Geology of the Tungsten, Antimony and Gold Deposits Near Stibnite, Idaho

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GEOLOGY OF THE TUNGSTEN, ANTIMONY, AND GOLD DEPOSITS NEAR STIBNITE, IDAHO

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ABSTRACT

The deposits of tungsten, antimony, silver, and gold described in this report occur in an area about a mile wide and 3½ miles long near the town of Stibnite, Valley County, Idaho. Ore has been mined from only two deposits in the area, the Yellow Pine and Meadow Creek mines of the Bradley Mining Co. The Yellow Pine mine was the largest source of tungsten and antimony ores in the United States from 1942 to 1944. Gold and silver ores also are taken from this mine. Only gold, antimony, and silver ores were mined in the Meadow Creek mine, which was closed in 1938.

Quartz monzonite and related rocks of the Idaho batholith, locally containing large roof pendants of metamorphosed sedimentary rocks, are the principal rocks of the area. Intense and widespread faulting, controlled in part by older structures in the sedimentary rocks, has been accompanied by much shearing in the quartz monzonite. Dikes of basalt, quartz latite porphyry, trachyte, and rhyolite were intruded after the main faulting but before the final fault movements.

Metalization took place in three stages, with intervening periods of fracturing. The first stage is represented by extensive replacements by gold-bearing pyrite and arsenopyrite, the second by less extensive replacement by scheelite within the gold ore bodies, and the third and final stage by replacements by stibnite and silver, localized in part by the same fractures that localized the scheelite.

The main ore bodies occur along the Meadow Creek fault, a shear zone as much as several hundred feet wide cutting the quartz monzonite. The ore bodies are localized by changes in strike or dip of the main fault zone and by intersecting subsidiary faults associated with these changes. The tungsten-antimony ore body at the Yellow Pine mine has the general shape of a flat upright funnel flaring to its widest diameter at the surface and tapering to a narrow neck, which extends below the bottom of the minable tungsten ore. The under side of the ore body is very irregular in detail. The highest grade of tungsten ore was concentrated toward the center of the mass and was surrounded by an envelope of antimony ore containing only a little tungsten. The richer gold ore bodies not only are clustered around the antimony "funnel" but are distributed elsewhere in and near the fault zone where there is little associated tungsten and antimony ore.

Ore mined at the Meadow Creek mine contained 0.23 ounce of gold per ton and 1.6 percent of antimony. That mined at the Yellow Pine mine contained less gold but about 4 percent of antimony and 2 percent of WO_3.

The tungsten ore body at the Yellow Pine mine was exhausted in 1945. A total of 831,829 units of WO_3 were contained in the tungsten concentrates produced. Antimony and gold are still being produced from the mine.

Reserves of antimony at the Yellow Pine and Meadow Creek mines were estimated on June 1, 1943, at nearly 40,000 tons of metallic antimony contained in indicated ore averaging more than 1 percent of antimony, and more than 20,000 tons in indicated gold ores averaging less than 1 percent of antimony. Additional amounts may be produced from now undeveloped prospects in the area.

The antimony at the Yellow Pine and Meadow Creek mines, and presumably that in the other deposits, contains silver in the approximate ratio of half an ounce of silver to 20 pounds of antimony.

The Yellow Pine mine will probably be a gold producer for many years to come because of its sizable reserve of indicated gold ore. Other mines and prospects in the area should add to the total gold output. The district is believed to contain nearly 600,000 ounces of gold in indicated ore averaging 0.1 ounce per ton or better, and about 140,000 additional ounces of recoverable gold in antimony ore.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The area described in this report is near the town of Stibnite, in the Yellow Pine mining district, Valley County, Idaho. (See fig. 9.) It is in a mountainous largely undeveloped region. Altitudes range from 6,000 to nearly 9,000 feet above sea level. Both water and timber are abundant.

The area can be reached by graded dirt and gravel roads from Cascade and McCall, which are on the McCall branch of the Oregon Short Line Railroad. The roads are kept open during the winter months but are impassable for a month or more during the spring thaw; at that time the area is accessible only by air. There are excellent airports at Yellow Pine and Stibnite, and airplane service is available throughout the year.

HISTORY AND PRODUCTION

Deposits of quicksilver, antimony, and gold were discovered in the area about 1900 during the gold boom at Thunder Mountain, which is about 9 miles east of Stibnite. A little exploratory work was done in the years immediately following discovery, but the inaccessibility of the deposits discouraged development. The high quicksilver prices during the first world war stimulated interest in deposits several miles east of the area described in detail in this report. The Fern quicksilver mine was opened in 1917 and the Hermes quicksilver mine in 1918. The Fern mine was operated intermittently until 1924, but total production was small. The Hermes mine was operated intermittently on a small scale until 1942, when it was taken over by the Bonanza Mines, Inc. In 1943 it was among the leading quicksilver producers in the United States.

In 1914 Albert Hennessy recorded two groups of gold-antimony claims near Stibnite. These claims, known as the Meadow Creek and Hennessy groups, were acquired later by the United Mercury Mines

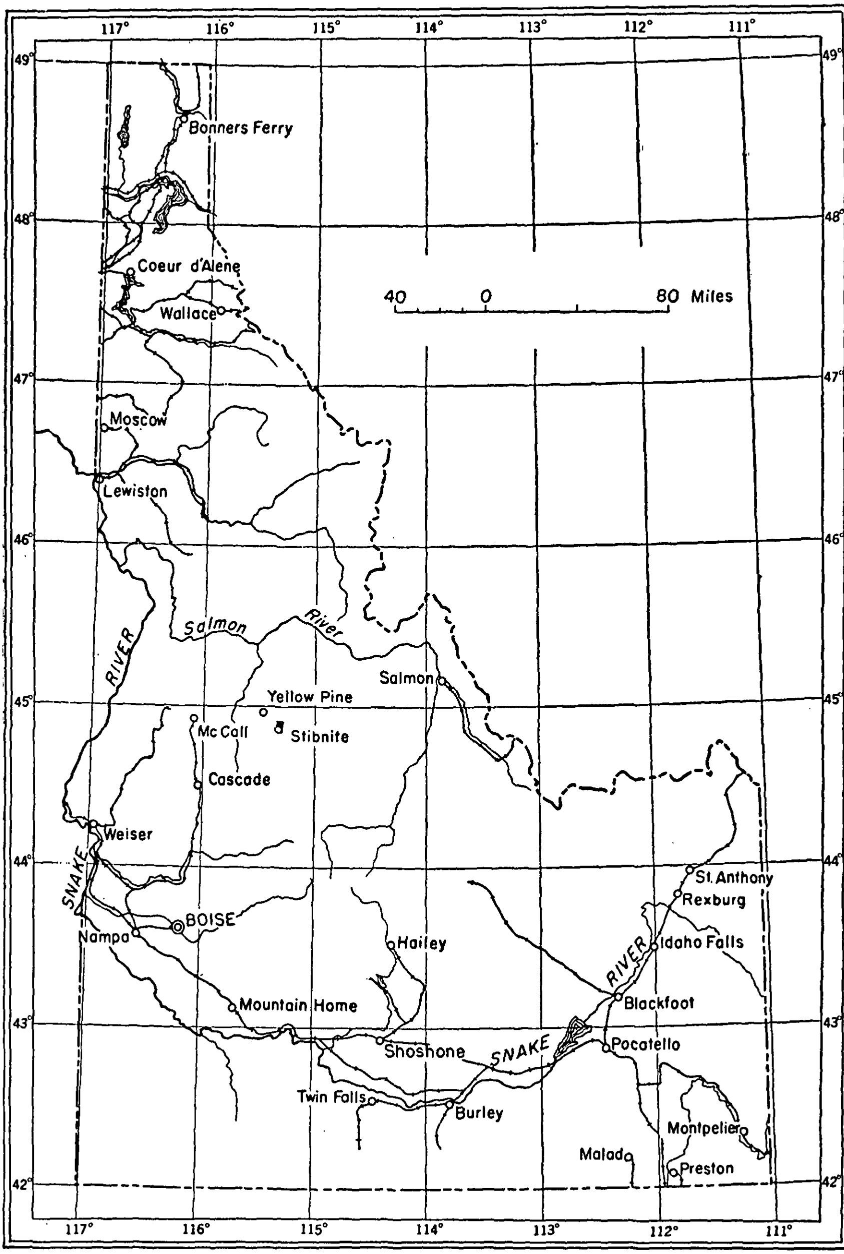

FIGURE 9.—Index map of Idaho, showing location of the Yellow Pine district.

Co. of Boise, Idaho. In 1927 the late F. W. Bradley of San Francisco, Calif., obtained an option on the Meadow Creek group and in 1933 on the Hennessy group. The operating company was known as the Yellow Pine Co. until 1938, when all of its assets were acquired by the parent company, the Bradley Mining Co.

Commercial development of the gold-antimony deposits was begun in 1929 by the Bradley interests at the Meadow Creek mine at Stibnite. This mine was in production from 1932 until June 1938, when it was shut down. The Yellow Pine mine was opened in September 1937 as a quarry operation 2 miles north of the Meadow Creek mine and has been in continuous operation to the present time. The Yellow Pine mine was first called the Hennessy quarry, and the underground tungsten mine later opened in the quarry area was called the Idaho Tungsten mine during part of its life.

Tungsten was discovered at the Yellow Pine mine in 1941 by D. E. White of the United States Geological Survey in the course of the strategic minerals program of the Survey and the United States Bureau of Mines. In the late summer of 1939, the Survey and the Bureau of Mines almost simultaneously started separate projects for the investigation of the antimony ores of the Yellow Pine district. White spent 6 weeks during August and September of that year in mapping the surface geology of the Yellow Pine mine. The Bureau of Mines explored a number of antimony showings in the district and started a diamond-drilling project at the Yellow Pine mine in November, which lasted 4 or 5 months. White returned in the summer of 1940 to map the regional geology, log the drill cores of the previous winter, and collect specimens for further study. The Bureau of Mines started a new drilling project at the mine just before White's regional mapping was completed. In January 1941 White discovered scheelite in the course of microscopic study of one of the drill-core specimens he had collected. The discovery was immediately reported to the Bradley Mining Co. and the Bureau of Mines. Exploratory work was concentrated on the tungsten discovery, which soon proved to be of major importance. The results of the extensive and intelligent drilling program of the Bureau of Mines proved of great value in blocking out the deposit.

The tungsten ore was first mined in August 1941. By the end of that year large quantities were being produced, and during 1942, 1943, and 1944 the Yellow Pine mine was the largest tungsten producer in the United States. The tungsten ore body was exhausted in July 1945. Retreatment of tailings from the tungsten operation was completed in December 1945. With the exhaustion of the tungsten ore body, the remaining gold-antimony ores were exploited at an increased rate.

Statistics given by Cole and Bailey (1948, p. 4) show that the production from the Yellow Pine and Meadow Creek mines to the end of 1945 totaled 1,184,079 tons of ore which yielded 95,358 tons of concentrate, containing 831,829 units of WO_3,[1] 14,981 tons of metallic

[1] A unit of WO_3 is 20 pounds of tungsten trioxide. Tungsten concentrates are sold on the basis of units of contained tungsten trioxide.

antimony, 101,437 ounces of gold, and 592,211 ounces of silver. There has been little if any production of these metals from other deposits in the area discussed in this report.

PREVIOUS WORK

Brief descriptions of the geology of the district based on reconnaissance studies have been published by Larsen and Livingston (1920, pp. 73–83) and Schrader and Ross (1926, pp. 137–164). A later report by Currier (1935) gives a detailed petrographic description of the igneous rocks. The regional geology of the district was mapped in considerable detail by White in 1940 (White, 1946). His preliminary report on the Yellow Pine mine area (White, 1940) contains a geologic map of the mine area and gives the results of a study of the microscopic characteristics of the gold-antimony ore. Bailey (1934, pp. 162–163) has described the Meadow Creek mine, J. D. Bradley, Mecia, and Baker (1943, p. 64) the Yellow Pine mine, and Worthen Bradley (1943, pp. 32–34, 40–44) the Hermes mines.

FIELD WORK AND ACKNOWLEDGMENTS

The author spent about 7 months in the field between March 18 and October 28, 1943, under the direction of T. B. Nolan, commodity geologist for tungsten, and P. J. Shenon, regional geologist. Capable assistance in the field was given by R. P. Full for nearly 2½ months and by S. E. Clabaugh for about 3 weeks. T. W. Amsden gave much valuable help in compiling large-scale maps and detailed reserve estimates included with the first draft of this report, released in open file on June 14, 1944.

S. W. Hobbs of the Geological Survey revisited the district in August 1944 to bring the Yellow Pine quarry map and tungsten reserve estimate up to date. Although all maps and sections of the mine show the shape of the quarry as it was on June 1, 1943, the profile of August 23, 1944, is also shown on the sections on plate 42 to indicate the progress of mining.

The maps and cross sections are tied to the coordinate system of the Bradley Mining Co. The surface maps were made with plane table and telescopic alidade controlled by the company's triangulation stations. Their transit stations in the mine furnished control for the underground maps. Diamond-drill and assay data were obtained from the Bradley Mining Co. and the Bureau of Mines.

The management and staff of the Bradley Mining Co. cooperated in every way. They provided living and working quarters in the field and gave full access to the company's maps, drill logs, and assays, as well as permission to publish information.

GENERAL GEOLOGY

The area mapped is underlain by quartz monzonite and related rocks of the Idaho batholith and by metamorphosed sedimentary rocks, which are part of a large roof pendant in the batholith. The sedimentary rocks were folded and faulted before intrusion of the quartz monzonite, and later faults, controlled in part by these older structures, cut the quartz monzonite. Dikes of basalt, quartz latite porphyry, trachyte, and rhyolite were intruded after the main faulting that followed the quartz monzonite but before the final movement on these faults. Stream erosion and localized valley glaciation have formed a rugged topography of high relief. The slopes are largely covered by residual soil and landslide material and the valley bottoms by glaciofluvial deposits and recent alluvium.

