large grains of muscovite are present in places but are distinctly a product of a later stage of mineral formation, possibly in part closely succeeding the microcline stage but possibly a phase of a still later stage in which sericite was formed.

From the petrographic evidence, therefore, the principal steps in the genetic history of the quartz monzonite of this part of the Yellow Pine district seem to be the intrusion of a magma somewhat more basic than the rock now appears to be and the profound alteration of this basic rock during the late stages of consolidation and the immediately succeeding hydrothermal stage, with the successive formation of (1) quartz and microcline, (2) apatite, zircon, and sulphides, (3) quartz, sericite, muscovite, and sulphides. The various stages may not have been distinctly separated but may represent, rather, a continuous sequence conforming to gradual decrease in temperature and to gradual change in the chemical character of the volatile constituents that concentrated during the later stages of consolidation or arose from depths as the cooling, consolidation, and fracturing of the batholith proceeded downward.

At Meadow Creek, in the Yellow Pine district, the quartz monzonite has the following modal composition: Quartz, 28 percent, plagioclase, 45 percent; orthoclase, 26 percent; biotite, 5 percent. The plagioclase is sodic andesine, about Ab70An30, and shows slight zoning. The potash feldspar is dominantly microcline, subordinately orthoclase. The composition thus indicated places

1/ "Myrmekites" is the name given to a microscopic intergrowth of feldspar and quartz in which the quartz penetrates chiefly the outer zones of the feldspar grains. It is conceived to represent the replacement of a feldspar by one of lower silica content, the excess silica crystallizing as rods or irregular rounded grains of quartz. It is ordinarily attributed to the process of alteration of the rock during the later stages of its consolidation.

2/ Ross, C. F., manuscript.
this rock, which is typical of the "granite" in the vicinity of the Meadow Creek mine, remote from contacts with the sedimentary rock series, in the quartz monzonite class but with a somewhat calcic aspect tending toward the granodiorite family. Characteristically the quartz monzonite facies carries abundant biotite and no hornblende.

Accessory minerals in the rock at Meadow Creek include zircon, apatite, muscovite, and probably allanite and zoisite, largely of late magmatic introduction. Samples of the altered quartz monzonite from the sheared and mineralized zone that carries the ore bodies generally show pronounced silicification and sericitization.

A specimen of moderately altered rock from the ore zone at the south end of the main level at the Meadow Creek mine shows sericitization of plagioclase throughout and development of sericite, muscovite, and carbonate prominently along a fracture which also carries numerous large zircons. Minute grains of sulphide are intimately mixed with the shreds and plates of sericite and muscovite along this zone. A very subordinate amount of biotite is present in the rock and some of this mineral has been altered to chlorite. This lack of biotite appears to be a feature of much of the sheared and altered granite.

Granodiorite and quartz diorite facies. Border facies of the quartz monzonite mass, that is, zones at and near contacts with sedimentary rocks of the roof pendent, are commonly more basic and show a more pronounced gneissic structure than the general mass of the granite. Hornblende is a common constituent and in places equals the biotite in amount. The plagioclase is andesine, and potash feldspars are very subordinate or wanting. Thus the border facies may be quartz diorite or granodiorite. The rocks in general display a pronounced gneissic structure. Basic border facies of the Idaho batholith have also been noted by others, particularly Ross 1 and Anderson 2.

1/ Ross, C. P., manuscript.

A thin section of a granodiorite phase, about 1,600 feet south of Sugar Creek and east of the road, shows the following mode (Hosmal): Quartz, 40 per cent; plagioclase (Ab70An30), 38 per cent; microcline, 15 per cent; biotite, 7 per cent. Apatite and zircon are prominent accessories, associated chiefly with biotite, which may be in part of comparatively late development. At least some of the quartz is late. It replaces biotite (directionally), and feldspar forming myrmekite, is closely associated with the apatite and zircon, and occurs as minute veinslets. In thin sections it shows very little sericitization.

A thin section of biotite-quartz diorite from One Creek, about a quarter of a mile above Sugar Creek, contains sodic andesine, quartz, and biotite as the dominant minerals, with little or no potash feldspar. Part of the plagioclase is somewhat more calcic than that generally found in the quartz monzonite facies, but it is also more variable in composition and shows strong zoning. One crystal of zoned feldspar showed a range from Ab90An10 to Ab90An10. Zircon, apatite, and titanite (?) grains are associated especially with zones of biotite. There has been some shearing of the granite in places, and a small amount of pyrite has been introduced. Muscovite is present, definitely replacing plagioclase along crystallographic directions.
Material from the dump of the Doris K mine, which apparently came from the drift and represents rock of the border zone very near the quartzite of the roof pendant, is a hornblende-biotite-quartz diorite in which potash feldspar is negligible in amount and the plagioclase is intermediate andesine. Some of the feldspars shows zoning. Quartz is abundant, partly in myrmekitic intergrowth. Biotite and hornblende are approximately equal in amount and make up as much as 40 to 50 per cent of the rock. Apatite and titanite are very abundant, especially titanite, which is clearly visible in the hand specimens. These two minerals appear to be a relatively late development, possibly of an early hydrothermal stage. The titanite occurs as large grains or groups of grains; as groups of small grains, especially in areas of fine-grained quartz; and with streaks of ferromagnesian minerals that are clearly earlier than the titanite.

Aplitic quartz monzonite. An aplitic facies of the quartz monzonite is represented by an outcrop on the north side of Sugar Creek about half a mile from the East Fork. Here a white granitic rock, of somewhat finer texture than the average batholithic material, is exposed in a belt about 75 feet wide, where it forms a ridge running N. 45° W. This rock is cut by aplite and pegmatite stringers.

Under the microscope the rock is seen to consist of quartz (37 per cent); orthoclase-microcline (33 per cent); calcic oligoclase, about Ab75An25 (28 per cent); and accessories, chiefly chlorite, biotite, muscovite (2 per cent). Apatite and zircon are exceptionally rare. The chlorite is probably hydrothermal, in part derived from the alteration of biotite; muscovite and sericite are also secondary. The replacement of plagioclase by microcline and myrmekitic quartz is clearly seen. This relatively alkalic facies of the quartz monzonite probably represents a differentite intermediate between the batholithic country rock and the series of aplites and pegmatite veins that are common in the district.

What are probably reaction rims of the plagioclase grains (see also p. 9) are markedly developed in this rock. These border zones have indices slightly less than those of oligoclase but markedly greater than those of the microcline and show a biaxial interference figure. The albite twinning of the plagioclase grains continues through these rims, which are common where microcline and plagioclase grains are in contact.

