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ANTIMONY DEPOSITS OF A PART OF THE YELLOW PINE DISTRICT VALLEY COUNTY, IDAHO

A PRELIMINARY REPORT

BY

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By Donald E. White

ABSTRACT

The area described in this report lies in the northeastern part of the Yellow Pine district, Valley County, in central Idaho. It has produced much gold and little else in the past, but it has a special interest at present because it contains what is probably the largest reserve of antimony in the United States.

The ores, as ores of antimony, are in general of low grade Stibnite, the only antimony mineral present, occurs partly in veins and veinlets and partly disseminated throughout wide shear zones in quartz monzonite of the Idaho batholith. The main shear zone, which strikes northeastward, may be an offshoot of the north-striking Monday fault. Both the shear zone and the fault are in quartz monzonite and are probably related to the nearby contact of the monzonite with a huge roof pendant of metamorphosed sedimentary rocks.

Two periods of mineralization are represented in the area, the first by pyrite, arsenopyrite, and gold; the second by antimony and silver. The two periods are believed to have been genetically related and to have occurred in Tertiary time. Mineralization in even the earlier period is thought to have taken place at relatively shallow depth. The temperature was high during the early stages but decreased considerably while the ore minerals were being introduced.

The principal mine of the area is the Yellow Pine mine. The Meadow Creek mine also contains possible reserves. The main workings of the Yellow Pine mine are two quarries, one on each side of the East Fork of the South Fork of the Salmon River. The ore in the eastern quarry will be referred to as the East ore body, that in the western quarry as the West ore body, though the two may be continuous under the stream. The mine is owned by the Bradley Mining Co. That company is mining at present only in the East ore body, which is rich enough in gold to be profitably worked but contains only a negligible amount of antimony. The West ore body contains a much higher proportion of antimony, as well as some gold and silver, but it was not being mined in late 1939 because the net value of the ore at the current price of antimony was considerably less than that of the ore in the East body.

Some mining may soon be done in the West body because of a temporary emergency. The recovery of gold from ore of the East body is unsatisfactory, and to increase the percentage of recovery a cyanide plant will probably be built. It may then be deemed expedient to suspend mining in the East body until the cyanide plant is put in operation and to keep the miners busy meanwhile in the West quarry. But long-continued mining of the West ore body will not be worth the owners' while unless the ore can be made to yield at least as high a profit as that of the East ore body.

This condition might be brought about through a rise in the contract price paid by the smelter for antimony; the price of 3.75 cents a pound paid in 1939 for the antimony contained in the concentrates would have to be raised to about 7 cents. The West ore body might also be made profitable by building a plant for electrolytic separation of antimony. Such a project is not likely to be attempted unless an open-market price of 12 cents a pound could be assured for several years. Under either of the two conditions stated the largest possible production would probably be between 1,200 and 1,600 tons of antimony. Greater production might follow a price high enough to warrant expansion of the plants at mine and mill. It is not easy to predict how high a price would be necessary to encourage greater production, but it might be about 10 cents a pound for antimony contained in concentrates, or the equivalent price of 15 cents a pound for metallic antimony. Assured stability of price, however, be it said again, would be essential.

The easily minable reserves in the West ore body are estimated to be at least 193,000 tons of ore, containing 7,620 tons of recoverable antimony. About 2,625,000 tons more, estimated to contain 18,350 tons of recoverable antimony, may lie between the creek level and a depth 200 feet lower; but this estimate is more doubtful than the preceding, especially with respect to grade. It appears likely that a large additional tonnage may lie in ground either outside or beneath that now known to be productive that could be explored at low cost. The amount of antimony ultimately mined must of course depend on the prices obtainable for it.

INTRODUCTION

The Yellow Pine mine is in the northeastern part of the Yellow Pine district, Valley County, in central Idaho, at approximately latitude 44°56' north, longitude 115°20' west. (See fig. 40.) The district, which is now regarded as consisting approximately of the northern half of the Yellow Pine quadrangle, contains gold and antimony deposits and, in the southeast corner, several quicksilver deposits. The area here described is adjacent to the mine. It is about 10 miles east of Yellow Pine and 2 miles north of Stibnite and is accessible by a good dirt road from Cascade, which is on the McCall branch of the Oregon Short Line Railroad. Cascade is 73 miles