ROCKS

Metamorphic rocks.—Quartzite, quartzitic conglomerate, mica schist, metamorphosed limestone, dolomite, and tactite are distinguished on the areal geologic map (pl. 38). The stratigraphic succession in the area has never been worked out, and the outcrops are so scarce that the inferred contacts are tentative. Although no fossils have been found in the rocks, Ross (1934a, pp. 937–1000) concludes on the basis of lithology that the series is lower Paleozoic, probably Ordovician in age.

The quartzite is a vitreous rock, white to pale buff in color, composed almost exclusively of quartz. It is resistant to erosion and forms prominent massive outcrops and talus slopes.

The quartzitic conglomerate is also a massive resistant rock, differing from the quartzite only in containing well-rounded quartz pebbles with a maximum diameter of about 1 inch. The percentage of pebbles is variable, and stratification is not clearly marked. The thickness varies considerably along the strike. The conglomerate is very prominent and apparently thick just south of the Fern mine but appears to thin out to the northwest, disappearing on the south slope of Sugar Creek, about 2½ miles to the northwest. Only the thin northwestern part of the formation is within the area mapped.

The mica schist is a fine-grained to medium-grained micaceous and foliated rock containing scattered metacrysts that are locally discernible to the unaided eye. White (1940, p. 252) reports the presence of muscovite, biotite, and quartz with variable amounts of sillimanite, cordierite, chlorite, and tourmaline. The rock was formed by the metamorphism of an argillaceous sediment.

The metamorphosed limestone and dolomite are similar in appearance and are hard to differentiate in some outcrops. The limestone exposed on Midnight Creek and on the slope east of the Homestake prospect is a thin-bedded fine-grained blue-gray rock, which effervesces vigorously with cold acid. The limestone exposed on Clearwater Creek, at the north end of the mapped area, is also relatively pure. The other limestone units mapped appear to be interbedded with dolomite and to grade into it.

Both limestone and dolomite are notably altered by hydrothermal and contact metamorphic processes. The least altered limestone is a fine-grained to medium-grained blue-gray rock, whereas the dolomite is steel gray to buff. Both grade into coarse-grained white marble. The dolomite exposed about 400 yards southwest of the Bonanza prospect on Sugar Creek is highly silicified. The rock is partly replaced by fine-grained quartz and is cut by ramifying white quartz veinlets. The intensity of silicification increases toward the north, suggesting that the mineralizing solutions rose along the Meadow Creek fault zone. The effects of contact metamorphism by the quartz monzonite intrusion can be seen in both limestone and dolomite, the best examples being near the quartz monzonite contact along Garnet Creek in the southern part of the area mapped and along Clearwater Creek in the northern part. Other examples can be seen in the road cuts along Sugar Creek and elsewhere for a distance of a quarter of a mile or more away from exposed quartz monzonite. Although the mineral associations have not been worked out in detail, they are evidently those of typical contact silicates, consisting of various proportions of garnet, epidote, pyroxene, and other contact minerals. A little pyrite and magnetite are also found in the contact zones.

Quartz monzonite.—The part of the Idaho batholith containing the tungsten, antimony, and gold deposits is a medium-grained granitic rock, light to medium gray in color, with a weak gneissic foliation. Both platy and linear foliation were observed but the foliation was too poorly defined to map.

The rock is here called quartz monzonite in keeping with the classifications of Currier (1935, pp. 8–12) and White (1940, pp. 253–254). White says the typical rock, where relatively unaltered, consists of about 25 percent quartz, 60 percent feldspar (slightly more than half oligoclase, the remainder microcline and orthoclase), 10 percent biotite, and 5 percent chlorite, muscovite, and other minerals. Currier describes the rock in detail, pointing out that it has granodiorite and quartz diorite border phases. White has identified a granite also.

Aplite, presumably related to the quartz monzonite, is very abundant in the Yellow Pine and Meadow Creek mines. It is typically a sugary-textured, fine-grained to medium-grained light-colored rock consisting of feldspar and quartz with almost no biotite or other dark constituents. Locally the coarser phases grade into pegmatite. The aplite was intruded into shattered quartz monzonite in small irregular dikes and stringers which could not be mapped satisfactorily. Away from the ore deposits aplite is less abundant.

Dike rocks.—The dikes, which include basalt, quartz latite porphyry, trachyte, and rhyolite, are mostly in or near large shear zones like the Meadow Creek fault zone (pl. 38). Small faults cut and offset the dikes a few inches or a few feet, but as the dikes are notably less sheared than the enclosing rocks they must have been intruded after the main fault movements.

All the known dikes are younger than the rocks of the Idaho batholith (late Jurassic or Cretaceous) and older than the glaciofluvial deposits (Pleistocene). The writer believes they were intruded in middle Tertiary time because of petrographic similarity to Tertiary dikes in nearby areas. Bailey (1934) believes that the basic dikes of the Meadow Creek mine are basic differentiates of the Idaho batholith and that they are of Cretaceous age.

The basalt and related rocks are fine-grained and greenish gray to black in color. The least altered specimens were found in narrow dikes along Clearwater Creek (pl. 38). One of them, which is nearly black on the fresh surface, consists of approximately 80 percent plagioclase (sodic labradorite), 10 percent pyroxene (mostly enstatite with some augite), and 10 percent brown hornblende. It is probably best classified as pyroxene andesite, although the relatively calcic feldspar suggests basaltic affiliations. It is similar to the augite andesite dike Currier (1935) describes as cutting the lower conglomeratic beds of the Tertiary lavas near Cane Creek.

The basic dikes of the Meadow Creek and Yellow Pine mines, classified as lamprophyres by the geologists of the Bradley Mining Co. (Bailey, 1934) and as diabase by Currier (1935), are at least in part basaltic in character. They are fine-grained rocks and range from black to greenish gray on fresh fracture, the color depending on the amount of alteration. Small amygdules and altered feldspar phenocrysts are visible in hand specimens. Thin sections commonly show fluidal textures characteristic of basalt. The dikes have chilled once glassy selvages an inch or less thick along contacts with the country rocks.

The original mineral composition is difficult to determine because of alteration. Plagioclase apparently made up about 70 percent of the rock. The other constituents appear to have been augite, hornblende, olivine, biotite, iron oxides in varying amounts, and in some specimens a little quartz. The primary minerals are altered mostly to carbonate with lesser amounts of chlorite and clay minerals.

The age of the dikes with respect to the metallic mineralization is not definitely determined. Schrader (Schrader and Ross, 1926, p. 155), Currier (1935, p. 20), and Bailey (1934) believe they are older than the earliest (gold) stage of mineralization. In favor of this interpretation are the apparent dike control of ore bodies at the Meadow Creek mine (p. 181) and the fact that certain small fractured parts of the dike in that mine carried 0.05 to 0.07 ounce of gold per ton (Bailey, H. D., personal communication). The writer believes the dikes at the Yellow Pine mine are younger than the gold, because no gold is revealed by chemical analyses of the dike rock (Mecia, J. A., personal communication), and the alteration of the dike rock is unlike the alteration of the adjacent gold ore. It is possible that the dikes are as old as the antimony stage of mineralization. Films of calcite with tiny euhedral pyrite crystals coat fractures in the dike at the Yellow Pine mine. At one place in the Meadow Creek mine the margin of the dike is fractured, and the fractures are filled with dolomite, later calcite, and stibnite, which appears to have been deposited throughout the carbonate sequence. In both cases deposition of these minerals probably took place during the last stages of mineralization. The basalt dikes at the Yellow Pine mine are tentatively considered younger than the gold and older than the antimony. The dikes in the Meadow Creek mine may be older.

The quartz latite porphyry, classified as dacite by White (1940, p. 254) and by geologists of the Bradley Mining Co., forms one or more dikes at the Yellow Pine mine. It is a light grayish green rock. The original constituents, feldspar, quartz, and biotite phenocrysts in an aphanitic groundmass, have been largely altered to sericite, carbonate, and a clay mineral. Most of the original feldspar has been completely destroyed, and only remnants of the original biotite remain. At several places, however, about 40 percent of the feldspar phenocrysts are unaltered glassy orthoclase, whereas the remainder are chalky altered plagioclase (?). Because of the high orthoclase content, the writer classes the rock as quartz latite rather than dacite. The rock is correlated with the quartz latite porphyry dikes that Shenon (Shenon and Ross, 1936, pp. 13–14) has described from Profile Gap, which are clearly as young as middle Tertiary. They belong with the related group of dikes described as "dacite porphyry" by Ross (1934b, pp. 62–63) and "porphyritic andesites and dacites" by Currier (1935, pp. 12–13), both of whom point out that there is much variation in the composition of the rocks of the group from place to place.

The quartz latite porphyry dike exposed in the Yellow Pine mine has rolling irregular walls and is not constant in strike or dip. Small faults younger than the latite have been observed, but the irregularities of the dike are due to the fact that it was intruded into intensely sheared rock, and although it follows the Hennessy fault throughout most of its known length it does not follow a single shear plane. Soft gougelike zones, common within the dike parallel to its walls, are thought to be due to chemical alteration rather than shearing because they contain euhedral phenocrysts, uncrushed and unoriented, exactly like those in the hard latite. Euhedral feldspar crystals can be picked from the clayey groundmass at many places. True gouge derived from the dike was seen at several places and is readily distinguished from the soft zones just described.

Dikes of rhyolite as much as 40 feet thick were found in the landslide scar above the Meadow Creek mine and along a southward-flowing tributary of Sugar Creek at the north end of the mapped area (pl. 38). The rock is white to pale gray or buff. It is fine-grained, but small phenocrysts of quartz and feldspar are visible in hand specimens. Microscopic examination shows that the groundmass is an aggregate of feldspar, quartz, and subordinate quantities of mica. There is some secondary sericite, carbonate, and a claylike mineral, possibly halloysite. Currier (1935, p. 13) reports the presence of specks of later sulfides, pyrite, and stibnite in the dike at the Meadow Creek mine. The rhyolite is therefore considered older than the antimony. Shenon (Shenon and Ross, 1936, p. 14) reports that the rhyolite of Profile Gap cuts the Idaho batholith, the earlier Tertiary quartz diorite and granodiorite, and the quartz latite porphyry; it is cut in turn by lamprophyre dikes. The rhyolite dikes have generally been correlated with the nearby Challis volcanics (late Oligocene or early Miocene).

A trachyte dike crosses the tributary of Sugar Creek where the rhyolite occurs. It resembles the rhyolite except for its slightly darker color and the absence of quartz and feldspar phenocrysts. A thin section shows the rock to have a typical trachytic texture and to contain less than 5 percent of quartz and about 2 percent of magnetite. The alteration minerals are the same as those in the rhyolite. The trachyte contains amygdules of chalcedony and calcite.

Glaciofluvial deposits and Recent alluvium.—The bottoms of the larger valleys are partly filled by glaciofluvial deposits and Recent alluvium. The two are similar in general, and no attempt was made to map them separately. Glaciofluvial deposits are well exposed in the West quarry of the Yellow Pine mine. They consist of moderately rounded pebbles and boulders with a maximum diameter of 10 feet in a sandy groundmass. Large exposures commonly show a rude stratification and also occasional lenses of cross-bedded sand. Although no glacially faceted or striated boulders were seen in the deposit, a glaciofluvial origin seems certain because of the great size of the boulders and the fact that fresh gravel extends high up on the valley sides. The topography as well as the distribution of the gravel indicates that a valley glacier formed by the confluence of several tributary glaciers above Stibnite followed the Meadow Creek-East Fork Valley to a point not far north of the Yellow Pine mine. There is no indication that the lower part of Sugar Creek was glaciated. The gravel left when the Meadow Creek glacier retreated is about 50 feet thick at the Yellow Pine mine. Drilling shows that the gravel near the junction of East Fork and Meadow Creek is 75 feet thick and close to the edge of the valley flat near the Meadow Creek mine 135 feet thick. It is probable that the maximum thickness of gravel in this area exceeds 200 feet.

The Recent alluvium resembles the glaciofluvial deposits but lacks the huge boulders. It is found in unglaciated valleys and forms prominent alluvial cones where small tributaries flow out onto the larger valley flats.

Landslide material.—Postglacial landslides are numerous on the steep valley sides. (See pl. 38.) The most interesting landslide is that on the Meadow Creek fault zone north of Stibnite. The sheared and gougy rock of the fault zone has favored sliding, which was repeated at intervals in the past and is still taking place. The material forming the toe of the slides is a mixture of subangular fragments, some of which are large enough to be mistaken for outcrops.

STRUCTURE

Metamorphic rocks.—The metamorphosed sedimentary rocks east of the Yellow Pine mine have a regional northwest strike and steep northeast dip between Sugar Creek and Monumental Summit, a distance of about 4 miles. Although crumples in the beds are indicated by flat dips and southwest dips along West End Creek, no major folds are evident in the small area mapped. The regional geologic map by White (1946) shows an overturned synclinal axis along the west side of the metamorphic mass. (See pl. 38.) The writer's observations indicate that if such a structure exists, its axis strikes slightly more toward the northwest than is shown on White's map and is truncated by the quartz monzonite in the vicinity of Midnight Creek. Low dips at the head of Garnet Creek fit in well with the position of the axis as White shows it there. If this interpretation of the structure is correct, as seems probable, the whole rock succession exposed along Midnight and Sugar Creeks may be overturned; however, symbols indicating overturn are not shown on plate 38.