Completely untwinned potash feldspar grains are common in addition to the generally well-marked microcline; they are probably orthoclase formed at an earlier stage and at higher temperature than the microcline.

Pegmatite and aplite veins. The quartz monzonite contains abundant veins of aplite and some of pegmatite, especially in the general Meadow Creek-Sugar Creek area. Pegmatite, however, is greatly subordinate in amount to aplite. These vein rocks consist dominantly of microcline, with quartz, a small amount of plagioclase (sodic oligoclase), and a very small content of accessory minerals, including minute grains of biotite.

Aplitic exposed at a prospect on the north slope of Sugar Creek Valley, about three-fourths of a mile above the East Fork, shows an average grain size of nearly half a millimeter and a maximum of about 1 millimeter. The composition as indicated by study of a thin section is approximately as follows: Microcline
(and orthoclase), 30 to 35 percent; oligoclase (about Ab$_{85}$An$_{15}$), 45 to 50 percent; quartz, 15 to 20 percent. A few grains of biotite, muscovite (clearly of late generation), and chlorite are also present. Myrmekite quartz appears in plagioclase grains. Apparently the aplite is consanguineous with the batholithic country rock, which is more alkaline and sillitic. The exposed rock contains considerable pyrite in fractured portions.

An unusually large number of aplite veins cut the granitic rock in and near the Meadow Creek mine. Although they show no metallization, the exceptional concentration of aplite material in this area permits reasonable inference of close genetic connection with the metallic minerals in that it suggests a higher local concentration of volatile substances in the original magma than is common for the batholithic material in general.

**Dikes**

**Diabase**

Two or more dikes of diabase occur in the workings of the Meadow Creek mine in close structural association with the known ore bodies. These rocks are very dark-colored, fine-grained to aphanitic, and show numerous small grains of secondary calcite, resembling phenocrysts. The dikes range in width from 2 to 6 feet and trend generally north. A further description of the dikes in their relation to the ore bodies is given on pages 21 and 22. Under the microscope the rock displays a diabasic texture and may have been originally porphyritic, as the outlines of areas now occupied by carbonate and chloritic material suggest phenocrysts of a ferric mineral, probably a pyroxene. Plagioclase feldspar is the dominant mineral. It shows pronounced zoning, and its average composition is apparently within the labradorite range; the most calcic grains have a composition approximately Ab$_{45}$An$_{55}$, as indicated by the maximum extinction angles of 37° (Michel-Levy statistical method). Next in abundance is brown biotite, much of which displays euhedral shapes. Magnetite as individual crystals and as groups of parallel and branching growths is an abundant constituent. Apatite is present in considerable amount in the finer groundmass and also as long acicular crystals.

A diabase dike having the composition of augite-andesite is exposed about a third of a mile north of Cane Creek and about 1½ miles northeast of the junction of Cane and Sugar Creeks. This dike cuts the basal conglomeratic beds of the Tertiary lavas and bears a close resemblance in texture and mineral composition to the dikes in the Meadow Creek mine. The Cane Creek rock is composed essentially of plagioclase feldspar (calcic andesine to sodic labradorite) and has abundant grains and phenocrysts of augite. A few grains of fresh and partly altered biotite are present. Alteration of the rock has developed considerable serpentine, limonite, and some epidote throughout the mass. The texture is slightly finer than that of the diabase of Meadow Creek, and the plagioclase is slightly more sodic, but the general mineralogic similarities suggest the possibility that these rocks may be of similar age.

**Porphyritic andesite and dacite**

Several porphyritic dikes of andesitic composition are exposed in the area. They cut both the granitic rocks and the Tertiary lavas. In general these dikes carry phenocrysts of plagioclase, biotite, and quartz in a dense gray groundmass. The amount of quartz is variable but in most of the dikes is insufficient to warrant classification of the rock as a dacite. The dikes on the ridge west of Cinnabar Creek and about a mile south of the junction of Cinnabar...
and Sugar Creeks and the dike near the junction of Sugar and Cane Creeks are the most quartzose and may be termed "porphyritic dacite".

The most extensive exposure of the porphyritic andesite occurs about three-fourths of a mile east of the junction of the East Fork and Meadow Creek at altitudes between 7,100 and 7,500 feet. The dike is exposed a few hundred feet northwest of the trail leading to the Doris K mine and is crossed by the trail higher up, about 1,000 feet northwest of the mine. It apparently trends about N.60°E., and may be as much as 100 feet wide in places. Float material of similar type was found in the slope on the south side of Meadow Creek in a position approximately along the extended course of the dike exposures, and it may represent the same body. A microscopic study shows the dike to be composed of andesine, biotite, and a few quartz (resorbed) phenocrysts in a dominantly feldspathic groundmass. The rock shows considerable alteration, chiefly by sericitization of feldspar and chloritization of biotite. Epidote, calcite, and serpentine are present, also much accessory apatite, zircon, and magnetite and a few grains of titanite.

**Rhyolite**

**Porphyritic rhyolite at Fern and Hermes mines.** Mine workings in the north wall of the cirque at the head of Fern Creek have been driven partly in and across a wide dike of porphyritic rhyolite. Exposures of this dike and at least one other dike of similar type are to be found at the surface in the vicinity of the mine. The exposures show widths of 50 to 50 feet, and a maximum width in excess of 100 feet has been reported. A dike of similar type in the workings of the Hermes mine has been reported by Ross 2/ and Bell 3/ but was not seen by me because the mine workings were not accessible.

Most of the dike rock in the Fern mine is greatly altered adjacent to the mineralized zone, but some specimens show abundant phenocrysts of orthoclase, quartz, and biotite and probably sodic plagioclase, in a dense groundmass. The orthoclase phenocrysts are glassy, well-formed, and mostly less than a centimeter in length, though some as large as 5 centimeters have been noted. 4/ The feldspars have been altered to claylike material of the montmorillonite type. Some secondary calcite is also present in the mass. The alteration was probably of hydrothermal origin at comparatively low temperature and apparently was related to the mineralization of the adjacent rock, but the dike material itself shows no mineralization with cinnabar.

These dikes are tentatively considered to be of Tertiary age and genetically connected with the extrusive rocks (Challis volcanics) that are exposed along the eastern and northeastern borders of the area.

**Rhyolite at Meadow Creek mine.** Several crossovers in the main level of the Meadow Creek mine reach a rhyolite dike roughly parallel with the ore zone and 60 to 100 feet west of the diabase dikes noted on page 12. Surface exposures of the rhyolite are found on the slope above the adit portals. The rock is very much altered but originally was fine-grained and composed chiefly of alkaline feldspar and quartz with a very small amount of ferromagnesian mineral. A few small phenocrysts of feldspar are apparent in hand specimens. Biotite and chlorite are present, as well as specks of later sulfides—pyrite and stibnite.