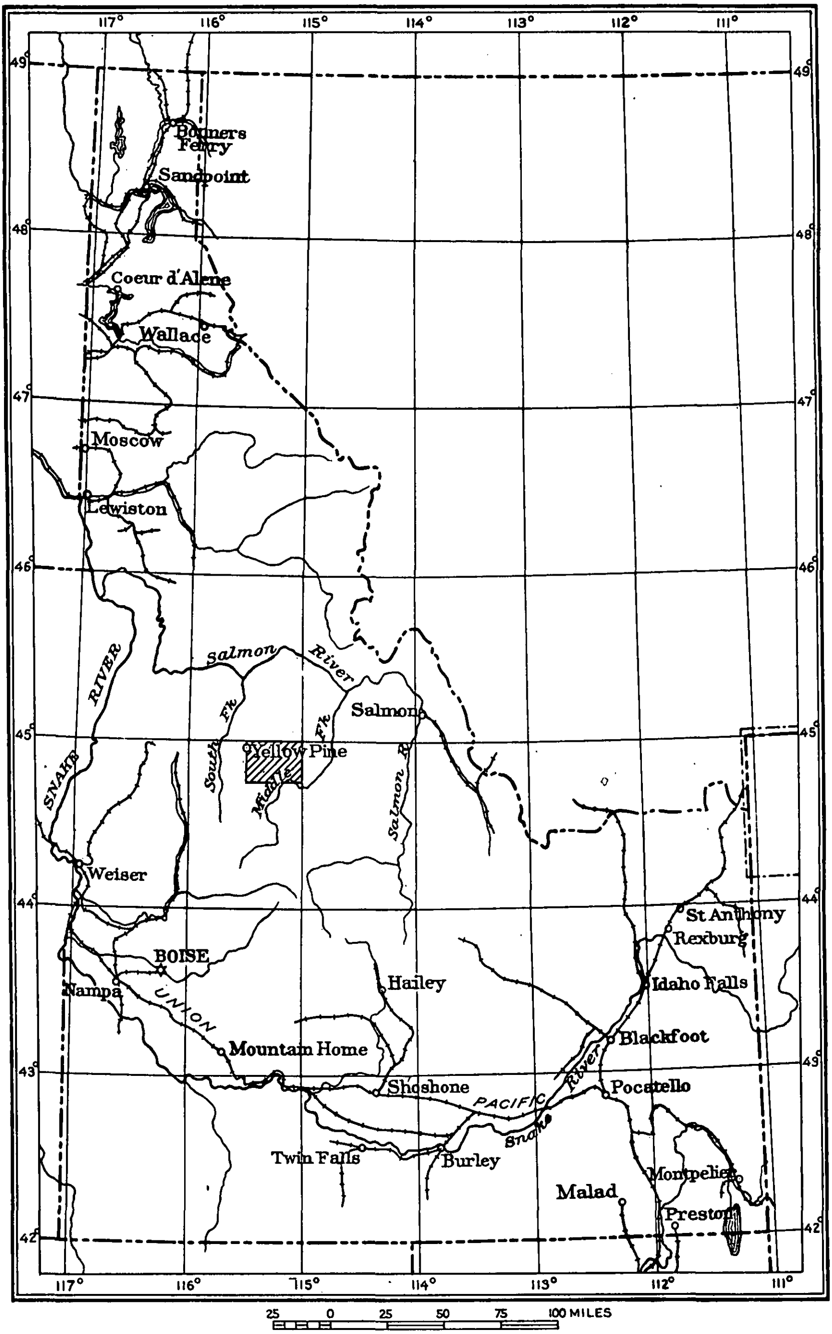


Figure 40.--Index map of Idaho showing location of the Yellow Pine district.

from the junction of Sugar Creek with the East Fork of the South Fork of the Salmon River, which will hereafter be called simply the East Fork. Snow makes the road impassable during the winter, usually from about the middle of November to the middle of May, and during this period traffic is handled by scheduled airplane service from Cascade. The relative inaccessibility of the area has retarded its development, for a high proportion of operating cost is chargeable to the trucking of concentrates, equipment, and material to and from Cascade.

Some of the deposits within the area have been known for many years, but only within the past few years have the size and richness of the principal deposit, that in the Yellow Pine mine, been appreciated. In 1933 the Yellow Pine Co. took an option from the United Mercury Mines Co. on the Hennessy group of claims (which contain the ore body of the Yellow Pine mine), and the Cinnabar, Meadow Creek, and Antimony groups of claims.

The Yellow Pine Co. did most of its early work at the Meadow Creek mine, 2 miles south of the area here described. This mine was operated from 1932 until June 1938 and during this interval produced $1,547,000 in gold, $116,000 in silver, and $215,000 in antimony. In August 1938 the Bradley Mining Co. took over the assets of the Yellow Pine Co. and relinquished the option on the Cinnabar and Antimony groups. Their efforts have been concentrated on the development of the Yellow Pine mine.

Operations on the West ore body were started September 1, 1937, and continued until July 1939, when activities were transferred to the East ore body, where the value of the ore is higher because of a larger gold content, although the antimony content is almost negligible. The antimony produced from the West ore body as shown below is based on an estimated content of 1.08 percent of metallic antimony and a recovery of 77.2 percent.

Output, in tons, from West quarry

	Ore milled	Antimony in concentrates (approx.)
1937	4,193	35
1938	27,872	233
1939	20,505	171
	52,570	439

The present report is based on 6 weeks of field work in the area, from mid-August through September 1939. The area was mapped on a scale of 500 feet to 1 inch, with a contour interval of 25 feet, and was based on triangulation in and about the valley of the East Fork. Because the slopes are steep and heavily forested they were mapped by carrying plane-table and pace-compass-aneriod traverses out from triangulation points.

Messrs. J. D. Bradley, vice president of the Bradley Mining Co. and manager of the Yellow Pine mine, and H. D. Bailey, general superintendent, cordially cooperated with the author and gave him full access to the company's maps, assays, and production figures, as well as permission to publish pertinent information. All these favors are deeply appreciated. Warm thanks are due also to Messrs. D. T. McMillan and W. R. Wagner for capable assistance in the field and to several local residents for help of various kinds.

GEOLOGY

Rocks

The oldest rocks of the area (pl. 38) include a thick series of metamorphic sedimentary rocks, among which are vitreous quartzite, mica schist, calcareous schist, crystalline dolomite, and hornfels. These rocks form part of a large roof pendant surrounded by the Idaho batholith. The most abundant intrusive rock in this area is the medium-grained biotite-quartz monzonite that constitutes most of the batholith, but aplite and pegmatite are abundant in places. A fine-grained biotite-muscovite-quartz monzonite that crops out in the eastern part of the area may be a part of the Idaho batholith. A few dikes of basalt, dacite, rhyolite, and lamprophyre represent the youngest igneous rocks in this area.

Pleistocene glacial and stream deposits and Recent gravels cover much of the lowlands. They are mapped on plate 38 as a single unit.

Metamorphic rocks.--Coarse-grained white vitreous quartzite, having in places the appearance of vein quartz but in places containing appreciable amounts of mica, is one of the most conspicuous of the metamorphic rocks. Its abundance is likely to be overestimated, for it forms the most prominent outcrops because of its great resistance to erosion. Landslides of quartzite have concealed the contact with quartz monzonite along the slope southeast of the Oberbillig prospect on Sugar Creek.

Mica schists are more abundant than the outcrops would suggest. Muscovite, biotite, and quartz are their essential minerals; they also contain variable amounts of sillimanite, cordierite, chlorite, and tourmaline.

The dolomites where not contact-metamorphosed are crystalline and white or buff, but near the contact with quartz monzonite they have been metamorphosed to complex assemblages of silicate minerals, which it is not essential to describe here. Silicified dolomite forms two prominent knobs, one on each side of Sugar Creek. Both are in the same stratum, one at its contact with the main body of quartz monzonite and the other, farther southeast, at its contact with fine-grained quartz monzonite.

Quartz monzonite.--The quartz monzonite contains the principal gold and antimony deposits of the Yellow Pine district. The typical quartz monzonite where relatively unaltered is a medium-grained rock that consists of about 25 percent of quartz, 60 percent of feldspar, 10 percent of biotite, and 5 percent of chlorite, muscovite, and other minerals. Microscopically the feldspar is seen to be slightly more than half oligoclase, the remainder being microcline and orthoclase. The oligoclase is commonly somewhat zoned and is more sericitized than the potash feldspar. The mineral composition of the quartz monzonite and related rocks is of great importance in connection with mineralization.

A granite forming part of the Idaho batholith has been identified, but it is not easily distinguishable from quartz monzonite in the field; another facies is porphyritic, with phenocrysts of orthoclase as much as an inch in diameter.

Dikes and small ill-defined irregular bodies of aplite and pegmatite are abundant in the mineralized zones of the two Hennessy quarries. Both the aplite and the pegmatite consist essentially of feldspar and quartz, with almost no biotite or other dark constituents; they differ from each other only in grain size and apparently grade into each other. The grains in the aplite are mostly less than one-eighth inch in diameter, those in the pegmatite mostly more than one-half inch.

The fine-grained quartz monzonite that occupies the east-central part of the area may be a part of the Idaho batholith. It differs from the normal quartz monzonite mainly in grain size, but it contains more muscovite than biotite.