Near Sugar Creek, the beds swing to a more nearly north-south strike. Along Clearwater Creek, at the northeast end of the mapped area, the beds strike a few degrees east of north. The eastward bend in strike is related in some way to the northeast bend in the quartz monzonite contact and the narrow tongue of metamorphic rocks extending toward the northeast. Currier (1935, pp. 14–15) has suggested that the north extension of the roof pendant was faulted northeast for at least two-thirds to three-quarters of a mile along the approximate line of Sugar Creek. The bend in strike of the metamorphic rocks and the direction of displacement on the Meadow Creek fault are in accord with such an offset, but evidence against it is found east of the Bonanza prospect, where the single exposure of the contact between the quartz monzonite and the metamorphic rocks is intrusive and the fault zone is wholly within the quartz monzonite.

White's mapping shows that the roof pendant is cut by three major northeast-southwest faults, which are cut off by the quartz monzonite. (See pl. 38.) From south to north, these faults are the Fern, Garnet Creek, and West End. The Fern fault passes near the Fern mine and, according to White's map, offsets the northern part of the synclinal axis about 2,000 feet to the west. The Garnet Creek fault is parallel to and a mile and a quarter northwest of the Fern fault. It crosses the head of Garnet Creek and strikes toward the Meadow Creek mine. The north block along the Garnet Creek fault is offset a maximum of a few hundred feet to the west. The West End fault is roughly parallel to and about a mile and a half northwest of the Garnet Creek fault. Where exposed by bulldozer cuts near West End Creek it is represented by a shear zone 50 to 100 feet wide striking toward the West quarry of the Yellow Pine mine. It offsets the northern extension of the sedimentary beds as much as 1,500 feet to the east, in a direction opposite to the offset on the Fern and Garnet Creek faults. The large displacements on the Fern and West End faults are certainly older than the quartz monzonite intrusion, but smaller movements may have taken place following the quartz monzonite intrusion, as suggested for the West End fault on plate 38. No field evidence was found to either prove or disprove this possibility, which is suggested by the fact that the two main ore bodies of the area, at the Yellow Pine and Meadow Creek mines, are located where faults older than the quartz monzonite project into the Meadow Creek fault zone. (See pl. 38.) Lines of weakness like these older faults could reasonably be expected to influence the position and character of younger structural features.

Quartz monzonite.—The Meadow Creek fault zone along which the main ore bodies occur (pl. 38) is a wide shear zone in the quartz monzonite. It strikes a few degrees east of north from the Meadow Creek mine for about 2 miles and then, just south of the Yellow Pine mine, turns abruptly to N. 35° E. The shear zone extending northeastward from the Bonanza prospect may be the faulted extension of the Meadow Creek fault zone, or it may be a parallel echelon zone, as it is shown on the map. The Meadow Creek fault zone is so wide that it is desirable to split it up for detailed description. Near the Yellow Pine mine the chief movement took place along the southeast side of the zone in a band of gouge and intensely sheared rock about 150 feet wide, which will be referred to henceforth as the Meadow Creek fault. (See pl. 39.) The western boundary, called the Monday fault by

White (1940, p. 256), is marked by a 10-foot basalt dike (pls. 39, 41, 42), which follows a shear zone on the projection of the west edge of the Meadow Creek fault zone south of the northeasterly bend in the fault zone. The north boundary is here called the Hanging Wall shear. It is exposed near the top of the East quarry and strikes N. 45° E. and dips 50° NW. (See pl. 39.) The sheared and shattered rock between the Meadow Creek fault and the basalt dike and the Hanging Wall shear contains the ore bodies of the Yellow Pine mine.

In the Meadow Creek mine, the Meadow Creek fault lies west of the ore bodies in parts of the mine that were inaccessible at the time of the writer's work. The level maps of the Bradley Mining Co. show the east wall with a strike near north-south and a dip of 65°–80° E. between the *A* and 100 levels and 65°–75° W. between the 200 and 400 levels. (See pls. 43, 44.) The Meadow Creek fault zone is concealed on the surface between the Meadow Creek and Yellow Pine mines except for an outcrop in the landslide scar near Stibnite. It is exposed, however, in the North and Monday tunnels (pl. 38) driven in search of deposits similar to those at the Meadow Creek mine. Both tunnels are now caved a short distance from the portals. The Monday tunnel is reported to have been in gouge for about 3,500 feet, and the gouge zone is reported to have been 200 feet wide at the crosscut.

The Meadow Creek fault is the key to understanding the complex structure at the Yellow Pine mine. Where crossed by the Bailey tunnel, the fault is 145 feet wide; it strikes N. 25° E., and the main gouge and shearing planes dip 53°–90° W. (See pl. 40.) Both slickensides and cleavage indicate that the west, or hanging wall, moved obliquely upward and to the north relative to the footwall. The horizontal component was greater than the vertical. The other fractures reflect this direction of movement and the northeastward bend of the Meadow Creek fault zone previously described. As would be expected, the movement was partly distributed on shear planes with less sharp bend than the Meadow Creek fault. Chief among these planes are the shear marked by the basalt dike, which presumably splits off the Meadow Creek fault some distance south of the mine, and the Hennessy fault, represented by 2 to 15 feet of intensely sheared rock and tough leathery gouge, which splits off from the Meadow Creek fault at the south end of the mine workings. (See pls. 39–42.) There is a complex system of smaller shears and fractures with prevailing strikes between N. 20° E. and east-west. Geologists of the Bradley Mining Co. distinguish five of them as *A*, *B*, *C*, *D*, and *E* structures. The most persistent of the smaller fractures, of which *C* is a good example, strike N. 50°–70° E. and dip about 60° NW. (See pls. 39, 41.) Along many of these northeastward-trending fractures, the northwest side moved upward and northeast relative to the southeast side.

The structure pattern is best interpreted as the result of a north-south shearing couple (west side, north; east side, south). The stress would result in planes of maximum shear lying nearly north-south (Meadow Creek and Hennessy faults and basalt dike) and east-west; the tension fractures would be northeast-southwest (fractures parallel to *C*). At the Yellow Pine mine the structure is complicated by the bend in the Meadow Creek fault, which may have been due to the difference in competence of the quartz monzonite and the metamorphic rocks, as White (1940, p. 258) has suggested, or to the existence of the older West End fault, which projects into the Meadow Creek fault near the bend. Whatever caused the bend, the assumed shearing couple seems to provide a rational explanation of the fracturing. The north-south plane of maximum shear, being nearly parallel to the forces, developed into the main structural feature, the Meadow Creek fault. Where it swings northeastward, the shearing strain was partly distributed on the Hennessy fault and other faults roughly parallel to it. The east-west plane of maximum shear, being nearly at right angles to the forces, was expressed in a few weak northwest to east-west fractures. Tension formed *C* and other northeast fractures, but they did not remain open tension cracks. A corollary of the horizontal component of movement on the Meadow Creek fault would be either the formation of a great void in the area of the Yellow Pine mine, that is, north of the eastward bend in the Meadow Creek fault, or lateral displacement of rock in this area. That lateral displacement did actually take place is indicated by the large horizontal component of movement now evident on *C* and other fractures that were initially tension cracks. Most parts of the old tension cracks were closed by the lateral movements, but enough local openings remained to provide access to ore-forming solutions.

One interesting feature of the structure at the Yellow Pine mine is that whereas the Meadow Creek fault dips west, the Hennessy fault and the basic dike dip east. As for all practical purposes the Meadow Creek fault forms one boundary of the ore zone and the basic dike the other, there is a progressive narrowing of the ore zone with depth.

ORE DEPOSITS

The Yellow Pine mining district contains two types of ore deposits of commercial importance, (1) deposits of low-grade disseminated gold ore containing local concentrations of antimony-silver and tungsten and (2) deposits of quicksilver. Although there are many prospects on each type of deposit, ore has been mined in significant quantities from only two mines on the first type, the Meadow Creek and Yellow Pine mines, and from two on the second, the Fern and Hermes mines. The Yellow Pine and the Meadow Creek mines and a number of prospects on the first type of deposit are the only ones discussed in detail in this report.

The deposits of the first type, described in detail on pages 174–190 and shown on the geologic map (pl. 38), are hydrothermal replacements in fracture zones. The earliest ore minerals, gold-bearing pyrite (FeS_2) and arsenopyrite ($FeAsS$), were followed by scheelite ($CaWO_4$) and finally by stibnite (Sb_2S_3). The early sulfides are sparsely disseminated, the ore carrying 0.05 to 0.23 ounce of gold per ton. At the Yellow Pine mine the ore forms a single irregular body 700 feet wide, 2,000 feet long, and in places more than 400 feet deep. At the Meadow Creek mine the ore occurs in a number of separate lenses 2 to 40 feet thick, and at some prospects, like the Murray, the early sulfides are concentrated in thin veins. Scheelite, deposited in and near local fractures younger than the gold, is widely distributed in minute amounts and at the Yellow Pine mine occurred as a large body of tungsten ore, averaging about 2 percent of WO_3 within the gold ore body. Stibnite, introduced near the same fractures that localized scheelite and also near other fractures, occurs as ore carrying 1 to 4.5 percent of antimony. Both tungsten-antimony and antimony ores are generally low in gold.

LOCALIZATION AND MODE OF OCCURRENCE

The location of the known deposits and the distribution of detrital quicksilver and tungsten minerals indicate a regional mineral zoning. All the quicksilver has been found east of a north-south line about a mile east of Stibnite. The important tungsten, antimony-silver, and gold deposits are west of the line. Both areas are shown on plate 38. White (personal communication) suggests that the zoning may be due to depth below the land surface at the time of mineralization. The erosion surface of earlier Tertiary time was covered by the Challis volcanics and then tilted to the east about 10° before it was eroded to the present topography. Thus the quicksilver deposits of the Hermes and Fern mines were formed nearer the land surface of Tertiary time than the tungsten-antimony-gold deposits at the Yellow Pine and Meadow Creek mines, although today the two types of deposits are at approximately the same altitude.

The distribution of metals and minerals, shown on plate 38, indicates the localization of mineralization along fault lines. The Meadow Creek and Yellow Pine mines and also several antimony-gold prospects are along the Meadow Creek fault zone. The older faults that preceded the quartz monzonite also have localized deposits. The Fern fault passes near the Fern mine and may be responsible for the local southwestward extension of the quicksilver area into the quartz monzonite. Good pan showings of cinnabar in several small gulches tributary to Fern Creek from the west suggest that important quicksilver deposits may occur along the fault near the contact between quartz monzonite and the roof pendant. It is suggestive that the southwestward projection of the Garnet Creek fault passes close to (1) the Murray prospect, (2) a small antimony vein near the Stibnite schoolhouse, and (3) the Meadow Creek mine. The West End fault has localized extensive gold deposits near West End Creek. It may be partly responsible for the eastward bend of the Meadow Creek fault at the Yellow Pine mine and thus, indirectly, for the large ore body there.

Most of the gold, tungsten, and antimony minerals are disseminated in shear zones in quartz monzonite, as at the Yellow Pine and Meadow Creek mines described on pages 174–184. Disseminated gold with a little stibnite has been found in sheared schist and quartzite at the Homestake prospect and at several places along West End Creek. A little disseminated scheelite is found in sheared quartzite at the Peterson prospect on Clearwater Creek. A little scheelite occurs also in small calcite veins that filled fissures north of the Yellow Pine quarries. A dozen or more of these veins have been found in diamond-drill cores and in the Bailey tunnel. A high-grade stibnite vein an inch or two thick cuts fresh quartz monzonite near the Stibnite schoolhouse, and probable many other small veins of the same kind are present in the area.

Composition of the host rock controlled the shape and grade of some of the gold ore bodies. The early gold-bearing sulfides replaced biotite to a greater extent than the other minerals in the quartz monzonite. As a result, the aplite dikes, which contain little or no biotite, commonly have a lower gold content than the adjacent quartz monzonite. In parts of the Yellow Pine and Meadow Creek mines, where small irregular aplite bodies are abundant, the average grade of the gold ore is lower. Separation of the quartz monzonite from the aplite during mining is impractical, and no method has been devised to reject aplite prior to concentration. The original mineral composition of the host rock seems to have had little or no effect in localizing tungsten and antimony ore.

MINERALOGY

White (1940, pp. 260–264) has described the mineralogy in detail, but as he discovered scheelite after the description was written the subject is reviewed here and revised to include the tungsten mineralization. White's observations have been drawn upon freely and are supplemented by the writer's own observations. The inferences and conclusions are those of the present writer.

Pyrite and arsenopyrite.—White estimates that the early sulfides pyrite (FeS_2) and arsenopyrite ($FeAsS$) make up about 3 percent and 1 percent, respectively, by weight of the average ore. The arsenopyrite forms nearly euhedral crystals, the pyrite both euhedral crystals and rounded grains. The diameter of the grains ranges from about 0.003 to 0.60 millimeter and averages about 0.03 millimeter. The larger grains are pyrite and on polished surfaces commonly show cavernous centers, which White reports were once filled with quartz or feldspar. The early sulfides are distributed through the quartz monzonite without obliterating the granitic texture and without obvious relationship to particular fractures. They are most abundant in sericitized biotite but occur also in sericitized feldspar, generally at or near the boundaries of the feldspar grains. The tungsten-rich portions of the ore contain less than the average amount of pyrite and arsenopyrite, and the grains tend to be smaller and more irregular in shape, suggesting corrosion by the tungsten solutions.

A little pyrite and arsenopyrite form coatings on tiny fractures. Most of these coatings were probably contemporaneous with the disseminated early sulfides, but some, consisting of euhedral pyrite in calcite, appear to be of later generation.

Gold.—The mineralogic form of the gold in the primary ore has not been determined. White (1940, pp. 262–263) discovered one small grain of native gold in oxidized ore from the North tunnel dump, but the writer could detect no native gold in the ore or in the valley detritus of the region.

