Gold in the Black Pine Mining District, Southeast Cassia County, Idaho

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By BRUCE T. BRADY

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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GOLD IN THE BLACK PINE MINING DISTRICT, SOUTHEAST CASSIA COUNTY, IDAHO

By BRUCE T. BRADY

ABSTRACT

Base and precious metals in the Black Pine mining district, Black Pine Mountains, Cassia County, Idaho, occur in two types of deposits—deposits of disseminated gold, and vein deposits containing base metals and subordinate amounts of silver and gold. Geologic studies were undertaken in the district to determine the mode of occurrence and genesis of the mineral deposits. In addition to geologic mapping, mineralized areas were examined and limited geochemical sampling and analysis done.

Sedimentary rocks of Late Mississippian to Early Permian age in the Black Pine mining district consist of limestone, silty and sandy limestone, calcareous sandstone and siltstone, quartzite, dolomite, and argillite. Low-grade metamorphism has altered dark pelitic rocks to argillite and caused recrystallization of many of the carbonate rocks. Poorly exposed narrow mafic dikes of probable Tertiary age crop out in a few places in the district. Quaternary silt, sand, and gravel cover part of the area.

Low-angle faults along which younger rocks have been moved over older ones or over rocks of partly equivalent ages are the dominant structures in the Black Pine Mountains. High-angle normal faults are much less prominent. Folds trend principally north and northeast.

The quartz veins are steeply inclined tabular bodies of pronounced differences in thickness, and have isolated pods and stringers containing some tetrahedrite (freibergite), sphalerite, jamesonite, less pyrite, even less cinnabar, and some oxidation products. Production of lead, silver, gold, and copper from the vein deposits amounted to less than 1,000 metric tons.

Disseminated gold occurs in altered Pennsylvanian silty carbonate rocks. Siltstone is common in what appears to be the principal area of altered rock. Siltstone and claystone there are tan, brown, and green with prominent iron-oxide coatings along numerous small fractures.

Gold and pyrite are the principal metallic minerals and appear to be disseminated chiefly in siltstone. Associated gangue minerals include calcite, barite, and quartz. Gold grains are submicrometer in size, as shown by the electron microscope, and are commonly less than 0.5 μm (micrometer) in diameter. Samples from the open pit and vicinity also have anomalous concentrations of mercury, arsenic, and antimony. These elements and tungsten occur in anomalous amounts with disseminated gold deposits elsewhere in the Basin and Range province.

The fine-grained gold presumably was deposited at some depth in a hot spring environment. The age of the mineralization is unknown. It certainly is younger than the Permian rocks and also is younger than the major deformation in the area, but that deformation is not closely dated.

INTRODUCTION

Base and precious metals occur in the Black Pine mining district on the southeast side of the Black Pine Mountains in southeast Cassia County, Idaho (fig. 1). Two types of mineral deposits are identified, and these are mostly in Pennsylvanian strata. One type consists of replacement deposits containing base metals and subordinate amounts of silver and gold, and the other consists of deposits of disseminated gold and minor amounts of associated base metals.

The geologic setting and mineralogy of the base-metal deposits that were worked prior to 1930 have been discussed by Anderson (1931). An occurrence of cinnabar was described by McKaskey (1917) and Larsen (1919), and summaries of Larsen's discussion appeared later (Ransome, 1921; Shannon, 1926; and Bailey, 1964). Other descriptions of mineralized rock in the Black Pine district may be found in Varley and others (1919), Ross (1941), Hubbard (1955), and Ross and Savage (1967). French (1975) briefly summarized the occurrence of fine-grained disseminated gold in the area.

This investigation is part of a geologic study of the Black Pine Mountains within the Strevell 15-minute quadrangle mapped by Smith (1982, 1983). Stratigraphic and structural information presented here derives from that project. Smith cooperated in the more detailed fieldwork in parts of the mining district.

GENERAL GEOLOGY

SEDIMENTARY ROCKS

The Black Pine Mountains are composed predominantly of sedimentary and some slightly metamorphosed sedimentary rocks, which range in age from Devonian to Permian. Units in the mining district are Mississippian to Permian (fig. 2). The Upper Mississippian and Lower Pennsylvanian Manning Canyon Shale is composed mostly of dark-gray to black argillite with lesser amounts of siltstone, claystone, and shale, and much less quartzite and limestone. Pennsylvanian units of the Oquirrh Formation consist of limestone, silty and sandy limestone, quartzitic sandstone lenses, and dolomite. A Pennsylvanian and Lower Permian member of the Oquirrh Formation is composed of calcareous sandstone and siltstone and less silty and sandy limestone and quartzite. Quaternary silt, sand, and gravel cover part of the area.