Dike rocks.--Several dikes of rhyolite, dacite, and basalt occur in the area. The basalt is fine-grained and dark green where fresh but reddish brown on weathered surfaces. The dacite is light gray where fresh and contains phenocrysts of yellowish feldspar, green muscovite, and clear quartz. Where weathered the dacite is yellowish brown, with mottled patches or bands. A thoroughly weathered dike occurs within the ore zone at the entrance to the Bridge tunnel of the East ore body. No conclusive evidence as to whether the dike is pre-mineral or post-mineral was seen; but the fact that a specimen from a diamond-drill core is unaltered and less fractured than the mineralized quartz monzonite suggests that the dike is post-mineral. The rhyolite dikes are buff to yellowish brown and contain small phenocrysts of quartz and feldspar. A dike of fine-grained gray-green lamprophyre, which bounds the West ore body on the west, was encountered in the diamond-drill holes. It strikes N. 10° E. and dips 60° W.

Pleistocene and Recent deposits.--On the accompanying map (pl. 38) the Recent stream gravels, which are negligible in bulk, have not been differentiated from glacial till and outwash. The glacial material, which is very thick in places, covers an undetermined part of the ore body of the Yellow Pine mine and may overlie a large mineralized zone along Fiddle Creek.

The contact of the glacial deposits with quartz monzonite is in many places difficult to trace, because much of the bedrock is concealed under a thick mantle of forest-covered soil. Areas of glacial material are commonly recognizable, however, by the character of their forest cover. The forest on the monzonite consists mostly of lodgepole pine but includes considerable fir and spruce, whereas on the glacial deposits firs are few and the pines are shorter, more closely spaced, and lighter green.

The Monday tunnel was driven through glacial material for more than 500 feet, and at the point where it passes into bedrock the overburden is at least 200 feet thick. There, as well as in the Bridge tunnel of the East ore body, very coarse water-worn material containing boulders several feet in diameter directly overlies the bedrock. Most of the Bridge tunnel is in mineralized quartz monzonite, but just east of the crosscuts and in the short northern spur coarse water-worn boulders are exposed. Most of the long Cinnabar tunnel is likewise in bedrock, but it is in stream gravel from 360 feet to 520 feet, from 530 feet to 660 feet, and from 900 feet to 950 feet east of the entrance. The bedrock is thus shown to have a very irregular surface, quite unlike the present topographic surface.

No evidence was found that the lower valley of Sugar Creek has been glaciated; the gravels there were probably deposited by an aggrading stream originating from several small glaciers in tributary valleys. The East Fork glacier probably never extended down the valley of East Fork much beyond the site of the Yellow Pine mine.

Structure

General features.--The structure of the metamorphic rocks has not been worked out in detail. The general strike is about N. 20° W., and the dip wherever it has been determined is steeply to the northeast. No repetition of beds by isoclinal folding has been observed.

The boundaries of the intrusive quartz monzonite commonly crosscut the bedding of the older rocks, although in the southern part of the area the contact with quartzite is nearly parallel to the bedding. Little could be determined regarding the dips of the intrusive contact, but the course of the contact at Midnight Creek suggests an easterly dip. Unfortunately the detailed structure in critical areas within the quartz monzonite is determinable only where bedrock is revealed in the quarries, surface trenches, and tunnels.

Monday fault.--The Monday fault, a major structural feature of the area, is almost certainly the northern extension of the Meadow Creek fault, in which the Meadow Creek ore bodies lie. This fault is not apparent on the surface, and its position is known only in the Monday tunnel, which was driven along it in the hope that ore bodies similar to those of the Meadow Creek mine might be discovered.

The Monday fault throughout its known length of about 1½ miles is approximately parallel to the contact of the quartz monzonite with the metamorphic rocks, but it lies about 2,000 feet west of the contact within the quartz monzonite. Its trend is nearly due north, and it may well be a part of a regional system of north-trending faults that is prominent about 30 miles to the northwest and west.1/

Yellow Pine shear zone.--The shear zone that contains the ore body of the Yellow Pine mine is here called the Yellow Pine shear zone. Until recently it had been supposed that two distinct mineralized shear zones striking N. 35° E. were exposed in the two open cuts of the mine, one on each side of the

1/ Reed, J. C., Geology and ore deposits of the Warren mining district, Idaho County, Idaho: Idaho Bur. Mines and Geology Pamph. 45, pp. 20-23, 1937. Capps, S. R., personal communication.

East Fork; these are here called the East ore body and the West ore body. Recent diamond drilling has indicated that shearing and mineralization are probably continuous between the two quarries. The structural picture must therefore be revised, but more information is needed to fill in its details. A mineralized shear zone about 180 feet wide, striking N. 35° E. and dipping steeply to the east, extends northeastward from the Bridge tunnel. It has been explored northeastward nearly to the crest of the ridge above the pipe line, but it has not yet been proved to continue farther to the northeast, although a line of prospect pits has been dug approximately on its strike. Shearing and brecciation are much more pronounced near the eastern border of the zone than elsewhere. The limits of pronounced shearing around the West quarry are unknown; the commercial ore is there bounded on the west by a lamprophyre dike, which strikes N. 10° E. and dips 60° E., but sheared unmineralized quartz monzonite extends for an undertermined distance west from the dike.

The prominent fractures in the West quarry seem to form two systems: The first, which strikes nearly north, consists of fractures, commonly containing from half an inch to 2 inches of gouge. This system is possibly divisible into two sets, the more definite striking from N. 15° W. to N. 7° E. and dipping 40°-85° E., the other striking N. 2°-32° E. and dipping steeply to the west. The fractures of the second system contain from a quarter of an inch to an inch of gouge; they strike nearly at right angles to the first, from N. 65° E. to S. 75° E., and dip 35°-85° S. Fractures that do not contain gouge fall in general into two more sets, one of which strikes about N. 60° W. and dips steeply to the north and south, whereas the second strikes about N. 45° E. and dips nearly vertically.

In the East ore body northeast-striking fractures and zones of gouge are the most prominent, particularly near the southeast border.

Two possible explanations of the structural features just described seem possible. Two shear zones, the eastern of which strikes N. 35° E., may converge to the southwest. The zones may or may not be of the same age, and they may be unrelated to the Monday fault. A more probable explanation is that widespread shearing and brecciation have occurred between the Monday fault and the zone of movement that strikes N. 35° E., which is so apparent in the eastern part of the Bridge tunnel. The zone of movement may be a contemporaneous genetically related offshoot of the Monday fault, bearing shear-plane relations to the forces that produced the fault if the east side of the fault moved south. The force relations suggested by the fracture pattern of the West quarry are consistent with this explanation.