The gold is clearly related to the early sulfides. Quartz monzonite, which has been mineralized by fine pyrite and arsenopyrite, contains 0.01 to 0.30 ounce of gold per ton. Assay data on thousands of feet of diamond drilling at the Yellow Pine mine show that large bodies contain 0.05 to 0.17 ounce of gold per ton. The pyrite-arsenopyrite flotation concentrates from the Yellow Pine mine contain 1.5 to 2.5 ounces of gold per ton. The very small gold content of the tungsten and antimony concentrates is probably associated with contained pyrite and arsenopyrite. The gold in unoxidized ore cannot be recovered by cyanidation even from the finely ground concentrates.

Bailey (1934, p. 163) states that most of the gold at the Meadow Creek mine is associated with arsenopyrite in a fairly constant ratio of 0.05 ounce of gold to 1 percent of arsenic, but this rule does not appear to hold throughout the district. Both Bailey and Mecia (Bradley, Mecia, and Baker, 1943, p. 64) believe that the gold was introduced after the pyrite and arsenopyrite.

With the hope that the mode of occurrence of the gold might be determined, three briquettes of the gold concentrates were prepared and polished. Mr. M. N Short has very kindly examined them and reports (letter of March 6, 1944) in part:

I must report failure to discover any gold or gold minerals. I examined the three sections carefully with our Leitz le Chatelier model micrographic camera using a 4-millimeter lens. The magnification was about 500. I identified only three minerals—pyrite, arsenopyrite, and stibnite. Tungsten minerals may be present, but I did not recognize them. The separation of stibnite from the hard sulphides was not very clean, as the amount of stibnite is approximately equal to the combined amount of arsenopyrite and pyrite. Of the two hard minerals, pyrite is the more abundant.

With the magnification I had I could have recognized gold as small as 1 micron in diameter, if it had been present. Neither the pyrite nor the arsenopyrite has inclusions of any recognizable mineral other than stibnite. Nothing would be gained in finer grinding.

Scheelite.—Scheelite ($CaWO_4$) is the chief tungsten mineral and the only one observed by the writer, although White (1942, p. 4) has reported a very minor amount of tungstenite (WS_2). The scheelite is white to creamy pink with bright blue fluorescence. It forms grains less than 0.01 millimeter to more than 10 millimeters in diameter. Probably 80 percent of it is in the finer sizes and is recognizable only by using the miscroscope or ultraviolet lamp. The larger grains, particularly where embedded in massive stibnite, are readily distinguished in hand specimens.

The scheelite occurs in several ways. Much of it is disseminated in brecciated gold ore. A very common ore type is a cemented breccia with fine scheelite disseminated in both fragments and groundmass but more abundant in the groundmass. In places a large proportion of the scheelite occurs in branching veinlets and stringers 1 to 5 millimeters thick. The most spectacular ore consists of large scheelite crystals and fragments embedded in massive stibnite. The original texture and mineral composition of the quartz monzonite have been largely destroyed by the introduction of dolomite, quartz, and other minerals in the high-grade tungsten ore.

In the Bailey tunnel and in diamond-drill cores north of the Yellow Pine mine, scheelite grains several millimeters in diameter were found in lenticular calcite veins 1 to 6 inches thick. Some of the calcite veins in this area are barren, but scheelite was found in about a dozen places, mostly concentrated near the middle of the veins. No commercial concentrations of this type have been found to date, but they may be present. Ten feet of the core from diamond-drill hole B 51 is tungsten ore, probably of this type, averaging 1.37 percent of WO_3. (See pl. 42, sec. *P–P′*.) Diamond-drill holes B 52 and B 106, which are close to section *P–P′* but are not shown on it, were drilled with the hope of finding the extension of the ore, but they cut no scheelite.

At some places the gravel overlying the tungsten ore body contained enough detrital scheelite and boulders from the scheelite ore body to be considered as commercial ore. A considerable proportion of the scheelite was in subangular to rounded decayed pebbles and boulders. The remainder was in minute grains, which E. N. Pennebaker, consulting geologist for the Bradley Mining Co., has examined microscopically and reports (personal communication) to be rounded detrital grains carrying tiny pointed overgrowths of scheelite.

Stibnite.—Stibnite (Sb_2S_3) occurs as disseminations, microveinlets, stockworks, massive lenses, small fissure-filling quartz-stibnite veins, and euhedral crystals coating late fractures. The first four grade into one another and together constitute more than 95 percent of the antimony ore at the Yellow Pine mine. The typical disseminated stibnite is in small irregular grains with fairly even distribution. Some of the grains are less than 0.01 millimeter in diameter and nearly equidimensional. Others are irregular with branching threadlike apophyses along cracks or cleavage planes of older minerals. These grade into stringers and microveinlets crossing several adjacent grains of other minerals. The stringers are irregular because they were formed by replacement at the sides of tiny fractures, and some minerals were more readily replaced than others. Calcite was easily replaced, quartz less so, and scheelite was not readily replaced. The stibnite grains in the microveinlets are intermediate in size between those of the disseminations and of the massive stibnite lenses. The massive stibnite lenses, having a maximum thickness of 10 feet in the central part of the ore body, consist predominantly of stibnite in blades as much as several inches long associated with scheelite, quartz, dolomite, and other minerals.

The fissure-filling quartz-stibnite veins are neither large nor abundant. The largest seen at the Yellow Pine mine was a few millimeters thick and several inches long. They have straight clear-cut walls and cross the other minerals indiscriminately. Euhedral quartz lines the vein walls, and stibnite fills the central part. Apparently these veins are somewhat later than the disseminated stibnite and the microveinlets.

Delicate euhedral stibnite crystals as much as an inch long are commonly found coating late fractures. They may be contemporaneous with pyrite coatings on similar fractures, but the two minerals were not found together in the same fracture. The stibnite coatings must have been deposited after the last episode of major fracturing. It is possible that they are of supergene origin, for H. D. Bailey (oral communication) reports that delicate stibnite crystals have been found growing in open spaces in stockpiles of gold-antimony ore from the Meadow Creek mine.

Oxidized antimony minerals are scarce. After exposure for a few months in mine workings, the stibnite becomes coated with cherry-red to brownish-red kermesite (Sb_2S_2O). Kermesite and small quantities of the white and yellow antimony oxides are common near the bedrock surface in the quarries, but as the amount of antimony in the oxidized state is small no attempt is made to recover it.

Silver.—Silver is a minor constituent of the gold-antimony ores. Although the silver-bearing mineral has not been identified, most of the silver is associated with stibnite, possibly as argentiferous tetrahedrite or as a sulfantimonide. In general, ores that are high in antimony are high in silver, and the ratio between silver and antimony tends to remain constant with change in grade of ore. White (1940, p. 263) reports that assays of ore from the West quarry of the Yellow Pine mine show a strikingly constant ratio of approximately 0.5 ounce of silver to 1 percent (20 pounds) of antimony. More recent drilling in the West quarry area shows a systematic variation from this ratio as illustrated graphically on cross sections *B–B′* to *K–K′*, plate 42. The correlation of silver and antimony is very close at the south end of the ore body but is not apparent at the north end where both the silver content and antimony content are low. The silver-antimony ratio approximates 1 ounce to 20 pounds near the south end (sections *B–B′* to *E–E′*) but decreases to about 0.3 ounce to 20 pounds in and near the tungsten ore body (sections *E–E′* to *H–H′*) beneath which the tungsten and antimony "feeder" is located (p. 179).

The stibnite concentrate produced from tungsten-antimony ore contains 50 to 55 percent of antimony and 15 to 20 ounces of silver per ton according to Baker (Bradley, Mecia, and Baker, 1943), which is close to the ratio of 0.3 ounce af silver to 20 pounds of antimony deduced from assay data on the tungsten-antimony ore in place. The corresponding ratio deduced from production data furnished by the Economics and Statistics Branch of the Bureau of Mines was 0.29 ounce of silver to 20 pounds of antimony for 1942; the ratio in the gold concentrate the same year was 0.43 ounce of silver to 20 pounds of antimony. As both gold and antimony concentrates were derived from the same ore, the higher silver-antimony ratio in the gold concentrate indicates that a small part of the silver is associated with gold in the early sulfides. This silver is not apparent in most of the graphs because it is masked by the much larger amount associated with antimony. It is evident, however, in several graphs for the north end of the ore body where the antimony content is very low (cross sections *H–H′* and *I–I′*).

The ore at the Meadow Creek mine appears to have about the same silver-antimony ratio as that from the Yellow Pine mine. The Bradley Mining Co. produced 231,724 ounces of silver and 8,635,701 pounds of antimony from 1932 to 1941, inclusive, about half of which came from the Meadow Creek mine. The production is equivalent to a ratio of 0.54 ounce of silver to 20 pounds of antimony.

Gangue minerals.—The ore minerals at the Yellow Pine mine are associated with quartz, feldspar, sericite, and carbonate in various proportions. The quartz and feldspar are largely relic minerals from the original quartz monzonite. In part they are fine-grained aggregates, which commonly consist of nearly equidimensional feldspar grains containing tiny quartz blades elongated parallel to the *c* axis. It is not clear how much of the fine material was formed by recrystallization of the original rock and how much was introduced by hydrothermal solutions. Quartz, which was certainly introduced, forms euhedral crystals lining the walls of crosscutting quartz-stibnite veinlets. Several specimens from the tungsten ore body have a groundmass of optically isotropic material with index of refraction near 1.52. As the material appears to be harder than steel, it may be either cryptocrystalline chalcedony or cryptocrystalline potash feldspar.

Sericite, accompanied by various amounts of fine pyrite and arsenopyrite, has completely replaced the original biotite and partly replaced the original feldspar in the ore zone. Much of the sericite is in typical tiny scales, but part of that formed from biotite is in coarse flakes, which perhaps should be called muscovite. The sericite is more abundant in the comparatively less altered zone surrounding the tungsten ore body.

Fine-grained dolomite is very abundant in the tungsten ore body but is a minor constituent of the gold ore around it. Most of it occurs along or near fractures and is later than the sericite. The narrow tungsten carbonate veins north of the Yellow Pine mine contain calcite, rather than dolomite. At the Meadow Creek mine a small filled fissure, consisting of a margin of dolomite and a center of calcite, carries stibnite but no scheelite.

Miscellaneous metallic minerals.—A few ore minerals have been found that bear no evident relationship to the main deposits. The occurrences offer no economic promise in themselves and are mentioned only because they may shed light on the broad problem of mineralization in the district. The tactite at the Murray prospect on Garnet Creek contains small concentrations of magnetite and pyrite. A close genetic relationship with the quartz monzonite magma is evident. Small magnetite and pyrite concentrations were found also in the fault zone that crosses Sugar Creek several miles above its mouth. Several small quartz veins containing molybdenite and pyrite were found on one of the small northern tributaries of Sugar Creek. Bailey (oral communication) and Currier (1935, p. 18) report that molybdenite associated with pyrrhotite and chalcopyrite was found in the Monday tunnel. Currier correlates these minerals with the gold stage of mineralization, which he considers hypothermal.

AGE OF THE DEPOSITS

Although there is general agreement that the order of deposition was gold, tungsten, antimony, students of the deposits disagree on the age and genetic affiliations. Currier (1935, p. 19) believes they are pre-Tertiary in age and related genetically to the Idaho batholith in which they occur. Bailey (1934, p. 163) is of the opinion that the age of the stibnite is Tertiary and that it was superimposed on a Cretaceous pyrite-arsenopyrite-gold mineralization. White (1940, pp. 264–265) contends that the gold represents the first, high-temperature stage of the same process that later, at lower temperatures, caused the antimony to be deposited. He believes the whole mineralization sequence was of Tertiary age. Evidence for and against each opinion is presented in the references cited. The present writer agrees with White that all stages of the mineralization were genetically related and were Tertiary in age.

The writer's opinion is based in part on the fact that at least the last phases of mineralization are younger than dikes thought to be of Tertiary age (pp. 158–159). White believes that mineralization under relatively low pressure is indicated by the texture and mineral composition of the ore and that such conditions were possible only in the Tertiary period. The same kind of argument may be applied to the shape of the developed ore bodies. The Yellow Pine ore bodies flare out abruptly upward and terminate in part at shallow depths. The Meadow Creek ore bodies end abruptly a few feet above the 400 level. Deposits of near-surface origin commonly have such characteristics because they are formed in an environment where temperature changes rapidly with depth. Deep-seated deposits, on the other hand, end more gradually unless there are adequate structural causes for an abrupt termination. At the Yellow Pine mine, no adequate structural control for the broad flaring shape of the ore body is apparent.

SUMMARY OF ORIGIN

It is thought that the ores were formed in a single period of complex mineralization related to the Tertiary igneous activity of the region. The ore-forming solutions rose from below in three surges, each preceded and followed by fracturing and brecciation. During the first stage, sericite, fine-grained quartz and feldspar, pyrite, arsenopyrite, and gold were formed. During the second stage, carbonates, quartz, and scheelite were formed. The metallic minerals of the first stage were soluble in the solutions of the second stage and were partly leached from the tungsten ore bodies. A small part of the gold thus leached may have been deposited around the sides of the tungsten ore bodies, but probably most of it was deposited above the tungsten and later removed by erosion. In the final stage stibnite, accompanied by silver, quartz, pyrite, and carbonates, was formed. The initial fracturing was very extensive, but these fractures were sealed by the first, or gold, stage of mineralization. Intense but local fracturing near the center of the gold ore body then took place. The second, or tungsten, stage of mineralization was practically confined to this central area. The fractures along which the tungsten was introduced were reopened and extended prior to the final, or antimony, stage. Thus antimony is intermediate in extent between tungsten and gold.