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Volcanic rocks (Challis volcanics)

A series of lava and tuff beds overlies the granitic and sedimentary rocks of the northeastern and eastern borders of the area. This series constitutes the country rock of the Thunder Mountain mining district, several miles east of this area, but has yielded no ores in the Meadow Creek area.

The volcanic beds have been traced continuously from the eastern part of the mapped area along Monumental Creek into the Thunder Mountain district. Ross has also traced the series from the Casto quadrangle, where he applied the term "Challis volcanics" to it 1/4, northwesterly into the Thunder Mountain district, where he made a brief study of the ore deposits. He considers these volcanic rocks to be of early Miocene or late Oligocene age 2/, probably Oligocene. The complete series of Challis volcanics, according to Ross 2/, probably attains an aggregate thickness exceeding 5,000 feet and consists chiefly of basaltic and calcic andesite flows at the base (of local development only); andesitic and latitic flows with some tuff in the middle; and rhyolitic tufts and flows with very subordinate basaltic flows at the top. Minor beds of rhyolite also appear, at the top of the middle member.

In the Yellow Pine district the volcanic rocks dip appreciably toward the east and southeast and hence lie below the beds exposed in the Thunder Mountain district. They are dominantly of andesitic and latitic composition and correspond lithologically to the middle (andesitic) division as outlined in the preceding paragraph by Ross. Rhyolitic beds are abundant in the Rainbow Peak and lower Monumental Creek area and appear to form the top beds of the middle member of sequence as given by Ross. The lower member (basaltic and calcic andesite) is apparently absent.

The lowermost beds are in contact with the granitic rocks along most of the eastern border but also directly overlie sedimentary rocks on the north side of Cave Creek and in the divide between Monumental, Fern, and Cinnabar creeks. At several points the basal beds are conglomeratic, containing pebbles and boulders of granite in a clastic andesitic and latitic matrix. Flows and tufts of similar intermediate composition make up the bulk of the series between the conglomeratic basal facies and the rhyolitic facies of the Rainbow Peak-Monumental Creek belt. The rhyolitic facies of the Rainbow Peak locality includes white, purple, and red rhyolites, in part tuffaceous and in part carrying spherulites of obsidian.

The Challis volcanics of the area are cut by numerous dikes of porphyritic rhyolite.

FAULTING AND SHEARING

Three major fault zones have been indicated on the map (Fig. 2). They are not single fissures, however, but rather broad zones containing numerous shears. Thus tabular sheeted and brecciated zones have developed chiefly in the quartz monzonite masses, which have constituted accessible paths for rising solutions and places of mineralization.

It is not possible to measure the magnitude of displacement along the fault zones. Doubtless the displacement in each zone is distributed along a number of

3/ Ross, C. P., personal communication.
closely spaced slip planes, and the net shift is indeterminable because of the lack of identifiable correlative beds on opposite sides. The distribution of sedimentary rocks, however, suggests a shearing and displacement of the roof pendant along a northeast-southwest zone approximately following Sugar Creek, probably the Hennessey shear zone or one closely related to it. If this suggestion is correct, the block northwest of the fault has been shifted north-east, relatively, at least two-thirds to three-quarters of a mile. The distribution of quartzite and limestone east of the Sugar Creek shear zone suggests that the Sugar Creek fault has offset the Hennessey shear zone, the west block showing an apparent horizontal displacement to the north of 1,000 feet or more. These structural interpretations point to a shearing of the roof pendant, probably during the period of batholithic intrusion, and a later faulting that may have been connected with the epoch of Tertiary igneous activity. The writer wishes, however, to emphasize the scantiness of the evidence upon which these structural and diastrophic interpretations are based.

Meadow Creek shear zone

The Meadow Creek mine has been developed in a broad shear zone that apparently continues northward for 2 miles, to or beyond the Hennessey camp. The trend of the zone is almost due north, and at the Hennessey camp it probably intersects the Hennessey shear zone. Whether or not it continues beyond this intersection cannot be stated. Possibly the minor shearing in the area just below the junction of the East Fork and Sugar Creek represents this zone. Within the Meadow Creek mine several definite normal faults of approximately north-south trend and nearly vertical attitude appear to be part of the general shear zone.

Hennessey shear zone

A fractured and mineralized shear zone 50 to 100 feet wide crosses the East Fork at the Hennessey camp and, trending about N.40° E., crosses Sugar Creek about two-thirds of a mile above its junction with the East Fork. It is marked by shattering and closely spaced sheet jointing and is therefore similar in character to the Meadow Creek shear zone. It has been prospected in the vicinity of the Hennessey camp and, to a very slight extent, on Sugar Creek. The exact position of the zone on the north side of Sugar Creek and its relation to the belt of sedimentary rocks are rather obscure, but the faulting appears to cut off the sedimentary rocks along Sugar Creek, probably with a considerable offset. The zone is judged to be at least ½ miles long, but its possible extent to the southwest is not known.

Sugar Creek fault

A narrow fault zone crosses Sugar Creek about ½ miles above the East Fork and apparently offsets the sedimentary rocks to the northwest, bringing them into juxtaposition with the granite in the north wall of the Hennessey shear zone. The trend of the Sugar Creek fault zone is about N. 25° W. Considerable metamorphism of the country rocks along its probable course is evident. At the exposures along Sugar Creek mica schist constitutes the west wall and quartzite the east wall.

Jointing and shearing

Observations throughout the area of granodiorite and quartz monzonite exposures show planes of simple end sheet jointing in all attitudes, but most of them appear to come within several definite groups.
The principal systems of simple jointing deduced are as follows:

N. 15° - 40° W., dip 30° - 70° SW.
N. 60° - 75° E., dip 30° - 50° NW.
N. 15° - 30° E., dip varies widely.
N. 60° - 70° W., dip varies widely.

Systems of sheet jointing consisting of zones of closely spaced shears without apparent displacement fall largely within the following groups:

N. 40° W., vertical.
N. 75° - 35° E., dip variable.
N. 55° - 70° W., dip 45° - 75° NE.
N. 60° - 80° E., dip 45° - 60° N.

In general the prominent fracture systems of the area seem to trend N. 15° - 40° W., N. 15° - 30° E., and N. 60° - 80° E. (dip 30° - 65° NW.). Mineralization has occurred along faults and fractures that trend north (Meadow Creek shear zone); N. 40° E. (Hennessey shear zone); and N. 15° - 40° W. (minor joint, sheathing, and shear zones on lower and middle Sugar Creek).