The parallelism of the Monday fault to the monzonite contact south of the Yellow Pine mine is probably significant, as is that of the shear zone that strikes N. 35° E. to the part of the contact that swings abruptly northeast. The competency of the metamorphic rocks relative to that of the quartz monzonite was probably the controlling factor in determining the location and direction of the faulting and shearing in the district.

Some post-mineral movement has taken place within the shear zone and possibly along the Monday fault.

ORE BODIES

Occurrence

The antimony of the Yellow Pine district occurs in two ways: as small high-grade lenticular fissure-filling quartz-stibnite veins, rarely more than a foot wide; and as large low-grade disseminated deposits of stibnite in shear zones in quartz monzonite. The dissemination of stibnite and the deposition of it in small veins and micro-veinlets has followed an earlier dissemination of pyrite, arsenopyrite, and gold, which may or may not be genetically related to the later stibnite-silver mineralization. Ore bodies now mined chiefly for gold constitute the greater part of the antimony reserves of the area. They seem to be unique in character; at least the author is not aware of the existence of similar ones elsewhere.

The early sulphides, pyrite and arsenopyrite, are thoroughly disseminated in microscopic grains throughout the quartz monzonite of the shear zones but avoid the aplite and pegmatite. They show a marked tendency to replace biotite and sericitized plagioclase selectively. The gold is apparently all enclosed in the early sulphides. Minor amounts of arsenopyrite and pyrite are present in thin veinlets of fine-grained quartz and dolomite, but the scarcity of gangue minerals in association with these sulphides is one of the striking features of these deposits.

A considerable amount of movement is believed to have taken place within the shear zone between the two major stages of mineralization.

Some of the stibnite that is disseminated in the quartz monzonite markedly decreases in abundance with distance from the source-fractures. Much of the stibnite occurs in breccia zones and veinlets, together with dolomite, vein feldspar, and quartz and as coatings on fracture planes, particularly in brecciated aplite.

Low-grade ores occur in the Oberbillig prospect on the south side of Sugar Creek, in the Sugar Creek prospect near the northeastern corner of the area mapped, and in the Monday fault zone where it passes under Fiddle Creek.

Mineralogy

Pyrite.--Pyrite (FeS_2) is the most abundant sulphide in the average ore, probably constituting about 3 percent of it by weight, although it is greatly exceeded by stibnite where stibnite is locally concentrated. Several thin sections showed the pyrite mainly enclosed in muscovite, which was formed by alteration of biotite. It forms euhedral crystals, from about 0.01 to 0.07 mm. in diameter, and rounded lenses or blebs, with lengths of as much as 0.25 mm. which are oriented parallel to the cleavage plane of the mica; a few crystals occur in primary quartz or feldspar, generally at or near the crystal borders and near a concentration of pyrite in mica. Several other thin sections showed the mineral chiefly replaced by pyrite to be partly-sericitized plagioclase, which contains many euhedral crystals of the sulphide, whereas very few of the crystals are enclosed in muscovitized biotite or in the marginal parts of microcline or primary quartz grains. The reason for this inconsistency is unknown. Where pyrite selectively replaced mica the iron of the original biotite may have acted as a precipitant of the sulphur in the mineralizing solutions; but where muscovitization, with leaching of iron, preceded the formation of sulphides the altered plagioclase may have been selectively replaced.

Some of the pyrite in the ore has a roughly spherical habit, the centers of the spheres consisting of quartz or feldspar. Another peculiar association is a very fine grained micro-intergrowth of pyrite with an unknown hard semi-opaque mineral. These intergrowths, which are generally the largest grains in the ore, are bordered by euhedral arsenopyrite.

Arsenopyrite.--Arsenopyrite (FeAsS) is estimated to constitute about 1 percent of the ore by weight. The mineral is closely associated with pyrite and shows the same evidence of selective replacement. It forms nearly euhedral crystals, rather smaller than those of pyrite; some of these are isolated and some are in small radiating clusters. A minor amount of arsenopyrite is contained in veinlets with micro-crystalline quartz and dolomite. It is mainly concentrated near the borders of these veinlets but is in part distributed in tiny radiating clusters of micro-crystals throughout the veinlet. The disseminated arsenopyrite may have been deposited by solutions spreading into the rock from these veinlets, but in many places the disseminated grains are so evenly distributed that they show no obvious relation to any veinlet or fracture.

Stibnite.--Stibnite (Sb_2S_3) is the most abundant sulphide in the Meadow Creek mine, south of the area, but it makes up only 2 percent or less by weight of the disseminated ore of the Yellow Pine mine. It is the mineral that has most interest in the present survey of antimony reserves, although at present prices the antimony is greatly exceeded in value by the gold contained in the same ore.

About a third of the stibnite is disseminated in quartz monzonite. Some of it selectively replaces mica, but micro-veinlets of stibnite lying between silicate grains or indiscriminately crosscutting silicates and the early sulphides are common. Some of the micro-veinlets contain silicates, carbonate, and pyrite as well as stibnite; others consist of stibnite alone. The disseminated stibnite is much more closely related to the fracture systems than the early sulphides. The amount of stibnite decreases rapidly within an inch or two of most of the fractures.

About two-thirds of the stibnite occurs in veinlets and in fracture zones of brecciated and altered quartz monzonite, with a gangue of dolomite, albite, potash feldspar, and fine-grained quartz. Stibnite without appreciable gangue forms narrow veins, not more than 2 inches wide, and coatings on the walls of late fractures.

Most of the stibnite grains are anhedral and small, averaging about 0.1 mm. or less in diameter.

The stibnite is unaltered except in a shallow weathered zone a few feet thick, where it is partly oxidized to cherry-red or brownish-red kermesite (Sb_2S_2O) or is further oxidized to one or more of the white and yellow antimony oxides. The oxides have little or no commercial value at present because they are relatively minor in amount and are not recovered by the flotation methods, which are now being used by the Bradley Mining Co.

Gold.--Gold, the mineral for which the ore is now being mined, is worth much more to the owners than the associated antimony at the present (1939) contract price. The gold is so fine grained that it has never been seen in milling ore, even under the microscope, but one small grain of it was seen in a thin section of sericitized quartz monzonite from the North tunnel dump. The section contains several grains of pyrite but no other sulphide. In the Meadow Creek mine all or nearly all of the gold is associated with the early sulphides. For several years the stibnite was selectively floated from the pyrite and arsenopyrite, and the gold in the antimony concentrates was approximately proportional to the pyrite and arsenopyrite floated off with stibnite because of imperfect separation. Bailey [2/] states that most of the gold in the Meadow Creek mine is associated with the arsenopyrite in a fairly constant ratio of 0.05 ounce of gold to 1 percent of arsenic.