Erosion has laid bare the ore bodies, and supergene solutions have altered the ore somewhat. The early pyrite and arsenopyrite have been oxidized to limonite near the surface. The stibnite has been partly oxidized near the surface to kermesite (Sb_2S_2O) and to white and yellow antimony oxides. The abundant drill-hole data in the West quarry area suggest that there has been leaching and secondary enrichment of gold. No mineralogic or chemical evidence for the suggested gold enrichment has been discovered, but the drill-hole evidence for it is striking and is well illustrated on the cross sections of the ore body. (See pl. 42.) The gold values are abnormally low for 10 to 60 feet below the bedrock surface, and sections *A–A′* and *E–E′*, plate 42, show relatively high-grade bodies below and parallel to the impoverished surface zone. It seems unlikely that the relationship is fortuitous; there is no apparent reason for it other than leaching and secondary enrichment.

RESERVES

The tungsten ore body was mined out in 1945, but substantial reserves of low-grade gold and antimony ores still remain in the area. The writer estimated on June 1, 1943, that the area contained nearly 40,000 tons of metallic antimony in indicated ores averaging more than 1 percent of antimony—slightly more than half of the antimony being in ore averaging more than 4 percent of antimony. It was also estimated that an additional 20,000 to 25,000 tons of antimony was contained in indicated ore averaging 0.25 to 1 percent of antimony. Small percentages of antimony are recoverable in the area because the antimony-bearing ore also carries 0.06 ounce or more of gold per ton. Part of the best antimony ore has been mined since the estimates were made.

It is estimated that there are nearly 140,000 ounces of recoverable gold in the antimony ores averaging more than 1 percent of antimony, and, in addition, nearly 600,000 ounces of gold in indicated gold ore averaging 0.1 to 0.2 ounce of gold per ton and nearly 400,000 ounces in indicated gold ore averaging 0.05 to 0.1 ounce of gold per ton.

The indicated ore reserves discussed above amount to slightly more than 12,000,000 tons. The inferred ore reserve was estimated in 1943 at nearly 4,000,000 tons containing 5,000 to 8,000 tons of recoverable antimony and 390,000 ounces of recoverable gold. The estimate of inferred ore is considered conservative, particularly as far as gold is concerned. As the reserve of antimony ore is small compared to the reserve of gold ore, it seems evident that mining in the area will become increasingly dependent on the gold ore.

MINES AND PROSPECTS

YELLOW PINE MINE

HISTORY AND PRODUCTION

The Yellow Pine mine of the Bradley Mining Co. is the largest in the district. It is on the East Fork of the South Fork of the Salmon River (hereinafter called the East Fork), 2 miles north of Stibnite and 10 miles east of Yellow Pine post office. The deposit was discovered by Albert Hennessy early in the present century and was for many years known as the Hennessy lode. The first commercial operation was by the Bradley interests in the form of a quarry opened west of the East Fork in the fall of 1937 to obtain ore for treatment in the mill at the Meadow Creek mine 2 miles south of the deposit.

Operation of the old West quarry, at the north end of the present West quarry, was continued until July 1939, when activities were transferred to a new quarry called the East quarry on the opposite side of the East Fork, where gold values were higher but where antimony values were very low. Tungsten ore was discovered between the two quarries in January 1941. Because the tungsten ore body lay beneath a thick cover of gravel almost directly below the East Fork, it was decided to mine it by underground methods. The No. 1 shaft was begun in April, and the first tungsten ore was milled in August 1941. All mining and milling of gold ore was discontinued late in the fall (Bradley, Mecia, and Baker, 1943). During 1942 the underground mine, called the Idaho Tungsten mine, was in intensive production, and the overburden above the tungsten ore body was stripped preparatory to open-pit operation. For a time ore was mined both from the Idaho Tungsten mine and the greatly enlarged West quarry. The former was abandoned in May 1943 in favor of 100 percent open-pit operation.

The ore is treated in the company's mill at Stibnite, which at the time of the writer's field work in 1943 had a capacity of 800 tons per day and was producing five concentrates, as given in the table below. The ore was treated by selective flotation to give the four flotation concentrates, and a small part of the high-grade tungsten product was reconcentrated on a Wilfley table to make a concentrate of sufficiently high grade to meet standard specifications, at least 60 percent of WO_3 in scheelite concentrates. The tailings from the table operation were added to the low-grade flotation concentrate. These low-grade concentrates were shipped to the retreatment plant of the Metals Reserve Corporation at Salt Lake City, Utah, to the plant of the United States Vanadium Corporation near Bishop, Calif., and to the purification plant of the Bradley Mining Co. at Boise, Idaho.

Concentrates produced at Yellow Pine mine, October 1943

[Grade and monthly production estimated by Bradley Mining Co.]

Concentrate	Approximate grade	Approximate monthly production
Tabled high-grade tungsten	70 percent WO_3	1,000 units WO_3.
High-grade tungsten flotation	50 percent WO_3	12,500 units WO_3.
Low-grade tungsten flotation	10 percent WO_3	12,500 units WO_3.
Antimony flotation	50 percent Sb	375 tons Sb.
Gold flotation	1.8 ounces Au	540 ounces Au.

The production record of the mine to the end of 1945 is given in the following table. The tungsten ore body was exhausted in 1945, but mining of antimony-gold ore was continued at an increasing rate. During 1946 the capacity of the mill was increased to about 2,400 tons per day (Minerals Yearbook, 1946, p. 130). Metallic antimony contained in antimony concentrates totaled more than 5,000 tons during 1947 and 6,004 tons during 1948 (Minerals Yearbook, 1948, p. 130). Construction of an antimony-gold smelter at the mine was begun in May 1948 and has now gone into operation.

Production from the Yellow Pine mine

[Data from Cole and Bailey (1948, p. 4)]

Year	Ore mined (tons)	Concentrates (tons)	Metal content of concentrates			
			Tungsten (units of WO_3)	Antimony (tons)	Gold (ounces)	Silver (ounces)
1938	[1] 38,880	2,200	None	379	3,529	17,687
1939	56,074	2,677	None	228	5,810	14,844
1940	132,297	4,521	None	18	12,401	15,825
1941	95,156	5,789	27,921	380	10,355	18,981
1942	96,861	15,210	181,230	2,801	2,714	85,161
1943	178,747	22,787	303,502	2,734	4,529	109,307
1944	[2] 211,382	13,438	233,664	2,031	6,110	74,498
1945	[3] 109,796	7,590	85,512	2,895	6,505	87,815

[1] Includes about 5 months' operation of Meadow Creek mine.
[2] Includes 966 tons of tailings re-treated.
[3] In 1945, 45,359 tons of older tailings and 3,290 tons of older concentrates were re-treated in addition to 109,796 tons of crude ore (Minerals Yearbook, 1945, p. 666).

Between August 1941 and December 1945 the mine produced more tungsten than any other mine in the United States, and its total production places it among the major tungsten districts in the United States, as shown in the following table.

Tungsten production in the United States, 1900–1945

[Compiled by D. M. Lemmon; data based on Minerals Yearbooks]

District	*Approximate production (units of WO_3)*
Boulder, Colo	1,456,900
Atolia, Calif	993,967
Mill City, Nev	988,461
Bishop, Calif	912,915
Yellow Pine, Idaho	831,829
Boriana, Ariz	143,142
Ima, Idaho	111,303
Golconda, Nev	[1] 100,000
Minerva, Nev	91,324
Nevada Scheelite, Nev	72,947
Getchell, Nev	64,427
Silver Dyke, Nev	[1] 50,000
All others	845,584
Total	6,656,940

[1] Estimated.

DEVELOPMENT

The mine workings include the east and west quarries and the abandoned underground mine. The latter was developed on three levels at altitudes of 6,021, 5,964, and 5,863 feet above sea level. The No. 1, or main level, at an altitude of 5,964 feet, with 2,500 feet of drifts, was connected with the surface by the No. 1 vertical shaft, 174 feet deep, and by the No. 2 inclined shaft. The upper, or No. 2 level, at an altitude of 6,021 feet, with 1,450 feet of drifts, was connected with the No. 2 shaft and with the No. 1 level by several raises and stopes. The lower, or No. 3, level, at an altitude of 5,863 feet, with 700 feet of drifts, was connected with the No. 1 level by a winze and a raise.

The Bailey tunnel, a 4,000-foot drainage tunnel, carries the water of the East Fork from a point above the mine to the valley of Sugar Creek, near its mouth. Pumps were installed to dispose of the water in the quarry below the Bailey tunnel level. The Monday, Cinnabar, and North tunnels shown on plate 38, and the Bridge and East tunnels shown on plate 39 were driven by the Bradley interests prior to 1938 for prospecting purposes. The Cinnabar tunnel received its name because it headed toward the Hermes quicksilver mine and not because the mineral cinnabar was found in it.

About 44,000 feet of diamond drilling had been done in and near the mine by the end of 1943; approximately 16,000 feet was drilled by the Bureau of Mines in 1939–41 and the remainder by the company. The results of diamond drilling have been of great value in determining the size, shape, and grade of the ore bodies.

LOCALIZATION OF THE ORE

The ore bodies were formed in the permeable fractured rock between the Meadow Creek fault, the basic dike, and the Hanging Wall shear (pp. 162–163). A synthesis of data from geologic mapping, assays, diamond-drill holes, and other sources is presented on plates 39 to 42 and shows the following:

1. All the tungsten and antimony ore is west of the quartz latite porphyry dike. Although most of the gold ore is west of the same dike, the ore bodies in the Bridge tunnel and East quarry, east of the quartz latite porphyry, contain good gold ore and traces of tungsten and antimony.

2. The outline of the antimony ore body may be compared to that of an irregular upright funnel considerably drawn out in the upper part parallel to the Hennessy fault (N. 15°–25°E.) and to a lesser extent along the *C–A* structural segment (N. 50°–70° E.), with its neck extending downward in the obtuse angle between *C* and the Hennessy fault. (See pls. 41, 42.)

3. The tungsten ore body is confined principally to the upper part of the funnel-shaped antimony ore body, although a slender stem of low-grade material extends down the neck of the funnel.

4. Neither the Hennessy fault nor the persistent fractures parallel to either *C* or *A* are mineralized continuously. Small high-grade tungsten and antimony ore lenses commonly follow nonpersistent fractures that strike in various directions. Probably the prevalent direction is roughly east-west (fig. 10).

5. The antimony and tungsten ores are relatively low in gold (0.06 to 0.08 ounce per ton), but gold ore bodies of higher grade (0.10 ounce or more per ton) are clustered around the antimony ore body and extend down the neck.

6. Gold ore bodies with traces of tungsten and antimony occur northeast of the tungsten-antimony ore body on both sides of the Hennessy fault and quartz latite porphyry dike. Diamond-drill holes indicate that these ore bodies bulge upward and outward from the Hennessy fault. (See pl. 42, sections *I–I′* to *M–M′*.)

7. Movement took place on some of the faults after deposition of the gold. Movement on the Hennessy fault after the deposition of the tungsten is indicated by extremely fine-grained scheelite in the gouge at one place. The irregular bottom of the tungsten ore body is nowhere due to faulting that followed deposition of the tungsten.

8. Gold values are below average for a depth of 10 to 50 or 60 feet beneath the bedrock surface of the West quarry ore body. This does not appear to be the case in the Bridge tunnel and East quarry ore bodies, although fewer data are available.

The distribution and shape of the ore bodies suggest that the gold-

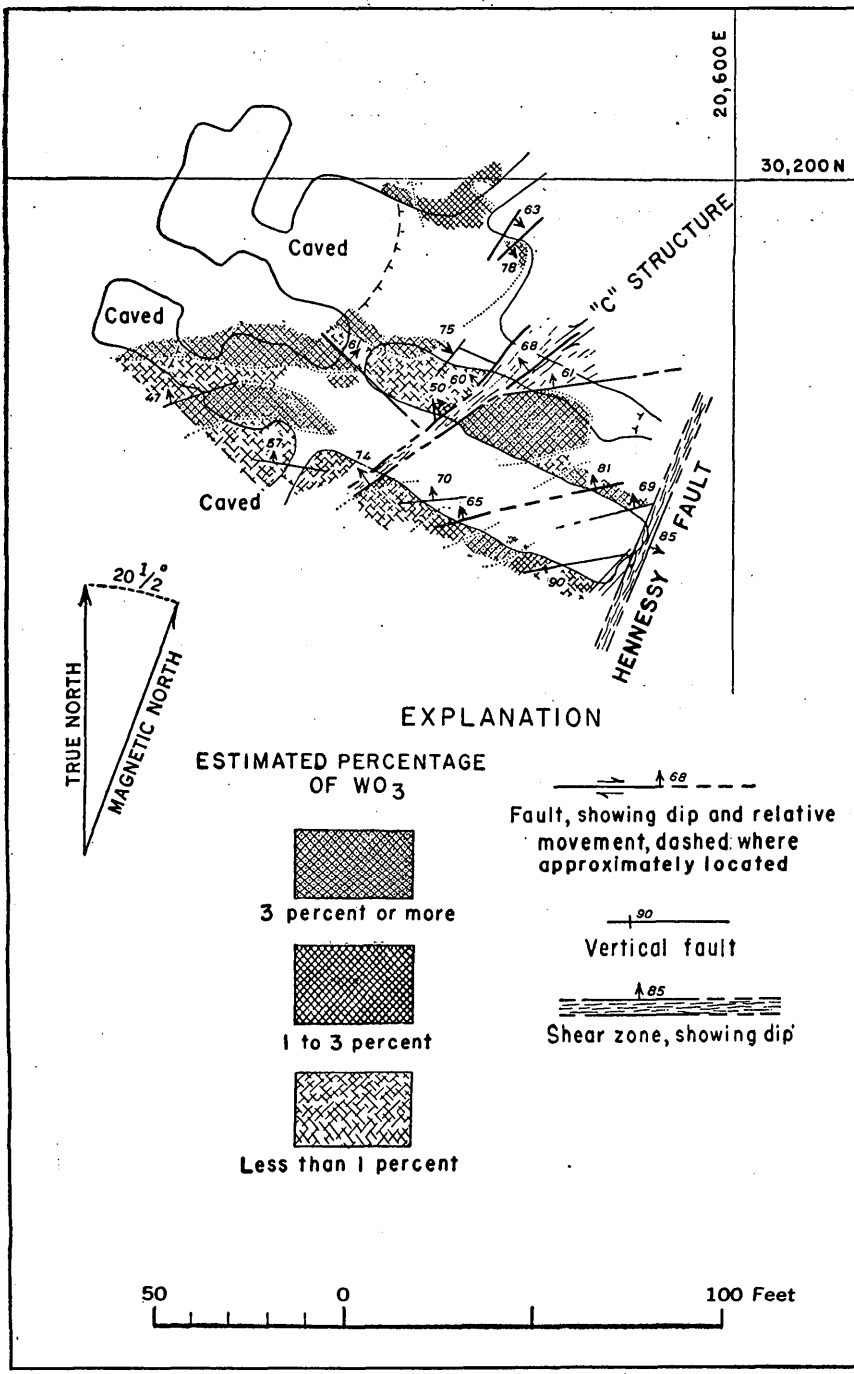

FIGURE 10.—Detail of a part of level 2 of the Yellow Pine mine.

bearing solutions rose along the Hennessy fault and spread out in fractures splitting off from the fault. These solutions soaked into the quartz monzonite so thoroughly that there is little relationship between ore bodies and particular fractures. Because of the selective replacement of biotite by the gold-bearing sulfides, the quartz monzonite contains higher gold values than the aplite or pegmatite.