METAMORPHIC ROCKS

Metamorphism in the Black Pine Mountains, of predominantly low rank, is most obvious in the dark pelitic rocks of the Manning Canyon

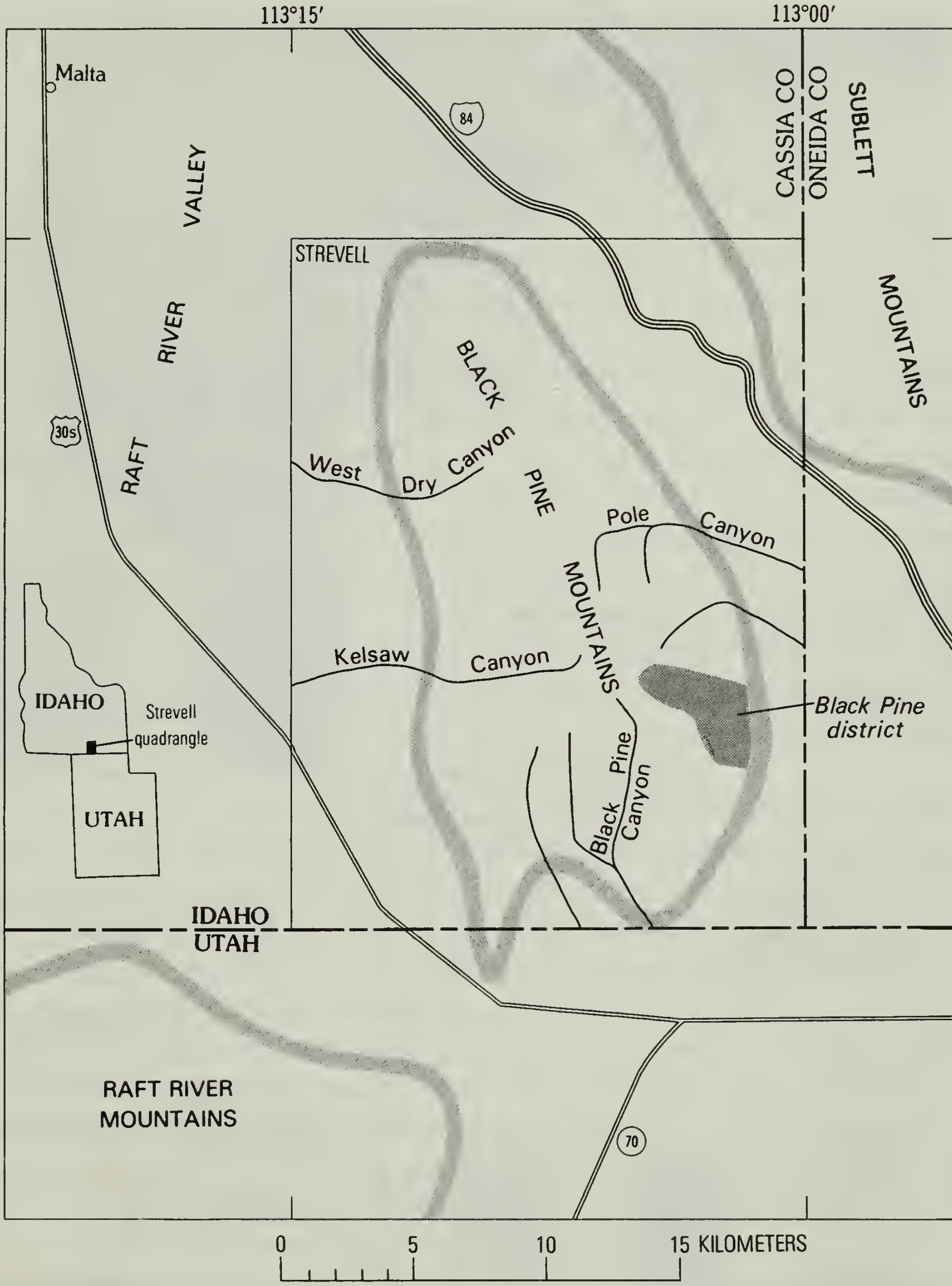

FIGURE 1.—Index map showing location of the Black Pine mining district in the Black Pine Mountains, Cassia County, Idaho.