Silver.--Silver is present in the ore in small amounts. It is closely associated with the stibnite, as shown by assays of the antimony and iron concentrates, but it apparently is not so exclusively bound up with stibnite as gold is with the iron sulphides. The mode of combination is not known, but the silver may be mainly in a sulphantimonide. Assays of ore from the West quarry show a strikingly constant ratio of approximately 0.5 ounce of silver to 1 percent of antimony. The ore from the southwest end of the Bridge tunnel assays about 0.8 percent of antimony and 0.5 ounce of silver per ton; but to the northeast the antimony decreases very rapidly, whereas the silver decreases gradually. The mill heads from the East quarry contain 0.15 to 0.35 ounce of silver per ton and almost negligible antimony. These assays collectively indicate that silver decreases and that antimony decreases still more with distance from the Monday fault. The relations suggest that most of the silver was deposited essentially at the same time as the stibnite but that a small part may be more closely related to the gold and early sulphides than to the stibnite.

2/ Bailey, H. D., Ore genesis at the Meadow Creek mine: Eng. and Min. Jour., vol. 135, No. 4, p. 163, 1934.

Other minerals.--A few minerals not of direct economic value will be discussed briefly. Primary and secondary constituents of the quartz monzonite are chiefly quartz, plagioclase, microcline, muscovite, and sericite. The plagioclase near the ore deposits has been changed from calcic oligoclase to albite and sericite. The microcline is generally clear, but the crystals are commonly broken; they are veined with untwinned potash feldspar, which has grown in parallel position to one of the sets of microcline twins. This vein feldspar has not been positively identified, but it may be microcline, either untwinned or twinned on a very small scale. Adularia might be expected in such an association, but its growth parallel to microcline seems unlikely.

The introduced gangue minerals, which are present in relatively small amount, include dolomite, albite, the potash feldspar described above, and fine-grained quartz.

An earlier report [3] on the area overemphasized silicification and quartz veining in the shear zones; one of the distinctive and unusual features of the mineralized shear zones is the comparative scarcity of introduced quartz, though more silicification has occurred in the east shear zone than in the west zone.

Origin

The ore deposits of the area are believed to have been formed by ascending solutions of igneous origin. A stibnite-silver mineralization followed an earlier high-temperature microcline (?) -albite-pyrite-arsenopyrite-gold mineralization. Although stibnite is typically deposited under low temperature

3/ Schrader, F. C., and Ross, C. P., Antimony and quicksilver deposits in the Yellow Pine district, Idaho: U. S. Geol. Survey Bull. 780, p. 152, 1926.

and pressure, its close association in some veinlets with albite, pyrite, and arsenopyrite--a very unusual association--indicates an early deposition at intermediate or fairly high temperatures.

Ross 4/ has argued that the stibnite mineralization occurred in the Tertiary and was superimposed on a Cretaceous (?) mineralization genetically connected with the Idaho batholith. The author agrees that the stibnite is probably Tertiary, but he believes that the pyrite-arsenopyrite-gold mineralization is also Tertiary and that it represents the first, high-temperature, stage of a process which later, at lower temperatures, caused antimony to be deposited. Although no direct support for this view can be given, several lines of evidence indicate that even the earlier mineralization took place under lower pressure than that which must have existed immediately after the emplacement of the Idaho batholith. The texture and mineral composition of the batholith, the present relief of 4,000 feet, and the additional thousands of feet removed by erosion all show that the batholith at the horizon of the ore deposits consolidated under a very heavy load. In contrast, the very fine grain of the early sulphides, their association with fine-grained quartz or chalcedony, and the association of some of the stibnite with albite and arsenopyrite suggest deposition under relatively low pressure, with the temperature high in the early stages but decreasing at a fairly rapid rate. The breadth of the shear zones also seems to indicate a relatively shallow depth. Other evidence indicates a mid-Tertiary age for a north-south fault system which is prominent to the west 5/ and to which the Monday fault and the Yellow Pine shear zone may be related.

4/ Schrader, F. C., and Ross, C. P., op. cit., p. 157.

5/ Reed, J. C., Geology and ore deposits of the Warren mining district, Idaho County, Idaho: Idaho Bur. Mines and Geology Pamph. 45, pp. 20-23, 1937. Capps, S. R., personal communication.

Whether or not the ore persists at depth cannot well be judged by comparison with similar deposits elsewhere, because, so far as the author is aware, no other deposit sufficiently similar exists. Most breccia-zone deposits decrease in grade with depth; and stibnite veins characteristically pinch out at relatively shallow depth. But exploration in stibnite-bearing veins has perhaps never been persistent enough to prove that additional stibnite lenses are not present below the known occurrences. In the Meadow Creek mine, 2 miles south of the Hennessy shear zones, the main ore body is cut off just below the 400 level by the Meadow Creek fault, but it has not been proved that other good ore shoots do not exist at greater depth. At the White Capps mine, in the Manhattan district, Nevada, high-grade pockets of stibnite have been found as deep as 1,100 feet below the present surface, although most of the stibnite apparently lies above the 600-foot level.

However, it must be admitted that persistence of the ore at great depth in the Yellow Pine mine cannot be predicted with any degree of confidence. If the ore was deposited at a relatively shallow depth, it is probable that the grade will decrease more rapidly than in most intermediate- and high-pressure deposits and that the antimony will decrease more rapidly than the gold. The ore may be expected, however, to continue several hundred feet below the creek level. One of the diamond-drill holes of the Bureau of Mines attained a depth of about 250 feet below the creek level opposite the West quarry, and it was in good antimony-gold ore when discontinued.

Localization

All the ore deposits are within the quartz monzonite of the Idaho batholith. The Fiddle Creek deposit and the Meadow Creek deposit, which is a mile south of the area mapped, are within the Monday-Meadow Creek fault zone. This zone throughout its known extent, is west of the contact between quartz monzonite and metamorphic rocks and parallel to it. The Yellow Pine shear zone may be an offshoot of the fault. The abrupt swing of the quartz monzonite contact to the northeast is of probable structural significance. The shear zone is parallel to the extension of this northeast line and may continue across the intervening ridge and slope to the Oberbillig prospect on Sugar Creek. A small vein and a shear zone exposed in prospects on the north side of Sugar Creek are also approximately on the continuation of this line. It is uncertain whether or not the effects of shearing and mineralization are continuous between these prospects, which are separated by areas covered with heavy soil and vegetation or with landslide material from the steep quartzite slopes to the southeast. The possibility that the zone is continuous warrants its further exploration.

The Sugar Creek prospect, near the northeast corner of the area, is not on the continuation of the Yellow Pine shear zone but is adjacent to the quartz monzonite contact. This fact suggests that all the prospects between the East quarry and Sugar Creek may be more directly related to local shearing near the contact, controlled by irregularities of the contact, than to a single continuous shear zone connecting all the prospects. In the absence of exposures this suggestion cannot be proved or disproved.