The fractures formed before gold deposition are believed to have been sealed by the gold mineralization and the tungsten and antimony ore bodies are thought to have been localized by later fracturing. The later fractures followed the old lines but were more restricted in occurrence. Both tungsten and antimony solutions came up in the hanging wall of the *C* fracture near the Hennessy fault. The *C* fracture swings toward the east and steepens between the No. 1 and No. 3 levels. The change in attitude caused this area to be put under tension by the regional shearing (p. 164), and open fractures formed there. The *A* fracture, which localized ore at higher levels in the mine, must either die out or flatten below the No. 1 level. On the No. 3 level of the mine the area near the projected position of *A* contains only small stibnite stringers, but in the hanging wall of *C*, a body of high-grade antimony ore extends downward. This downward extension appears to lack tungsten except for the narrow low-grade stem postulated on the basis of diamond-drill hole 31. (See pl. 42, section *A–A*.)

The relatively shallow bottom of the tungsten ore body and the extension of the antimony ore body below the deepest developed level are puzzling features of the deposit. The following factors have been suggested to explain the relationship, but admittedly not one of them is satisfactory:

1. The control may have been wholly structural even though there are no flat structural features forming the bottom of the ore body. If the gold mineralization had sealed the early fractures, newly opened fractures at the time of scheelite deposition may have been limited to the area occupied by the tungsten ore body. Movements following tungsten deposition may have reopened and extended these fractures, thus providing the locus for more widespread antimony deposition. Although this possibility is the most attractive of any that have been suggested, it is not clear why many steep fractures were opened at one horizon and the same fractures were not opened at a slightly deeper horizon. Moreover, the tungsten stem is low in grade, as though it were traversing a rock unfavorable for mineralization.

2. The scheelite may have been localized near an old land surface not far above the present one.

3. The control may have been determined by the composition of the host rock. This theory postulates that the roof of the batholith was only a short distance above the deposit and that the upper part

of the magma dissolved lime from the roof rocks. The scheelite is considered to have been confined to the upper contaminated shell. The general assumptions as to the proximity of the roof and the availability of lime therein are reasonable in view of the nearby contact of the batholith with calcareous sedimentary rocks. Beyond this, the theory has little to recommend it. No lime silicates such as might be contamination products have been observed near the ore bodies. The carbonates that are abundant in and near tungsten ore were introduced after consolidation of the quartz monzonite, apparently by the same solution that carried the tungsten.

4. The scheelite may have been formed by descending meteoric waters rather than by ascending hydrothermal solutions. This theory has been suggested by several persons simply because of the similarity in shape of the body to the secondarily enriched disseminated copper deposits of the Western States. The theory is incompatible with the texture, mineral association, and mineral sequence of the ore. A considerable proportion of the scheelite is in the form of large crystals embedded in hydrothermal minerals. The scheelite is veined and replaced by hydrothermal stibnite.

MEADOW CREEK MINE

HISTORY AND PRODUCTION

The Meadow Creek mine at Stibnite was the first mine in the area to produce antimony and gold on a commercial scale. Development was started by the Bradley interests in 1929. A mill was built, and commercial production of antimony and gold concentrates began in 1932. The mine was operated until May 1938, when it was closed. The production to the end of 1937 is given in the following table. The company records for the 5-year period 1932–36, inclusive, show that the mill heads averaged 1.62 percent of antimony and 0.23 ounce of gold per ton. Silver is a minor constituent in the ratio of about 0.5 ounce to 20 pounds of antimony, a ratio similar to that at the Yellow Pine mine.

Production from the Meadow Creek mine

[Data from Cole and Bailey (1948, p. 4)]

Year	Ore mined (tons)	Concentrates (tons)	Metal content of concentrates		
			Antimony (tons)	Gold (ounces)	Silver (ounces)
1932	34,366	3,242	489	6,915.76	18,488
1933	45,710	3,534	588	10,411.85	29,817
1934	54,000	3,735	404	10,491.36	25,384
1935	50,965	3,602	550	8,373.38	25,217
1936	43,324	3,787	729	7,797.96	32,615
1937	39,521	3,246	755	5,514.00	36,572
Total [1]	267,886	21,146	3,515	49,504.31	168,093

[1] A small production in 1938 was reported with the production from the Yellow Pine mine and is not included in these totals.

No work was done at the Meadow Creek mine between 1938 and 1943, although the mill was enlarged and modernized to treat the ore from the Yellow Pine mine. Scheelite was discovered on the Meadow Creek mine dumps following its discovery at the Yellow Pine mine. Most of the adit level was caved and the lower levels flooded, and it was therefore impossible to determine the size or grade of the tungsten occurrences. In the course of exploration for additional tungsten ore bodies, the Bradley Mining Co. dewatered the mine in 1943 to a few feet below the 300 level. The workings were found to be badly caved. The slow task of reopening the old workings was continued until late September, when it was abandoned in favor of other development work.

DEVELOPMENT

The Meadow Creek mine is developed on six levels, the *B*, *A*, 100, 200, 300, and 400, which are at altitudes of 6,741, 6,639, 6,432, 6,321, and 6,213 feet above sea level. (See pl. 43.) The highest, or *B*, level is an adit now caved near the portal. The main adit, or *A*, level is caved a short distance beyond the shaft, 430 feet from the portal. The 100 level is caved a few feet from the shaft station. The work done in 1943 was concentrated on the 200 and 300 levels. About 750 feet of workings on the former and about 1,080 feet of workings on the latter were reopened. Thus only a small fraction of the workings was accessible to the writer, who remapped the geology of these parts in 1943. The geology and outlines of workings of the inaccessible parts of the mine are taken from maps by H. D. Bailey.

LOCALIZATION OF THE ORE

The ore bodies at the Meadow Creek mine, like those at the Yellow Pine mine, are near the Meadow Creek fault, which is believed to be the basic structural feature localizing the ore at both places. In contrast to the occurrence of ore at the Yellow Pine mine, the Meadow Creek ores are on the east side of the fault zone, the heavy gouge of which was intersected by several crosscuts and drill holes running westward from the main workings. Apparently neither workings nor drill holes crossed the entire fault zone, although several cut a rhyolite dike within it.

The ore-bearing zone has a maximum width of 200 feet. The ore within it is very similar to that at the Yellow Pine mine except that it is localized in streaks and pods 2 to 40 feet thick separated from one another by relatively fresh quartz monzonite. No fresh quartz monzonite was seen in the ore zone at the Yellow Pine mine. Presumably the Meadow Creek area was less favorable for mineralization. There is no bend in strike of the Meadow Creek fault in the immediate mine area, although there is an apparent reversal in dip. (See pl. 44, section *A–A′*, and p. 163.)

Both Bailey (1934, pp. 162–163) and Currier (1935, pp. 20–22) have published maps and cross sections of the ore bodies and discussed the problem of ore localization. Bailey says that the passage of the ore solutions was controlled by two sets of faults and fractures, one striking east and dipping 25°–45° N. and the other striking N. 30° E. and dipping 25°–45° N. He believes that the basic dike is older than the ore and that it acted as an impervious barrier to the mineralizing solutions that followed along the under side of it. He offers two general guides to further exploration: First, the dike is usually the hanging wall of an ore body, and second, the size of an ore body increases as the dip of the dike decreases. Currier (1935, p. 17) says, in part:

> 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 gougy 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.

The present writer suspects that the basic dike may be younger than the gold, although it appears to be older than the antimony. Thus, there is some doubt that the dike acted as a barrier to the gold-bearing solutions. However, the dike follows a tough older gouge zone everywhere seen by the writer, and this gouge may well have been a barrier to the gold solutions. The writer agrees with Bailey that the gently northward-dipping faults and fractures guided the mineralizing solutions. This seems very clear from the stope outlines, particularly as seen on the longitudinal projection. (See pl. 44.) Small faults and fractures with this attitude are abundant in the accessible part of the mine (pl. 43) and at the surface. The best surface exposures are in the large quartz monzonite outcrop on the mountain slope northeast of the mine, where there are several sets of joints and weak shear zones, the most persistent of which strikes close to N. 55° E. and dips about 25° NW. Although most of the quartz monzonite is fresh, some of the persistent fractures dipping gently northwestward are characterized by a narrow band of alteration and sulfide mineralization similar to that in the mine. One such zone 15 to 50 feet wide and several of the smaller occurrences are shown on plate 38. The localization of mineralization along these fractures as much as 1,200 feet from the Meadow Creek fault indicates that they were favored channelways for the mineralizing solutions, presumably because they were relatively open and permeable.

Only small bodies of tungsten ore had been found in the Meadow Creek mine at the time of the writer's examination in 1943. There is a trace of scheelite on every accessible level, but principal interest centers in several places west of the basic dike where locally it dips eastward. On the 300 level, there is a lens of tungsten ore above 302 S drift near its west end. This has yielded 31 mine carloads that averaged 1.27 percent of WO_3. As exposed in June 1943, the lens was about 8 feet wide and 15 feet long. An 8-foot sample across it contained 0.83 percent of WO_3, but several short test holes drilled upward showed that the tungsten content dropped abruptly to a trace in that direction. The drift below the ore lens shows no tungsten, and 312 stope lies only a few feet to the south. There is a chance that tungsten ore may be found to the northeast where the company maps show 70 feet of unexplored ground before 308 stope is reached. Assay records show that this stope averaged 3.8 percent of antimony on the sill, making it one of the best antimony stopes in the mine. The close association of tungsten and antimony at the Yellow Pine mine would seem to indicate increased chances of worth-while tungsten discoveries in this direction.

Another interesting tungsten occurrence is in 201 W crosscut on the 200 level, where 20 feet of much-sheared and altered quartz monzonite apparently containing good antimony values is exposed west of the dike, which here dips steeply toward the east. About 6 feet from the dike there is a scheelite-bearing lens 3 feet wide, estimated to contain 2 percent of WO_3, bordered by about 10 feet of low-grade disseminated scheelite. A 15-foot sample cut by the Bradley Mining Co. across the whole scheelite-bearing zone assayed 0.55 percent of WO_3. To test the possible northward extension of this zone the company reopened 165 feet of 203 N drift, which runs along the projected strike of the tungsten zone. Traces of scheelite were found all along the drift, but no tungsten ore was seen either in the walls or in the caved muck filling the drift. The tungsten ore therefore pinches off toward the north. Southward the ground is unexplored for 65 feet to 203 stope, which is caved.

Too little is known about the tungsten occurrences to suggest what structural features controlled the deposition. The two occurrences described show that lenses of commercial ore are present but suggest that they are so small that it would be unprofitable to develop them for tungsten alone. If gold-antimony mining were resumed it would probably be worth while to examine the workings periodically with ultraviolet light and to mine the tungsten lenses selectively. It is important that all the tungsten ore so far discovered is west of the basic dike, and that the chief ore reserve in the mine, the west ore body, is also in this position and is relatively high in antimony and low in gold. There is a reasonable possibility, therefore, that there may be larger tungsten lenses than those now known.

Diamond drilling from the surface, several hundred feet south of the mine workings, has revealed commercial amounts of gold and antimony, although the grade of ore is apparently below that in the mine. There are only a few 5-foot stretches that contain more than 0.2 ounce of gold per ton and limited stretches that contain more than 0.1 ounce of gold per ton. Antimony values are low except for a few scattered streaks.

HOMESTAKE PROSPECT

The Homestake prospect, owned by the Bradley Mining Co., is in the Meadow Creek fault zone about a quarter of a mile northeast of the East quarry of the Yellow Pine mine. (See pls. 38, 39.) The two deposits are connected by a wide zone of shearing and alteration containing disseminated pyrite and arsenopyrite but apparently negligible gold values. The Homestake prospect is developed by means of three pits; in only one is bedrock exposed. This exposure, the only one in the vicinity, shows sheared altered and limonite-stained quartz monzonite resembling the oxidized gold ore in the East quarry. The Bradley Mining Co. has explored the deposit by diamond drilling (pl. 39) and discovered good gold ore. The position of the deposit suggests that it may have been localized at the intersection of the Meadow Creek fault and the Hanging Wall shear zone exposed near the East quarry, but the elongation of the mineralized area across the Meadow Creek fault zone is unexplained.