ORE DEPOSITS

Mineral deposits of economic value in the Yellow Pine district include ores of gold, antimony, and mercury. At present mining is confined to the production of gold and antimony from the Meadow Creek mine of the Yellow Pine Co. Some silver is recovered with the gold and antimony. In the past there has been a small production of mercury from the Fern and Hermes mines, but these mines have been inactive for several years. Lead, zinc, and copper minerals are known in the Yellow Pine district but have not been found in sufficient quantity to warrant exploitation. Very little prospecting was being done at the time of this investigation.

TYPES OF DEPOSITS

Three distinct types of ore deposits occur within the area—arsenical gold ores, antimony-gold-silver ores, and mercury ores. The probable genetic relationships between these ores are discussed below.

Besides mineralization of these types, contact metamorphism of the limestone beds by the intrusion of the granitic rocks of the Idaho batholith is evident at several places. Characteristic contact silicates were developed, and in a few places very sparse amounts of copper minerals were found. The degree of such metamorphism is apparently not great, however, and no economic concentration of ore minerals of such derivation is known.

Arsenical gold ores

Low-grade gold ores carrying arseniferous arsenopyrite and pyrite occur as lodes occupying wide silicified shear zones in granitic country rock, chiefly the quartz monzonite facies, also to some extent in quartzite of the roof pendant (prospects on Sugar Creek). Besides the characteristic mineral association of gold, pyrite, and arsenopyrite, very small amounts of pyrrhotite, chalcopyrite, and molybdenite have been found. Silicification of the highly shattered granitic country rock is a general feature of these deposits. Sphalerite is abundantly present in the Meadow Creek lode but appears to belong to a stage of mineralization later than the arsenopyrite-gold ores.
As the lodes consist of a complex network of small mineralized fractures and associated impregnation deposits in the wall rock, the boundaries of the variable and wide ore bodies are in many places determined by assay content rather than by structural features. Although the portions of relatively high grade are spotty and streaky within the lode, as judged by general conditions at the Meadow Creek mine, at a few places in the mine some of them appear to have been concentrated definitely beneath gassy minor cross slips of low dip. One of the larger ore bodies in the mine also appears to have been concentrated beneath the footwall side of a diabase dike that shows a markedly curved shape in both vertical cross section and plan. (See Figs. 5 and 6.) However, the development work along the lodes has been insufficient to suggest that the ore shoots follow any particular position with relation to such minor features, except that local conditions of exceptional fracturing, such as sheathing, probably facilitated access of ore-bearing solutions.

**Antimony deposits**

The antimony deposits, in which the chief ore mineral is stibnite, occur in part within the earlier gold-arsenopyrite lodes and in part in separate fracture zones in the quartz monzonite and quartzite country rocks. In the Meadow Creek lode the gold-arsenopyrite and antimony ores are mined largely as a unit. For the most part the antimony deposits seem to occur in narrow shear and fracture zones, which show a markedly higher concentration of metallic minerals than the gold-arsenopyrite deposits. Pyrite is a common accessory mineral, and quartz and carbonates are common gangue minerals. Stibnite deposits in the high plateau area east of the East Fork are reported to carry a little cinnabar.

Antimony deposits have been prospected in wide belts along both sides of the East Fork below Meadow Creek and Sugar Creek nearly to the junction with Cinnabar Creek; at the Doris K group of claims between the East Fork and the head of Fern Creek; and on Fern Creek just south of the area containing the cinnabar prospects. Thus, broadly considered, the area of stibnite mineralization as indicated by mines, prospects, and outcrops is in part coincident with the area of gold-arsenopyrite lodes and adjacent to the area of cinnabar mineralization. It is noteworthy that only a very small amount of cinnabar has been reported at any of the antimony prospects and that stibnite is correspondingly sparse in the cinnabar deposits. According to Mr. Lewers, metallurgical engineer for the Yellow Pine Co., the stibnite is argentiferous and carries very little gold.

The antimony deposits comprise narrow veins and networks of veinlets and, subordinately, disseminated deposits in the vein walls. The stibnite is generally well crystallized, and the crystals range in size from microscopic dimensions to several inches. In the Meadow Creek lode high-grade ore bodies present coarsely crystalline masses suitable for cobbing and hand picking.

The antimony deposits of the Meadow Creek-Sugar Creek area of the Yellow Pine district appear to be similar to those in the Johnson Creek area 6 to 8 miles farther west. 2/

**Mercury deposits**

The mercury deposits, in which the ore mineral is cinnabar, the red sulphide of mercury, are confined to a comparatively small area at and between the heads of Cinnabar and Fern Creeks. The total production has been very small, and there are no active mines in the district at present.

1/ Larsen, E. S., and Livingston, D. C., op. cit., p. 79.

17.
The deposits occur as narrow veins and replacement deposits in highly fractured zones in metamorphosed limestone, near or at the contact with quartzite. The belts of mineralization are elongated parallel to the strike of the beds. At least two parallel belts of limestone contain the known deposits, but these belts may be portions of a single thick bed repeated by close folding.

Cinnabar is the only prominent sulphide mineral in the deposits, but in places a small amount of pyrite and a very little stibnite occur with the cinnabar, indicating a possible genetic connection between the mercury deposits and some or all of the antimony deposits of the area. Dense cherty or chalcedonic silica of epithermal origin is a characteristic and prominent accessory gangue mineral. In places, especially in the Forn mine, the cinnabar deposits are adjacent to porphyritic dikes that are believed to be of Tertiary age and that display profound alteration by hot waters.

PARAGENESIS OF MINERALS

A study of polished surfaces of ores from the Meadow Creek mine was made to determine the order of deposition of the minerals. Brief descriptions of selected specimens follow:

B 6. Monday tunnel, 2,540 feet from portal, south end of mineralized zone. Sequence: (1) Pyrrhotite, (2) pyrite and quartz, (3) chalcopyrite and quartz.

H. D. Fractured and altered granitic rock from dump pile at Hennessey camp. Sequence: (1) Pyrite, (2) stibnite, (3) pyrite.

N. T. Altered and brecciated granitic rock from North tunnel. Sequence: (1) Pyrite and quartz, (2) stibnite. Mineralization of fractures in country rock and replacement of rock by both pyrite and stibnite. Network of minute veinlets of stibnite in pyrite; stibnite areas partly enveloping pyrite grains.

B 51. Drill core, 200-foot level, south end. Late quartz as veinlets cutting and replacing calcite and mineralized rock. Pyrite at contacts of quartz veinlets with rock.