In detail the localization of ore within the Yellow Pine mine is related to the degree of shearing and to the character of the country rock. Both gold and sulphides are most abundant where pre-mineral shearing is most pronounced, and they occur chiefly in the quartz monzonite. Both gold and sulphides are scarcest in the aplite and pegmatite. These rocks were apparently more competent than the quartz monzonite, probably because they contain hardly any biotite, and therefore resisted shattering, which was favorable to ore deposition. Biotite, moreover, has had a more direct influence chemically, in that the sulphides have selectively replaced it.

The relations as now recognized indicate zoning of antimony and silver. The antimony content decreases northeastward with distance from the Monday fault. The West quarry is nearer the fault than the eastern shear zone and is also richer in antimony; furthermore the west border of the western zone, adjacent to the lamprophyre dike, is considerably richer in antimony than the central portion. The East quarry contains very little antimony, particularly to the northeast. The zoning of silver is similar, but the silver does not decrease as rapidly to the northeast as the antimony. The gold is very differently distributed; the East ore body contains considerably more gold than the West ore body, it is richest in the central part of the zone, and its richness increases toward the southwest. The zoning of the antimony suggests that the solutions rose along the Monday fault and migrated upward and northeastward along the shear zones. Another possible explanation is that the mineralization was controlled entirely by permeability within the shear zone, which may have been more thoroughly brecciated to the southwest and west, at least during the late stages of ore deposition. The significance of the lamprophyre dike, which dips 60° E. and bounds the ore body on the west, is not yet understood. The ore body is so large that the dike might not be expected to have had a large influence on its deposition; but the ore body does show a definite relation to the dike, being limited by its hanging wall. The antimony content of the ore increases eastward to the dike, beyond which barren sheared quartz monzonite extends for an undetermined distance.

Structural control of another kind was exercised by a lamprophyre dike at Meadow Creek mine, 2 miles south of the Yellow Pine mine.[6] Some of the ore bodies of this mine lie at places on the footwall side of the dike where its dip has decreased, and others lie on the footwall side of gently dipping cross faults.

Size and grade of known ore bodies

Most antimony deposits are groups of small, lenticular, high-grade veins, in which it is impossible to block out large tonnages, of known tenor, ahead of actual mining. The West ore body of the Yellow Pine mine, on the other hand, is very large, and its percentage of antimony, though low, is relatively uniform. Because of these characteristics, it constitutes the largest dependable reserve of antimony in the United States.

The limits of the West ore body have not been determined, except on the west side. A block having a triangular horizontal cross section with sides of 650, 600, and 800 feet has been explored by diamond drilling (see pl. 39), and most or all of it consists of possible ore; but much more diamond drilling must be done to determine the exact boundaries of the ore body. Possibilities for continuance at depth are yet unknown, though good ore has been found in one hole as deep as about 250 feet below creek level.

6/ Bailey, H. D., Ore genesis at the Meadow Creek mine: Eng. and Min. Jour., vol. 135, no. 4, April 1934.

The best estimate of the grade of the West ore body is supplied by the records of the Bradley Mining Co.'s flotation plant for the two periods June to November 1938 and May to July 1939, when ore from only the West quarry was milled. The mill heads for those months consisted of 30,540 tons of dry ore, which assayed 1.08 percent of antimony. The recovery of antimony in the concentrates, by the flotation methods now used, averaged 77.2 percent, so that 0.835 percent of the mill heads was recovered as metallic antimony. Nearly all of this ore was quarried near the center of the shear zone. Diamond drilling indicates that the northwest part of the zone will assay nearly 1.5 percent of antimony and that a quantity of ore from 5 to 10 feet thick adjacent to the lamprophyre dike bounding the ore body on the west will assay nearly 5 percent of antimony. But because of uncertainties concerning the exact grade, particularly at depth, the above production figures are considered the best available estimate of the grade of the deposit as a whole.

The East ore body is at least 800 feet in length and averages probably about 170 feet in width, but the ore is so poor in antimony that it should not be considered in any estimate of dependable antimony reserves.

The dimensions and grade of the Oberbillig and Sugar Creek prospects have been estimated by the Federal Bureau of Mines. The tonnages in both deposits may be large, but the grade is apparently so low, particularly in the Oberbillig prospect, that operations could not be profitable unless antimony prices were unusually high.

The Monday tunnel entered an ore body of unknown extent directly under Fiddle Creek. For a length of 240 feet beyond this point assays averaged 1.1 percent of antimony and about $0.75 in gold per ton. Fifty feet of this length averaged

1.6 percent of antimony and another 40 feet averaged 2.35 percent. The relation of this ore body to the fault is not yet known, but it is of prime importance. If the ore body is wholly within the main fault zone the tonnage is probably small, but if it lies at the junction of a northeast-trending shear zone with the main fault it may be comparable in size to the West ore body. This ore body was inaccessible in 1939 because the tunnel was badly caved in the fault zone.

Although the Monday tunnel was driven in glacial material for the first 600 feet of its length, bedrock was exposed on the floor 370 feet from the portal. Diamond-drill holes driven northeastward and southwestward from this point were in ore for about 50 feet on each side of the tunnel. The ore is said to assay from $2 to $3 per ton in gold and from 1 to 2 percent of antimony. The orientation of the ore body and its relation to the main ore bodies of the Yellow Pine mine are not known.

RESERVES

At normal prices none of the antimony deposits of the district are rich enough in antimony to be profitably mined for that mineral alone. The Yellow Pine ore bodies are minable at the present time only because of their gold content. Under present conditions the ores are submarginal in respect to the antimony content. Any estimate of reserves must take into account not only the estimates of tonnage and grade given above but the factor of price, which must depend on future conditions not now predictable.

West ore body of the Yellow Pine mine

In computing the easily minable ore lying above the level of the creek, which is at an altitude of about 6,090 feet (see pl. 39), it may be assumed that the proved triangular part of the ore body has the volume of a block 275 feet wide, 495 feet long, and 110 feet high. If the overburden had an average thickness of 25 feet and a ton of ore had a volume of 12 cubic feet, the quantity of ore originally present amounted to 965,000 tons, of which 52,000 tons had been mined prior to January 1, 1940. If the grade of the remaining 913,000 tons is the same as that of the ore previously mined (0.835 percent of recoverable antimony), the deposit contains 7,620 tons of recoverable antimony.

If the triangular block tested by drilling near the surface extends downward with the western side dipping 60° E. and the other two sides vertical, 2,625,000 tons of ore lies between the creek level and a depth 200 feet lower. If the recoverable antimony decreases from 0.835 percent to 0.7 percent of the mill heads, 18,350 tons of recoverable antimony is contained in the deposit below the creek level. A total of 3,538,000 tons of ore, containing 25,970 tons of recoverable antimony, is believed to be a reasonably conservative estimate of the present content of the deposit between the surface and a depth of 200 feet below the creek level. The chance, moreover, that the block is wider and deeper than has been assumed seems excellent.