Although most of the deposit is in the quartz monzonite, the mineralized area extends southeastward into the metamorphosed sediments of the main roof pendant. This is indicated by diamond-drill holes B 44 and B 45, which were drilled southeast of the other holes and penetrated weakly mineralized schist and quartzite. (See pl. 39 and table, p. 185.)

The habit of ore bodies at the nearby Yellow Pine mine suggests that the Homestake ore body may contain a substantial ore reserve. Available assay information indicates that parts of it contain more than 0.2 ounce of gold per ton, placing it among the richest gold deposits in the district. Antimony is negligible in amount, and tungsten has not been found. The development work does not provide an adequate basis for the appraisal of the property. If the main pit is in ore, an ore body amenable to open-pit mining might be indicated, with supporting evidence from the good showings in diamond-drill holes, B 32, B 35, B 37, and B 40. (See the following table.) On the assumption that an area 75 feet long in the pit is in ore, an ore body in the form of a wedge striking about N. 20° W. is inferred. Future developments may reveal that the Homestake ore occurs in a number of small bodies not suited to large-scale operation. The property is well worth further development when and if the chief mining interest is again centered on gold production.

Diamond-drill holes in the Homestake area

Drill hole No.	Depth (feet)	Type of rock	Antimony (percent)	Gold (ounces per ton)
B 32	0- 55	Overburden		
	55- 75	Quartz monzonite	0.11	0.01±
	75- 90	do	.22	.05
	90-105	do	.35	.19
	105-175	do	.37	.08
	175-220	do	.40	.24
	220-245	do	.61	.06
	245-260	do	.46	.02
B 33	0- 40	Overburden		
	40-160	Quartz monzonite	Trace	Trace
	160-215	do	Trace	.06
	215-320	do	Trace	Trace
B 34	0- 50	Overburden		
	50-230	Quartz monzonite	Trace	Trace
B 35	0- 25	Overburden		
	25- 60	Quartz monzonite	Trace	Trace
	60-100	do	Trace	.06
	100-150	do	Trace	.12
	150-175	do	Trace	.27
	175-230	do	Trace	.01±
B 36	0- 15	Overburden		
	15- 90	Quartz monzonite	Trace	Trace
	90-185	do	Trace	.01±
	185-290	do	Trace	Trace
B 37	0- 10	Overburden		
	10- 30	Quartz monzonite	Trace	.27
	30- 70	do		.08
	70- 95	do		.32
	95-120	do		.11
	120-215	do	Trace	.02
	215-230	do		.33
	230-250	do		.04
B 40	0- 5	Overburden		
	5- 50	Quartz monzonite	Trace	.02±
	50- 65	do	.20	.06
	65- 90	do	.09	.20
	90-190	do	Trace	.07
	190-240	do	.05	.14
B 41	0- 30	Overburden		
	30-215	Quartz monzonite		
B 42	0- 25	Overburden		
	25- 60	Quartz monzonite		.01±
	60-125	do		.06
	125-180	do		.03±
	180-260	do		
B 43	0- 40	Overburden		
	40-140	Quartz monzonite		.01±
	140-185	do		.17
B 44	0- 20	Overburden		
	20- 60	Sheared schist and quartzite		
	60-105	Schist and quartzite		.05
	105-180	do		.02±
B 45	0- 15	Overburden		
	15- 65	Schist and quartzite	Trace	Trace

MURRAY PROSPECT

Merle Murray, of Stibnite, holds a gold-antimony-tungsten prospect on Garnet Creek. The prospect is developed by means of two adits and a number of pits and trenches. (See pl. 38.) There are two types of deposit on the property. One consists of pyrite and magnetite in tactite at the contact between dolomite and quartz monzonite; the other consists of gold, antimony, and tungsten in quartz monzonite, and is mineralogically similar to the ores of the Meadow Creek and Yellow Pine mines.

The chief interest is in the pyrite, arsenopyrite, stibnite, and scheelite, which occur as replacement veins along narrow shear zones in the quartz monzonite. The largest of these zones is 2 to 5 feet wide and is exposed in pits and trenches for a strike length of 300 feet. It has been developed to a depth of a little more than 100 feet below the outcrop by the main adit, at an altitude of 7,051 feet. The vein strikes about N. 4° E. and dips 70° W. Striae on the main plane of movement are nearly horizontal, and evidence of plucking indicates that the west wall moved northward relative to the east wall. (See fig. 11.) Presumably the shear zone was formed at the same time as the Meadow Creek fault, which is roughly parallel to it and has a similar direction of displacement.

The quartz monzonite in the vein is sericitized and contains disseminated pyrite and arsenopyrite. Stibnite is present in silicified lenses about 6 inches thick. A stringer of high-grade scheelite about 4 inches thick in the vein 10 feet from the face of the main adit dies out abruptly in both directions, although a width of 2 feet of very low grade disseminated scheelite is exposed in the face of the adit. No assay information on the vein is available, but inspection shows that the average content of antimony and tungsten is very low.

A number of pits within 400 feet of the main vein are in altered quartz monzonite containing pyrite, arsenopyrite, stibnite, and scheelite. The pits are so badly caved that it is impossible to make out the structural relationships of these occurrences. Several pits near the ridge crest suggest that there may be another north-south vein about 300 feet west of the main vein. A 4-foot zone of mineralized gouge and sheared quartz monzonite is exposed in the short upper adit at an altitude of 7,220 feet. This zone strikes about N. 60° E. and dips 20° NW. and projects into the main vein about 700 feet beyond the face of the lower adit. The zone has clear-cut walls in fresh quartz monzonite. Well-developed cleavage shows that the zone is a reverse fault. Lenses of high-grade stibnite ore as much as 18 inches thick and smaller pods of pure stibnite occur in the zone, but not scheelite was observed. About 10 tons of antimony ore has been mined from the upper adit and is piled on the dump.

BONANZA PROSPECT

The prospect known variously as the Bonanza prospect, Sugar Creek prospect, or the Antimony-Gold Co. prospect, is on the north side of Sugar Creek about a mile above its mouth. It was held for many years by the Antimony Gold Ores Co., J. J. Oberbillig, president, as part of a large group of claims on both sides of Sugar Creek from near

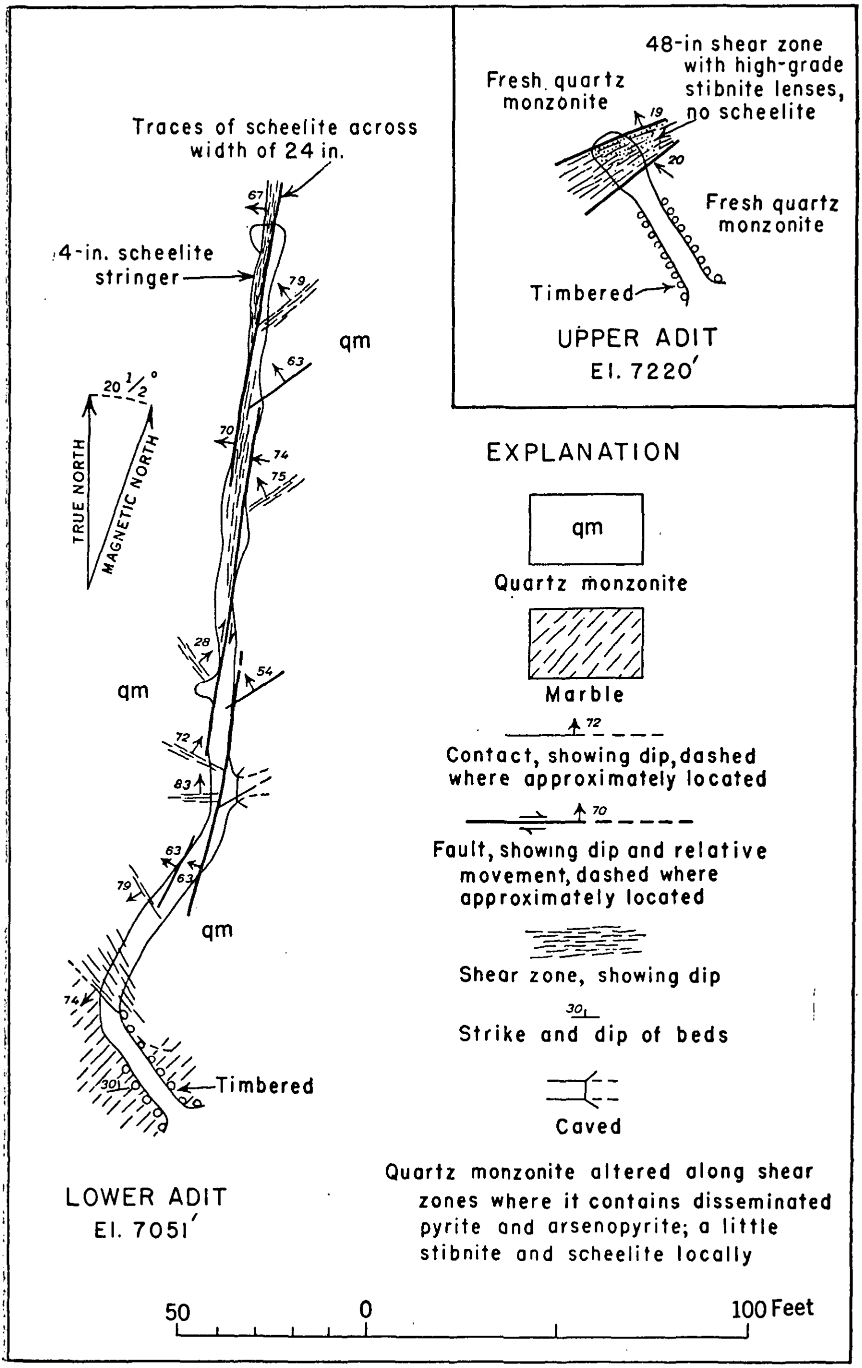

FIGURE 11.—Underground workings at the Murray prospect.

its mouth to well beyond Cinnabar Creek. The whole group was purchased by the Bradley Mining Co. in 1943.

The Bonanza prospect has been explored by means of a large open cut, two short adits, several bulldozer trenches, and several diamond-drill holes. The bedrock is sheared and altered quartz monzonite. It contains disseminated pyrite and arsenopyrite, a little stibnite, and a few grains of cinnabar.

During the summer of 1943 cinnabar associated with stibnite was discovered in a bulldozer cut severel hundred feet west of the main showing. The cinnabar, which is found in an area approximately 15 by 50 feet, occurs for the most part associated with stibnite in hard siliceous lenses several feet in diameter embedded in decomposed quartz monzonite. Although some of the lenses contain high-grade quicksilver ore, the zone as a whole is low in grade. The Bradley Mining Co. drilled four diamond-drill holes averaging 86 feet in depth to test the possible downward extension of the deposit. Quicksilver was detected in only one of the holes, in an insignificant quantity. The metal is confined to the first 45 feet of the hole, where it ranges from a trace to less than a quarter of a pound per ton. None of the holes show more than a trace of gold or more than 0.1 percent of antimony.

The main part of the deposit unquestionably contains higher gold and antimony values, but no assay information was available to the writer.

PETERSON PROSPECT

Pete Peterson discovered scheelite along Clearwater Creek in 1942 on ground that, unknown to him, was claimed by the Oberbillig interests. (See pl. 38.) A lawsuit to establish ownership was in progress at the time the writer left the field. The Bradley Mining Co. purchased the Oberbillig interest in the property in the summer of 1943.

The scheelite occurs as seams in quartzite and as disseminated grains in marble. It is not associated with any other ore minerals. The structural feature localizing the ore is a weak shear zone about 3 feet wide, striking N. 60° W. and dipping 70° N. Samples across the vein are said to have contained several percent of WO_3, but the small amount of scheelite seen by the writer was exposed in a single shallow pit. Because of the weakness of the shear zone and the patchiness of the mineralization the vein appears to have no commercial value. Possibly one or more of the larger faults, which cut the metamorphic rocks in the vicinity, may contain greater concentrations.

OTHER PROSPECTS ON SUGAR CREEK

There are several old prospects north and one south of Sugar Creek where the Meadow Creek fault crosses the stream about a quarter of a mile southwest of the Bonanza prospect. At the principal prospects (pl. 38) the quartz monzonite is sheared and iron-stained. Most of the shear planes have the northeastern strike characteristics of the Meadow Creek fault in this locality. Others, like those exposed in the prospect south of Sugar Creek, have a north to northwest strike. As Currier (1935, pp. 23–24) points out, these shear planes have a branching relationship to the main zone of movement, which lies nearby to the southeast. No stibnite or scheelite was seen at the prospects, but the presence of fine-grained pyrite and arsenopyrite indicates that there may be gold ore. No assay data were available.

WEST END CREEK PROSPECTS

The West End Creek gold prospects were discovered in 1943 in the course of bulldozer exploration by the Bradley Mining Co. for possible quicksilver and tungsten deposits in the metamorphic rocks in the valley of West End Creek and in Sugar Creek to and beyond the Bonanza prospect. (See pl. 38.) Several areas of gold concentration, one of which contains a little antimony, were exposed as a result of this work.

The main concentration is on the West End fault. Three bulldozer cuts in this area expose what appears to be a large lens of disseminated gold ore striking about N. 35° E. The discovery was made in a cut just west of the stream where the West End fault separates dolomitic marble on the north from schist and quartzite on the south. The structural relationships were poorly exposed at the time of the writer's visit in 1943 because of slumping of the soft clay gouge, but apparently there is a 15-foot zone of light-gray plastic gouge near the center of an iron-stained more or less schistose zone about 150 feet wide. The strike and dip of the fault could not be determined. Some pieces of gray siliceous rock carrying stibnite, which evidently came from a lens or lenses in the central gouge, were found on the dump of the pit. The Bradley Mining Co. cut samples across the iron-stained zone, and assays of the seven samples available to the writer indicated a gold content of 0.050 to 0.145 ounce per ton across a width of 130 feet.