B 4. Stibnite ore, south end B level. Sequence: (1) Quartz, (2) calcite, (3) stibnite.

B 5 III. Drill core, 200-foot level. Sequence: (1) Calcite partly replaced by (2) pyrite and quartz. Stibnite contemporaneous with pyrite (?).

The following sequence of alteration and mineralization is deduced from the study of thin sections of the country rock and of polished sections of ores:

Deuteritic alteration of the mass of granodiorite and quartz monzonite.

High-temperature hydrothermal alteration of country rock, affecting chiefly silicification and sericitization, accompanied by the deposition of arsenopyrite, pyrite, gold, quartz, and, to a very minor degree, pyrrhotite, chalcopyrite, and molybdenite (?).

Lower-temperature hydrothermal alteration by silicification and sericitization, accompanied by deposition of (a) pyrite and quartz; (b) carbonates (not general); (c) stibnite, pyrite, and quartz.

A considerable time interval may have elapsed between stages 2 and 3.

18.
The modes of occurrence, mineral compositions, and textures of the mineral deposits indicate deposition from rising solutions connected with igneous activity. The three types of deposits differ, however, in the directness of their affiliation with the exposed igneous rocks and in the physical and chemical environment that attended their precipitation. The close relationship between the gold-arsenopyrite deposits and the deuterically altered quartz monzonite country rock renders it not only plausible but probable that the minerals were precipitated from hot solutions that originated in the quartz monzonite or quartz diorite magma of the Idaho batholith. These solutions ascended along paths of access prepared by deep-seated fissuring of the batholith. The upper parts of the fissured zones became also the places of deposition. The tops of the mineralized zones have since been removed by erosion. The mineral association suggests that the gold-arsenopyrite deposits may belong to the class of hypothermal gold-quartz veins of Lindgren's classification. But the sparseness of pyrrhotite and molybdenite might be construed as indicating that they belong in the upper part of the hypothermal zone or the lower part of the mesothermal zone. If so, mineralization may have extended to a considerable depth below the present outcrops. This interpretation, dependent as it is upon inconclusive data, should be accepted with caution. The simplicity of the mineral association and lack of critical minerals in abundance is rather unsatisfactory mineralogic evidence, but the apparently close association of some sulphide minerals with features produced by high-temperature alteration in these zones may be significant.

The stibnite deposits are clearly of later origin than the gold-arsenopyrite deposits and were probably precipitated under conditions of lower temperature and pressure. Their common superimposition upon the gold deposits and occurrence largely in the granitic rocks or closely adjacent quartzites suggest a genetic affiliation with the gold deposits, representing a later period of mineralization by the batholithic magma. They would thus constitute a lower-temperature type of deposit -- mesothermal or epithermal -- superimposed upon the higher-temperature gold lodes as the magma congealed progressively in depth. On the other hand, the presence of Tertiary lavas in the area and the existence of Tertiary ore deposits in these lavas in the adjoining Thunder Mountain district point to the possibility that the stibnite deposits may be of Tertiary origin, having been deposited in fracture zones reopened by crustal disturbances attending the Tertiary volcanism. The presence of dikes that may be of Tertiary origin in the area somewhat strengthens this theory. The evidence is, however, decidedly inconclusive. It is, moreover, pertinent to note the lack of great sparseness of stibnite in the closely adjacent cinnamon bar deposits, believed to be of Tertiary origin, and of cinnamon bar in the stibnite deposits and the lack of stibnite in the Tertiary ores of the Thunder Mountain area. In view of these facts and the structural conditions, as well as the distribution of the deposits, the writer is inclined to the view that the stibnite deposits are of pre-Tertiary origin and genetically connected with the gold-arsenopyrite deposits.

The cinnamon bar deposits are believed to be of low-temperature hydrothermal origin (epithermal zone of Lindgren) and probably related to the general period of Tertiary igneous activity that produced the Challis volcanics and the associated gold ores of the Thunder Mountain district.

The sequence of the principal geologic events related to the formation of mineral deposits may have been as follows:

1. Intrusion of Idaho batholith (largely quartz diorite?) in late Jurassic or early Cretaceous time into Paleozoic and older rocks, accompanied by folding and shearing of these rocks and by contact metamorphism of the limestone beds (on Garnet Creek and elsewhere); ductile alteration of the granitic rock closely succeeded by high-temperature hydrothermal alteration along shrinkage joints and fracture zones.

2. Progressive cooling of the batholith inward and downward from the roof, accompanied by shrinking and cracking of the solidified roof zone and the deposition of aplite veins and intrusion of splotic quartz monzonite dikes.

3. Intrusion of complementary basic dikes (for example, diabase at Meadow Creek mine).

4. Shearing and fracturing of upper part of batholith, chiefly along certain zones that became deepened channels of access for mineralizing solutions (Meadow Creek shear zone and others).

5. Deposition of gold, arsenopyrite, pyrite, pyrrhotite, chalcopyrite, and molybdenite from solutions at comparatively high temperature rising from depth along fault zones; wall-rock alteration (silicification and slight sericitization) by these solutions.

6. Shearing, partly and perhaps largely localized along and within previously developed shear zones; time indefinite but may have been much later than stage 5 possibly attending the period of Tertiary volcanism.

7. Deposition of antimony ores from hydrothermal solution rising along fractures of stage 6. (?)

8. Minor faulting.

9. Extensive erosion, exposing large areas of granitic rocks and leaving isolated areas of Paleozoic and older (?) rocks.

10. Epoch of Tertiary volcanism and crustal disturbance, accompanied by deposition of cinnabar, and possibly the stibnite of stage 7.

According to the evidence presented above the writer infers that the ages of the three types of mineralization were as follows:

1. Gold arsenopyrite (hypothermal), pre-Tertiary, closely following the intrusion of the Idaho batholith.

2. Antimony, (mesothermal or epithermal), with some silver and gold probably pre-Tertiary, possibly early Tertiary, later than the gold-arsenopyrite and probably earlier than the cinnabar.

3. Cinnabar (epithermal), Tertiary, succeeding the Challis volcanics.

GOLD AND ANTIMONY MINES AND PROSPECTS

Meadow Creek mine

The Meadow Creek mine (No. 1, Fig. 2) is owned by the Yellow Pine Co. It is situated on the Meadow Creek shear zone, on the north side of Meadow Creek.
Fig. 4. Map of levels at Meadow Creek mine.
Fig. 5. Map of main and 200-foot levels of Meadow Creek mine, showing ore bodies, dikes, and faults. Data in part from level maps by H. D. Bailey
Fig. 6. Interpretative cross sections in part of Meadow Creek mine along lines indicated in Figure 5.
Fig. 7. Map of area along East Fork between Meadow Creek and Sugar Creek, showing claims held by Yellow Pine Company and location of chief developments.
shear zone, on the north side of Meadow Creek about half a mile above its junction with the East Fork. The main-level adits are at an altitude of 6,700 feet.