Other deposits

The other antimony deposits of the area have not yet been sufficiently explored to warrant any estimate of their tonnage or grade. The total antimony content of these unexplored deposits may be large, but it is probably much less than the estimated tonnages of the West ore body of the Yellow Pine mine, and the ore is probably of very low grade. Additional undiscovered deposits in the northerly extension of the Monday fault zone or its offshoots may underlie the glacial deposit in the valley of the East Fork.

The known reserves of the Meadow Creek mine, operated by the Yellow Pine Co., the predecessor of the Bradley Mining Co., deserve mention. H. D. Bailey,[7/] general superintendent, has estimated that there is in the West ore body of this mine about 100,000 tons of ore containing 1½ percent of antimony and 0.14 ounce of gold per ton and that there is in the stopes at the south end of the 200 level about 25,000 tons of ore containing 5 percent of antimony and 0.14 ounce of gold. This would be equivalent, altogether, to at least 2,100 tons of recoverable antimony, assuming a 77.2-percent recovery; and there is probably a large additional tonnage of low-grade ore, either undiscovered or containing too little gold to make it worth mining at current prices of antimony.

Influence of price on possible production

The degree to which a rise in prices of antimony would affect production depends on several factors. These will be considered in the order in which they would presumably become effective during a period of rising prices.

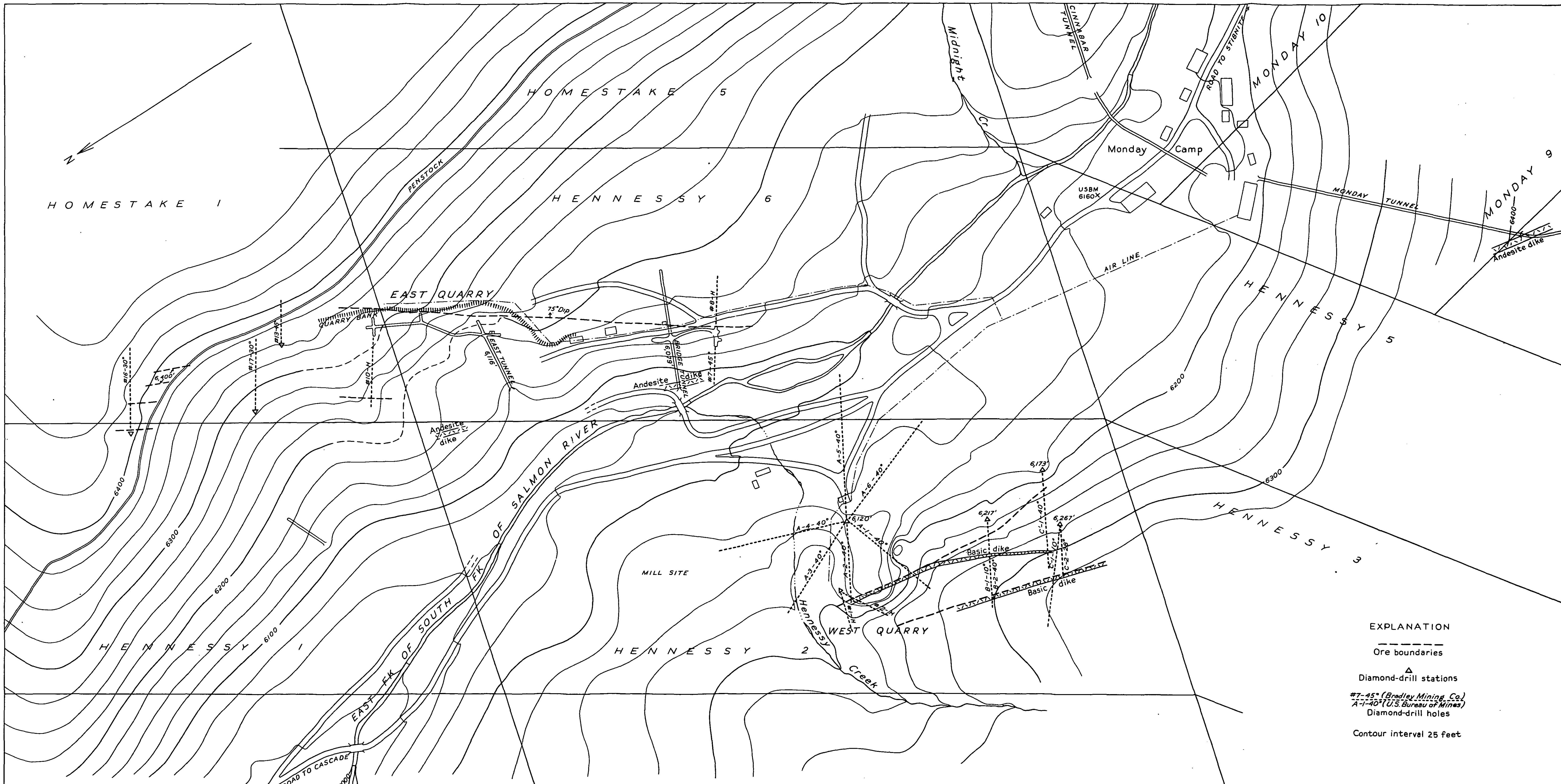
Until July 1939 most of the ore milled at the Yellow Pine mine had come from the West quarry. During the months of June to November 1938 and May to July 1939, while the ore was coming entirely from this source, the mill heads, weighing 30,540 tons, averaged $4.07 in gold, 21.61 pounds (1.08 percent) of antimony, and 0.51 ounce of silver per ton. The respective mill

7/ Personal communication.

recoveries were 79.2 percent, 77.2 percent, and about 80 percent. The value of the metals recovered per ton of ore totalled $4.15, of which $3.22 was in gold, $0.63 in antimony, and $0.30 in silver. The net value of the ore at the mill, after subtracting charges for smelter treatment, freight, and hauling, was $2.78 per ton.

During August 1939 the company shifted operations to the East quarry, where the ore contains considerably more gold but less antimony and silver per ton than in the West quarry. The mill heads for the months from October 1939 to February 1940 totalled 41,135 tons. They averaged $5.47 in gold and about 0.25 ounce of silver per ton but contained only a negligible amount of antimony. Only $3.60 in gold, or 65.8 percent of the mill heads, was recovered during this period, as compared with 79.1-percent recovery from the West ore. No difference between the ores of the two quarries that would seem to account for this difference in gold recoveries has yet been found. The net value of the ore at the mill was $2.77 per ton, or almost the same as the ore of the West quarry. The differences in the values of the concentrates and of the ratios of concentration of the two ores have been considered in arriving at the net values.