A cut on the east side of the creek about 100 feet northeast of the discovery cut exposed interbedded schist and quartzite which are iron-stained but not notably sheared. The West End fault appears to be offset by a cross fault between the two cuts. (See pl. 38.) Although the schistose beds east of the creek do not appear promising for gold ore, assays of preliminary samples taken by engineers of the Bradley Mining Co. indicated a gold content of a little more than 0.1 ounce of gold per ton over a width of 115 feet.

A bulldozer cut 300 feet southwest of the discovery cut and about

200 feet higher on the valley side also exposes gold concentrations. Complete assay records from this showing are available. Measuring southeastward from the position of the fault as shown on plate 38, the gold content is 0.084 ounce of gold per ton for 40 feet, a trace of gold for 30 feet, and 0.095 ounce of gold per ton for 150 feet.

Another cut about 550 feet southwest of the last and about 275 feet higher on the valley side contains pyrite and arsenopyrite but no gold in excess of 0.035 ounce per ton. The cut is on the projected trace of the lens determined from the lower showings but is apparently several hundred feet south of the West End fault. Trenching nearer the fault might expose ore.

There has been no underground development at the West End Creek prospects, which may contain a substantial tonnage of ore averaging a little less than 0.1 ounce of gold per ton. Its commercial interest lies in the fact that preliminary experiments by the Bradley Mining Co. have shown that it cyanides readily, unlike the unoxidized gold ores of the Yellow Pine and Meadow Creek mines. It is quite possible that it will be refractory a few feet below the intensely oxidized outcrop. The information now available indicates that the ore body could be mined by open-pit methods.

NEWCOMB'S PROSPECT

Newcomb's antimony prospect is at an altitude of about 7,700 feet in the NW¼ sec. 25, T. 19 N., R. 9 E., Boise meridian, about three-quarters of a mile due north of the northeast corner of the area shown on plate 38. The deposit was located by J. J. Powell and Tex Wiess in 1939 but was soon abandoned by them. It is part of the area obtained by the Bradley Mining Co. in 1943 from the J. J. Oberbillig interests and is here called Newcomb's prospect only because it was located and trenched by Mr. Newcomb in the summer of 1943 in the belief that it was open ground.

The stibnite is concentrated in dark cherty quartz veins that cut the quartz monzonite. The veins, a foot or less thick, contain high-grade antimony ore. There are two sets of veins (fig. 12), the main set striking about N. 40° E. and dipping northwest and a subordinate set striking N. 5°–20° W. The veins are too small to be of commercial value, but their location, a mile northeast of any previously described antimony deposits, extends the area that might contain antimony and possibly tungsten deposits.

SUGGESTIONS FOR FUTURE EXPLORATION

It was evident by early 1944, when the first draft of this report was written that the discovery of new tungsten ore bodies was urgently needed if the area were to continue as a tungsten producer. The fol-

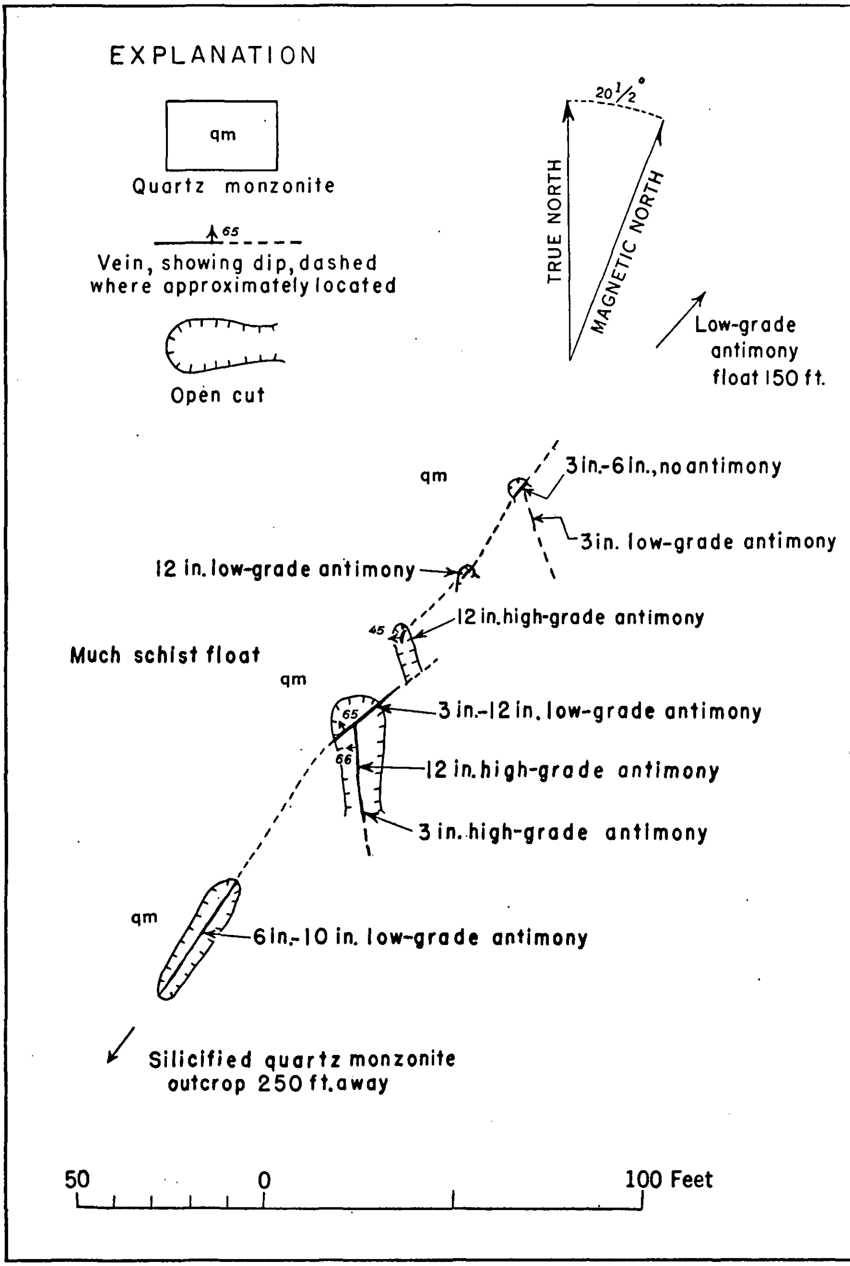

FIGURE 12.—Sketch map of Newcomb's prospect.

lowing general principles and specific suggestions were outlined at that time.

Nearly all the known tungsten occurrences in the area are associated with more extensive antimony deposits, which are, in turn, associated with still larger low-grade gold deposits. Because the association of tungsten with antimony is particularly close, all known antimony concentrations of consequence and any newly discovered antimony deposits should be explored thoroughly for tungsten. All known gold areas should be explored extensively if not intensively.

The Meadow Creek fault is the basic structural feature controlling the main deposits, and concealed stretches of this fault are relatively favorable ground, particularly where other fractures branch off. The structural pattern at the Yellow Pine mine is not duplicated elsewhere along the fault. Large areas are so thoroughly covered by overburden that areal mapping of structural features is of little practical assistance in locating favorable areas.

The occurrence of scheelite-bearing veins at the Murray and Peterson prospects proves that tungsten is not confined to the Meadow Creek fault zone. Moreover, detrital scheelite is almost invariably present in valleys heading in the metamorphic rocks east of Meadow Creek and the East Fork. Thus it seems probable that some scheelite is present in the limestone or dolomite. The evidence obtained by panning suggests that the occurrences are for the most part small but does not eliminate the possibility of deposits of commercial value. It is probable that any large deposits will be found along faults. The Garnet Creek and West End faults, among others, seem to merit more thorough prospecting. A gold ore body, possibly of large size, has already been found along the West End fault.

EXPLORATION BY PANNING

The valley detritus of the area was panned systematically in the hope that it would point the way to undiscovered tungsten deposits. Preliminary experiments with a gold pan showed that although gold could not be detected, presumably because it occurs in extremely small particles, both scheelite and cinnabar could be detected easily.

Small amounts of scheelite and cinnabar are widespread in the valley detritus. (See pl. 38, index map.) Nearly every stream valley in the tungsten area carries scheelite but no cinnabar; nearly every stream valley in the quicksilver area carries cinnabar but little if any scheelite. The area in which detrital scheelite occurs and that in which detrital cinnabar occurs overlap in a narrow zone in which the streams carry both scheelite and cinnabar.

In general, scheelite is more abundant in streams flowing across the metamorphic rocks than in those flowing only across areas of quartz monzonite. Comparison of the amount of detrital scheelite in two drainage basins of different size but similar geology showed that the larger contained more scheelite in nearly every case, suggesting that the scheelite is derived from numerous small occurrences and is concentrated by the larger streams. The best showings were found in the gulch along the Meadow Creek fault at Stibnite and in West End and Midnight Creeks.

The cinnabar occurrence at the Bonanza prospect on Sugar Creek was not revealed by panning, probably because any cinnabar eroded from it would go directly into Sugar Creek and be indistinguishable from that derived from sources farther upstream.

YELLOW PINE MINE

Deep drilling below the Yellow Pine ore body is strongly recommended. The immediate vicinity of the ore bodies has been so thoroughly explored that it is reasonably certain that the tungsten ore body ends close to the boundary lines shown on plates 39–42. The exploration also shows that the concentrations on the sides of the ore body are small and generally of low grade. Thus deep exploration is the only avenue left to possible new discoveries of importance. The writer believes that the funnel-like shape of the antimony ore body and that of the tungsten ore body with its stemlike downward extension show clearly that the solutions that deposited both metals rose through a narrow channelway. As a great deal of tungsten was carried up this channelway, any favorable structural features at a deeper level are likely to have been mineralized.

The deep exploration program should be directed toward testing the feeding channel to the greatest practicable depth. This channel follows the intersection of the *C* fracture and the Hennessy fault and thus plunges 50° to 60° in a N. 30°–40° E. direction. Simple vertical drilling under the ore body would not test the ground adequately.

The possibility that there may be valuable detrital tungsten downstream from the Yellow Pine ore body should also be explored. Probably a large part of the tungsten ore body was removed by Pleistocene and earlier erosion. The glaciofluvial gravel immediately overlying the tungsten ore body contained enough tungsten to constitute valuable mill feed. The fact that the amount increased toward the downstream end of the deposit and toward the bottom of the old gravel-filled channel suggests that the channel may contain an important tungsten reserve. If the amount of tungsten recovered could be made to pay the expense of stripping and mining, mining could be carried northward from the present West quarry. In addition, several sections across the East Fork Valley between the mine and Sugar Creek might be explored for possible local concentrations. This could be done by churn-drill holes to the bedrock surface. The amount of scheelite could be estimated by panning and by examining the sludges under ultraviolet light. The richer parts of the sludge could be assayed when desirable.

MEADOW CREEK MINE

Further exploration of the west ore body of the Meadow Creek mine is justified. This ore body is comparatively little explored and is known to contain small scheelite concentrations as well as relatively high grade antimony ore. The possibility of drilling a series of short diamond-drill holes from accessible parts of the mine should be considered in addition to the reopening of old workings.

ALLUVIAL FLAT OF MEADOW CREEK

Large concealed ore bodies may well occur under the Meadow Creek flat east of the Meadow Creek fault. Data from the Meadow Creek mine workings and from diamond drilling a short distance south of the mine show that gold and antimony concentrations continue out under the flat. The flat is along the projection of the Garnet Creek fault, as are the tungsten-antimony-gold showings at the Murray prospect and the high-grade antimony stringers east of the Stibnite schoolhouse. If the Garnet Creek fault was a channelway for mineralizing solutions and extends into the quartz monzonite, as suggested by the Murray and schoolhouse showings, the chances for large deposits are best near its intersection with the Meadow Creek fault.

The difficulty of diamond drilling through the gravel overburden, which is probably more than 200 feet thick in the center of the flat, has discouraged exploration in this favorable area in the past. Nevertheless, some way could be devised to explore the ground. Perhaps it would be best to drift southward from the lowest level of the Meadow Creek mine and drill from underground. Another possibility is to use a churn drill from the surface. By careful study of the sludges it would be possible to obtain much valuable information as to the presence of tungsten, both in the bedrock and in the lower part of the gravel. If tungsten were detected in the gravel it would be an incentive for further exploration upstream.

Exploration west of the Meadow Creek fault and at the northeastern end of the valley flat is also recommended, although these areas are considered less favorable than the one described above. The Bradley Mining Co. drilled two holes in the flat near the schoolhouse on the strength of the showings in the stibnite stringers. No valuable minerals were found, but the holes were probably northwest of the best area.

FIDDLE CREEK AREA

There is an antimony concentration in the Fiddle Creek area, which White (1940, pp. 270–271) discusses as follows:

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 at the fault zone.

The Bradley Mining Co. started to reopen the Monday tunnel in 1943, with the antimony occurrence as one of the objectives, but the work was abandoned before the antimony was reached. Exploration would require either continuation of work in the Monday tunnel or diamond drilling from the surface. The area is attractive as a tungsten prospect because of the association of tungsten and antimony in the district and because of the possibility of a large ore body at the intersection of a northeastward-trending shear zone with the Meadow Creek fault, as White points out. The lower part of Fiddle Creek Valley has an alluvial flat with linear northeasterly trend suggesting fault control.

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