The deposits on the west side of the East Fork between Sugar and Meadow Creeks were discovered about 1900 by Albert Henessy. The United Mercury Mines Co. acquired the properties at Meadow Creek about 1919. Between 1927 and 1930 these properties, together with others in the district, were leased to F. W. Bradley, who formed the Yellow Pine Co. This company had continued prospecting and development to the time of the writer's visit (1932). Most of the development since 1930 has been confined to the Meadow Creek mine.

General developments

The lode at the Meadow Creek mine is reached from the surface by two adits on the main level, 100 feet above Meadow Creek, and an adit on the B level, 100 feet above the main level. Levels at 200 and 400 feet below the main level have been established and are reached by a winze from the main level. (See Figs. 4-6.) From the adit, the main level drift has been driven about 1,175 feet north within the lode, and from it numerous crosscuts have been driven into both walls. Most of the recent development work has been carried on below the main level. Comparatively little stoping had been done up to the time of the writer's examination.

From Stibnite Camp, nearly 2 miles north of Meadow Creek Camp, the Monday tunnel (No. 6, Fig. 2) has been driven south along the lode at an altitude of about 6,500 feet for a distance of about 6,200 feet, with the intention of connecting with the 400-foot level of the Meadow Creek mine. At Fiddle Creek, half a mile south of Stibnite, another tunnel, the North tunnel, has been started at an altitude of 6,600 feet (No. 7, Fig. 2). It is expected that by these operations a large tonnage of low-grade ore can be blocked out and that ultimately the ores can be brought out by way of the Monday tunnel to a new mill to be erected on the East Fork near Sugar Creek. The relative positions of the several tunnels are shown in Figure 7.

Character of the ore bodies

Two types of ore occur in the Meadow Creek lode—gold-arsenopyrite ore of earlier and relatively high temperature origin and stibnite ore of later and lower-temperature origin. Because of their intergrowth and structural relations they are mined essentially as a unit, the mill operations producing two concentrates.

The gold ore bodies constitute a wide lode in sheared, crushed, and silicified quartz monzonite. Although in general the gold ores were formed by impregnation of the wide Meadow Creek shear zone, some local exceptional concentrations within the lode occur on the footwall sides of curved diabase dikes and on the footwall sides of low-angle minor premural cross faults. Maps of the main and 200-foot levels and generalized cross sections showing the structural positions of ore bodies in relation to one of the dikes are given in Figures 5 and 6. As yet there has been insufficient development below the main level to permit close correlation and tracing of minor structural features between levels.

The antimony (stibnite) ores occur within the gold-arsenopyrite lode as crosscutting veins; veinlets and breccia matrix connected with vein stibnite but disseminated somewhat through adjacent portions of the lode; and as thin lenticular masses and veins along slip planes and sheeting joints.
In some places diabase dike material has been brecciated and cemented, partly by stibnite and calcite; also, slickensided and gougy fault surfaces of dike material are mineralized with stibnite and pyrite. Assays of dike rock show little or no mineralization of the dike itself with gold.

The lode has not been sufficiently explored to permit a general statement regarding the form and occurrence of gold ore shoots. In the mine workings, which represent only a small portion of the Meadow Creek lode, the shoots have an irregular lenticular shape, modified and apparently limited in places by dikes and minor faults. The extent to which dikes and faults have controlled concentration of gold mineralization along the entire lode is not known. Economic bodies of gold-bearing ore may have been largely concentrated against the dikes and gougy slip planes, but apparently the relationship is not the same in the later antimony bodies, which show no consistent limitation by local minor structural features within the mine.

Tenor of the ore

The ores as mined are reported to range in value from 0.15 to 0.5 ounce to the ton in gold, but ores from the headings and stopes are mixed to make mill heads that average about $5 (gold at $20 an ounce). Antimony concentrates, according to figures reported to the writer, commonly run 55 to 60 percent of antimony, about 25 ounces of silver to the ton, and a slight amount of gold. The ratio of concentration at the mill is about 20 to 1, so that, on this basis, mill heads average $5 to 3 percent of antimony and 1 to 1.2 ounces of silver to the ton. In general, silver accompanies the stibnite but is negligible in the gold-arsenopyrite ores.

Several drill-core samples were reported to show assay values of 0.5 ounce of gold to the ton at the 400-foot level and 0.5 to 0.75 ounce at the 800-foot level. A sample of ore from the 200-foot level, south face, was reported to assay as follows: Gold, 0.17 ounce to the ton; silver, 17 ounces to the ton; antimony, 17 percent. This sample is said to represent the high-grade antimony ore.

Mineralogy of the ores

The minerals of the Meadow Creek ores are comparatively few and of simple composition. Gold and stibnite are the ore minerals. Associated metallic minerals include chiefly pyrite and arsenopyrite. Pyrrhotite,chalcopyrite, and molybdenite have been found in a few places but are nowhere prominent. The stibnite is argentiferous. Nonmetallic minerals introduced with the ores include quartz, calcite, siderite, and probably sericite.

The pyrite is apparently of two generations, occurring as small pellet-like grains associated with the stibnite or as larger grains and irregular masses of earlier deposition. Arsenopyrite is abundant in places but only as disseminated minute grains; much of it is not visible to the unaided eye. The stibnite is well crystallized as characteristic massive intergrowths of coarse crystals of bladed habit, minute acicular crystals disseminated and in veins, and drusy crystalline aggregates in vugs.

Quartz is the common gangue mineral of both gold and antimony ores and to a large extent represents hydrothermal silification of the country rock. In part it comprises veinlets of crystals showing comb structure or radial peripheral growths upon rock fragments. Calcite and siderite are associated with the antimony ores, are coarsely crystalline, and fill veinlets or compose the matrix of brecciated country rock. These minerals appear to be common but not abundant and of spotty occurrence in the ore zones. Sericite and muscovite are present
as effects of hydrothermal alteration of the granitic country rock and are associated with pyrite and other minerals of high-temperature origin.

Wall-rock alteration

Thin sections of the granitic country rock and of the ores from the Meadow Creek mine have been examined under the microscope. The most common type of rock alteration in the ore zone is a general silicification, which has transformed the most highly shattered and mineralized portions of the country rock into a silicious gangue. The quartz has developed (1) as relatively large replacement grains in the feldspathic country rock, accompanied by sericite and muscovite; (2) as fine-grained, almost chalcedonic material in streaks and veinlets, with much sericitic material; (3) as veinlets and vuggy fillings of subhedral to euhedral grains of long prismatic habit, to a considerable extent displaying comb structure. The third type appears to belong to the stage of stibnite mineralization and is believed to be of later and lower-temperature origin than the other types.