The Bradley Mining Co. may shift operations temporarily back to the West quarry at any time, because with present recoveries the net values of the two ores are almost identical, and by milling ore from the West quarry the higher-grade ore of the East quarry may be saved until a more efficient metallurgical treatment for it has been put in operation. Experimental cyaniding of the flotation tailings has given good results, and the company plans to build a cyanide plant which, with the flotation plant, is expected to recover from 85 to 90 percent of the gold content of the mill heads.



TOPOGRAPHIC MAP OF THE YELLOW PINE MINE SHOWING LOCATION OF DIAMOND-DRILL HOLES

100 0 500 Feet

Data furnished by Bradley Mining Co. December 1, 1939

By thus revising the metallurgical treatment, the relative net values of the ores will be changed considerably. If 90 percent of the gold and 85 percent of the antimony is recovered, the net value at the mill of the gold ore from the East quarry will be $4.09 and that of the gold-silver-antimony ore from the West quarry $3.22 per ton, with antimony at its present price. Recovery of 85 percent of the antimony is not too much to expect, for that recovery was exceeded during the month of June 1938.

When those recoveries are attained a net return of 8.15 cents per pound of antimony in the concentrates will be necessary in order to equalize the net values at the mill of the West-quarry and East-quarry ores, and until a price permitting this return is obtained the owners would profit most by mining only in the East quarry, where the antimony production is negligible.

Other assumptions would of course lead to different results. In making the above calculation, it has been assumed that the gross mill-head value of the ore in the East quarry is $5.47 per ton. This figure, however, applies only to the central part of the shear zone, striking N. 35° E. For the full width of the ore blocked out by the East tunnel, a value of $5.10 is probably more accurate. If this figure is used in the calculations, a price of 6.35 cents per pound of antimony is necessary to make the ores from the two quarries of equal net value. A higher price, on the other hand, would be necessary if the gold content in the southwest side of the East quarry proved to be greater, or the tenor in antimony and gold together in the West quarry proved to be less than has been assumed. The results of diamond drilling indicate that the total reserves of the West quarry will probably average less in gold than the ore that has been milled. In the opinion of Mr. J. D. Bradley, however, both ore bodies contain somewhat less gold than past production would indicate; he estimates the gold values per ton at $3.50 for the West quarry and $4.50 for the East quarry.

The Bradley Mining Co. has investigated a metallurgical treatment of the West-quarry ore whereby the antimony would be recovered electrolytically at Stibnite, and the other sulphides roasted, before shipment to the smelter. A part of the freight and hauling charges would thus be saved, and a much greater return on the antimony would be realized. The company estimates the cost of leaching, filtering, roasting, electrolyzing, casting, and loading at $11.00 per ton of concentrate and the costs of smelter treatment and freight on the roasted product at $13.30 per ton of original concentrate as compared with the present figure of $19.00 per ton. The total cost of the proposed treatment would exceed the present cost by $5.30 per ton of concentrate, or 29.3 cents per ton of ore, but this excess would be offset by increased saving of antimony. If 5.34 cents per pound is received for the electrolytically recovered antimony, the West-quarry ore will have the same net value under either of the two treatments.

A net price of 9.75 cents per pound of metallic antimony recovered by the electrolytic process is necessary for the West quarry ore to equal in value that of the East quarry. The net value of metallic antimony at Stibnite probably would be from 1 cent to 2 cents less than the New York quotations. If the gross value of the whole East ore body is considered to be $5.10 per ton instead of $5.47, a net price of 7.9 cents per pound of metallic antimony is necessary to make the two ores of equal net value.

The initial cost of installing new metallurgical equipment has not been considered in these calculations, but it is an important factor. The electrolytic plant would require 475 horsepower and might necessitate expensive additions to the hydroelectric power system.

The Yellow Pine Co. is of the opinion that an average net price of at least 10 cents per pound of metallic antimony must be assured in the future before the installation of metallurgical equipment for the electrolytic separation of antimony is warranted. The obvious advantage of the proposed metallurgical treatment in relation to the strategic-mineral situation in the United States is that an increase in the open-market price of antimony would immediately increase the net returns, because the company would sell in the open market. A greater production of antimony would likely result, either because of an expansion of the mine and mill facilities or because the highest-grade antimony ore would be mined in order to take advantage of the good market. At present, on the contrary, inasmuch as the antimony is sold by contract to the smelter, a rise in the open-market price does not immediately benefit the mine owners and fails to stimulate production.

The average price for metallic antimony from 1919 to 1938 was 9.97 cents per pound, and from 1930 to 1938 it was 9.89 cents per pound. The lowest yearly average for the period 1919-38 was 4.92 cents per pound and the highest was 17.50 cents. Whenever it seems probable that a market price of 12 cents, or 2 cents more than the average for the past 21 years, can be assured for several years, the Bradley Mining Co. might consider making the necessary metallurgical changes; but if continuance of the price were not assured, the price would probably have to be greater.

The present mill capacity has recently been raised from 150 to 400 tons of ore a day, or 146,000 tons a year, and this capacity can with little difficulty be further increased to 500 tons a day, or 182,500 tons a year. The Bradley Mining Co. would shift operations to the West quarry and would produce from 1,200 to 1,600 tons of antimony a year if (1) the smelter, under the present procedure of smelter treatment, would agree to pay 7 cents or more per pound of antimony contained in the concentrates, or if (2) an average open-market price of 12 cents per pound of metallic antimony seemed assured for several years in the future. In that case the company would undertake electrolytic separation of the antimony.

Even though the price continues to rise, production will likely remain at the same level until a price is reached that warrants expansion of milling facilities. The company is well aware of the advantage of large-scale mining, and it has considered in the past an expansion of its facilities. Its reserves of gold ore are now known to be very large. Those in the Yellow Pine mine may amount to 8,000,000 tons, and greater tonnages may be proved at relatively low exploration costs. With these large tonnages of low-grade gold ore as a sound basis for expanding its operations, the company probably could enlarge its milling facilities at any time regardless of the price of antimony. A rise in the net return from the antimony might be the deciding factor that would induce the company to undertake such enlargement with a view to putting the antimony in the West quarry ore promptly upon the market while prices were high. The author, however, is obviously not in a position to evaluate such possibilities.

An increase in mill capacity to 1,000 tons a day, or 365,000 tons a year, would result in the recovery of 3,050 tons of antimony a year. Still further enlargement of the mill capacity would give a correspondingly increased production. The following table gives the writer's estimates of the production to be expected at three price levels.

Assumed net return to operator (cents per pound)		Expected production (tons)	
Contract price with smelter for contained antimony in concentrate	Metallic antimony, electrolytically produced	First year	Second and third years
3.75 to 6	10	Negligible	Negligible
7 to 8	12	1,200-1,600	1,200-1,600
10?	15?	1,000-2,000	3,000-7,500

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