The original granodiorite was probably altered by deuteric reactions. There appears to be no clear mineralogic distinction between the late stages of such alteration and the early hydrothermal stages of mineralization, but it seems clear that wall-rock alteration of the ore-forming epochs consisted of general silicification and some sericitization.

Hennessey lode

The Hennessey lode occupies the Hennessey shear zone, and the Hennessey group of claims, now held by the Yellow Pine Co., follows this belt in part. The chief workings are at Hennessey Camp (No. 10, Fig. 2), but at the time of the writer's visit no workings were accessible and no prospecting was being done on the lode.

The mineralized shear zone constituting the Hennessey lode trends about N. 45° E. from Hennessey Camp across the East Fork and Sugar Creek. At the camp it probably intersects the Meadow Creek lode. An exposure of the Hennessey lode where it is crossed by the pipe line on the east side of the East Fork shows a highly shattered and sheared zone 75 to 100 feet wide in granitic country rock. Exposures along its course on the slopes between this point and Sugar Creek are poor, and its geologic relations to the belt of sedimentary rock that appears half to three-fourths of a mile east of the pipe line are not clear, but it is probable that the shear zone truncates the sedimentary belt and forms its north boundary, as indicated on Figure 2. The distribution of prospect pits indicates that the width of the zone in places may exceed 200 feet.

The granitic rock along the zone is similar to that of the Meadow Creek zone and shows similar silicification. The lode is mineralized with gold and stibnite; pyrite is accessory. Specimens from prospects on the north side of the zone also showed abundant arsenopyrite.

Nethek (No Name) prospects

The Nethek prospects (No. 6, Fig. 2) in the No Name lode are situated in the south bluff of Sugar Creek half a mile above its confluence with the East Fork. Two adits about 400 feet apart have been driven a few feet along shear zones of northwest trend. There are two prominent fracture systems—a set
striking north and dipping 75° E, and a set striking N. 15° W. and dipping 40° W. These prospects are probably on shear zones that intersect the Hennessey lode, which passes close by on the south.

The country rock of the Nethken prospects is considerably altered and bleached and is crossed by many aplite veins. It also shows prominent shearing and mineralization with pyrite, pyrrhotite, arsenopyrite, and stibnite. So far as can be ascertained, therefore, the lode at these prospects displays mineralogic and structural features similar to those of the Meadow Creek lode.

Kennedy prospects (Bonanza ledge)

The Kennedy prospects (No. 12, Fig. 2), on the north side of Sugar Creek about three-fourths of a mile above its mouth, show shear zones trending north and northwest in granodiorite that has been greatly altered along the shear planes. They have been prospected only slightly. Stibnite and pyrite are disseminated in the sheared granitic rock.

Doris K Prospect

The Doris K prospect (No. 5, Fig. 2) is on the northwest side of Stibnite Creek at an altitude of about 7,600 feet, or about 1,000 feet above the East Fork at Meadow Creek. The prospect was opened by the Doris K Mining Co., and later was acquired by the United Mercury Mines Co.

The workings were not accessible to the writer. According to previous reports 1/ the lode probably trends about N. 25° E. and is apparently similar in general character to other antimony lodes of the district, occupying a wide zone of sheared country rock, silicified and mineralized. The deposit is at the contact of the regional granitic rock with the quartzite that forms the westernmost bed of the sedimentary series. Titanite and apatite are abundant in the granitic rock, which is a quartz diorite contact facies of the batholith.

The chief ore mineral is stibnite; gold and silver are reported. Pyrite and a very small amount of pyrrhotite are accessory. Quartz is the chief gangue mineral.

Other antimony and gold prospects

On the north side of Garnet Creek about two-thirds of a mile from the East Fork (No. 15, Fig. 2), at an altitude of 6,950 feet, a prospect adit has been driven into granodiorite country rock at its contact with a small isolated area of marble. There appears to have been some mineralization by pyrite. No information is available regarding gold and silver found here. The granitic rock shows the usual type of shearing and alteration. About 500 feet southwest of the adit the marble at the contact with granodiorite shows extreme igneous metamorphism (see also p. 67), but no metallic minerals were seen. The garnetized zone has been cut into for several feet and shows a practically complete replacement of the original rock at this point.

There are a few prospect pits and adits in the granitic area on the north side of Sugar Creek and west of the Sugar Creek shear zone. One of these, on the Madam Queen claim (No. 11, Fig. 2), appears to be on a northwestward, trending shear zone, a continuation of a similar zone exposed in the north bank of

Sugar Creek (Bonanza ledge?). No information is available regarding ore found there, except that assays showing gold were reported. Pyrite, pyrrhotite, coarse dolomite, and siderite are present in places.

Several prospect trenches have been cut in the quartzite area on the north side of Sugar Creek about 1\(\frac{1}{2}\) miles from the East Fork (No. 13, Fig. 2). Here shear zones in the quartzite are mineralized with stibnite.

**MERCURY DEPOSITS**

Deposits of cinnabar, the red sulphide of mercury, occur at the heads of Cinnabar and Fern Creeks and in the intervening high summit area, being distributed over 4 or 5 square miles. The deposits have been mined at three places — the Hermes mine, at the head of Cinnabar Creek; the Fern mine, at the head of Fern Creek; and the mine of the Idaho Quicksilver Mining Co. on the Buckshad group of claims, on upper Fern Creek half a mile below the Fern mine. Several other claims in the general area have been slightly prospected.

The general facts of the history of cinnabar mining in the Yellow Pine district up to 1928 have been given by Livingston \(\frac{1}{2}\), Larsen and Livingston\(\frac{3}{2}\), and Ross \(\frac{3}{2}\). The mines were worked principally between 1917 and 1920. At no time, however, was production large; in 1918 the Yellow Pine district produced 22 flasks, practically all of which came from the Fern mine. A few flasks were produced at later times, but no production has been reported since 1928, when, according to statistics of the United States Bureau of Mines, the United Mercury Mines Co. (Hermes mine) produced 6 flasks.

In 1927 the holdings of the United Mercury Mines Co. were leased to F. W. Bradley, who formed the Yellow Pine Co., now operating the Meadow Creek mine.

A claim map of the Cinnabar Fern Creek Mercury district appears in an earlier report by Larsen and Livingston \(\frac{1}{2}\).

**Fern mine**

The Fern mine (No. 2, Fig. 2) was developed by the Fern Quicksilver Co. The claims are situated in and above the cirque at the head of Fern Creek. The developments consist of three adits driven into the north wall of the cirque at two levels, one at an altitude of about 8,400 feet and the other at 8,450 feet. About 400 feet of drifting has been done in all workings.

No large ore body was in evidence. The lower level is reported to have shown no ore. One of the drifts crosses a wide dike of porphyritic rhyolite (see p. 13) that shows effects of hydrothermal alteration. The crystalline limestone country rock is fractured and in part silicified, and irregular veinlets of chalcedonic quartz are abundant. Cinnabar occurs in both the unsilicified and the silicified portions of the country rock, but the richest ores are said to have been obtained from the quartz veinlets. There is apparently no regularity to the ore seams and lenses, but the general zone of fracturing and mineralization appears to follow the bedding, near the contact with the quartzite beds on the south. The general features of the area in the vicinity of the Fern mine are shown in Figure 8.

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2/ Larsen, E. S., and Livingston, D. C., op. cit., p. 74.
4/ Larsen, E. S., and Livingston, D. C., op. cit., p. 74.

26.
The workings of the Yellow Pine Quicksilver Co. are on the Bucks Bed claim, about half a mile east of the Fern mine on the north side of Fern Creek (No. 3, Fig. 2; Fig. 8). The mine openings were not accessible. Exposures of the country rock show the deposit to be similar in character to that at the Fern mine. It occurs in the same belt of limestone and, as at the Fern, lies at or near the contact with the quartzite bed on the south.

In exposures near the adit the crystalline limestone has been considerably brecciated and the fractures filled with chaledonic silice, cinnabar, or both, making a complex network of veinlets. One exposure of completely silicified limestone suggests by its shape and relationships a deposit formed by replacement along the front of a thermal spring.

Hermes mine

The Hermes mine (No. 4, Fig. 2) is situated in a cirque at the head of the south fork of Cinnabar Creek. The deposits were discovered about 1902 by Pringle Smith and in 1901 were acquired by the United Mercury Mines Co., which at this time effected a consolidation of the claims of the Idaho Quicksilver Co., Monumental Mercury Mines Co., and others, comprising all the claims except the Fern group. Development at the Hermes mine began in 1921, and a few flakes of mercury were produced during the period 1923 to 1926. In 1927 the holdings of the United Mercury Mines Co. were acquired for the Yellow Pine Co. by F. W. Bradley. This company started the Cinnabar or North Monday tunnel, on the East Fork at the mouth of Midnight Creek (No. 9, Fig. 2) with the purpose of developing gold and mercury deposits of the Cinnabar group (Hermes, etc.). The projected length of the tunnel is about 10,000 feet. So far, it has been driven about 1,500 feet. Inasmuch as this tunnel is at an altitude of 6,300 feet and the cinnabar workings at the heads of Cinnabar and Fern Creeks are at altitudes of 7,200 and 8,000 feet, respectively, the proposed tunnel will enter the Cinnabar area 900 and 1,700 feet below the surface at the present workings. According to Lindgren 2, known cinnabar deposits in other parts of the world "generally become impoverished at a depth of less than 1,000 feet," and "very few deposits have been profitable to a depth of 1,500 feet." On the other hand, the rich deposits at Almaden, Spain, are mined to a depth of nearly 1,200 feet, and in the mine at New Almaden, Calif., a continuos ore body extends to a depth of 1,600 feet. Analogy suggests that the North Monday tunnel may penetrate the Cinnabar Creek area near or below the base of the deposits.

The workings at the Hermes mine were not accessible to the writer. They were open at the time of Roast's visit, and a description is given in his report 2. Several adits have been driven into the limestone country rock in which the deposits occur. The limestone bed containing the deposits is 250 to 300 feet thick, stands nearly vertical, and has a northwest trend, paralleling the productive bed at the Fern mine. Quartzite borders the limestone on both sides. The deposits appear to be confined to the limestone.

Other cinnabar prospects

Other prospects in the Cinnabar area include the White Metal, east of and adjacent to the Bucks Bed; the Vermilion, east of the White Metal; and the Mountain Chief (No. 14, Fig. 2). Very little prospecting has been done at any of

these, and there is little to be seen on the surface. The White Metal and Vermilion are in limestone. The Mountain Chief adit is driven in the quartzite bed that lies south of the limestone bed of Fern Creek. Cinnabar, stibnite, gold, silver, and minerals of lead, zinc, and copper are reported to occur here. The workings were not accessible. Fragments from the dump showed pyrite, cinnabar, and galena. In the Vermilion prospect both cinnabar and stibnite occur.

CONCLUSIONS AND RECOMMENDATIONS

The part of the Yellow Pine mining district covered by this report contains workable deposits of gold and antimony ores. The ore bodies occupy faults and shear zones in granitic country rocks of the Idaho batholith. Mineralized zones occur also in quartzite beds near contacts with the granitic rocks. The principal belts of shearing and mineralization trend north and northeast, in general following the East Fork and Sugar Creek. Associated minor fracture zones of northwesterly trend are also mineralized in places.

The gold deposits are of low grade and occupy wide fracture zones rather than simple fissures. The lodes generally display prominent effects of fracturing, such as sheeting, minor faulting, and brecciation. In outcrops they may be conspicuously stained by brown and yellow iron oxides derived from the oxidation of iron sulphides. Silicification and bleaching of the highly fractured granitic country rock are also features of such zones. The low grade of the gold ores makes it probable that large-scale operations would be necessary for successful mining. Particular care should be taken to prove the existence of large tonnages of workable ore before attempts are made to exploit the deposits.

The antimony deposits probably constitute a valuable natural resource, and further prospecting and exploration for this metal would appear to be justified by the excellent showings at several places. To some extent the antimony deposits occur in gold-bearing shear zones, and at Meadow Creek ores of the two metals are mined and milled together. The presence of antimony sulphide complicates the milling of the ores and renders more difficult a satisfactory recovery.

Mercury deposits appear to be restricted to a comparatively small area in the high plateau region at the heads of Farm and Cinnabar Creeks; so far there are no indications that the ores are of wider distribution. Only a small amount of mercury has yet been obtained from these deposits, and the developments have not yet indicated the presence of large and rich ore bodies, but exploration has been confined to very shallow depths. The mercury ores are likely to be somewhat "pockety," and exploration and development should proceed very cautiously.

In view of the information already gathered, the writer recommends that further interest in this area be centered mostly on the possibilities of finding large tonnages of low-grade gold ores and antimony.

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