Shale, which are now chiefly argillites with well-developed fracture cleavage in most places. The mineral assemblages and chemical trends that were produced during metamorphism of the Manning Canyon were discussed in detail by Christensen (1975). These data indicate that temperatures may have reached 350°-400°C during metamorphism. Temperature ranges of 300°-500°C in the area are also indicated by color alteration indices (CAI) of conodonts from Mississippian, Pennsylvanian, and Permian strata (Anita G. Harris, John Repetski,

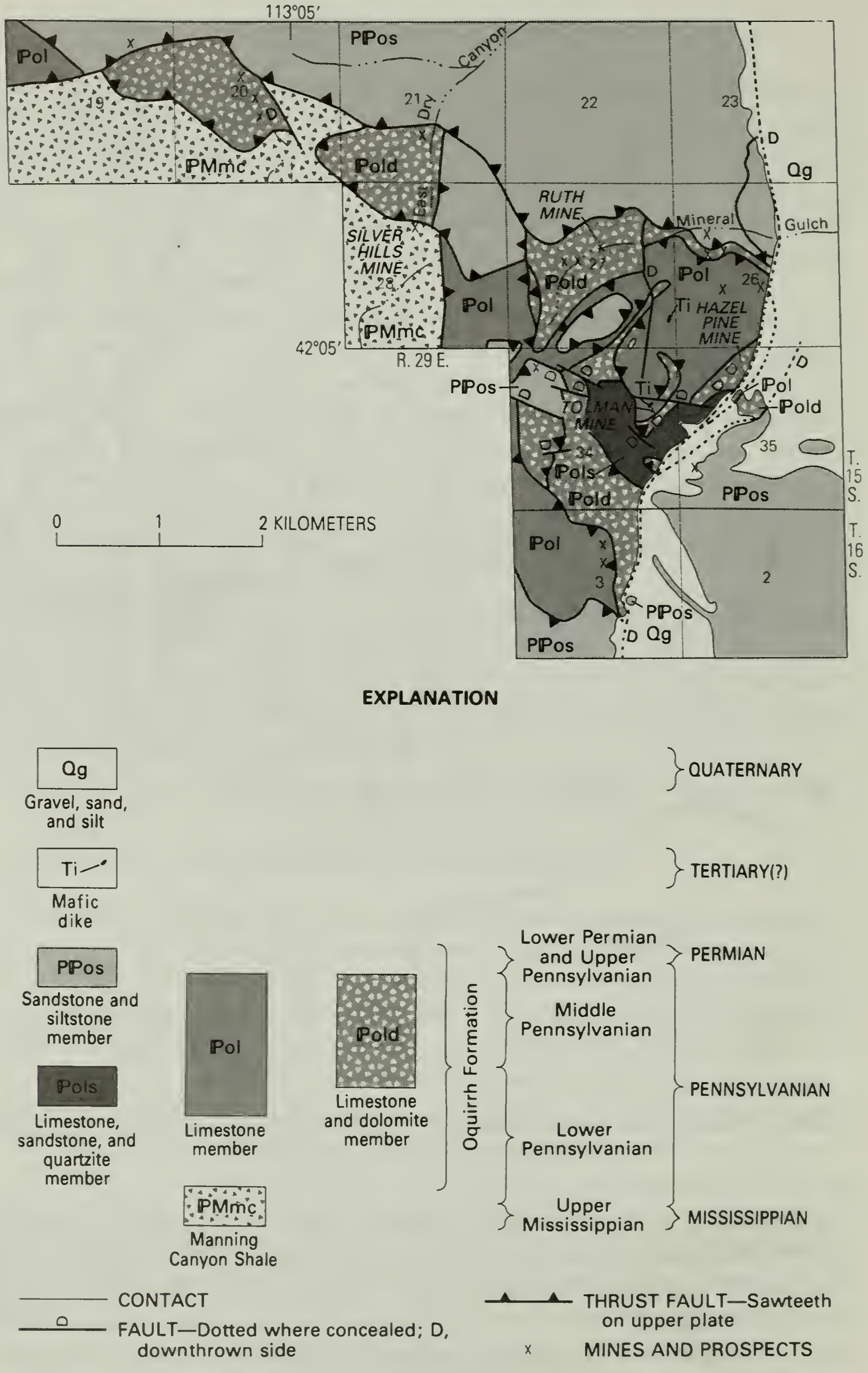

FIGURE 2.—Generalized geologic map of the Black Pine mining district, Black Pine Mountains, Cassia County, Idaho. Simplified from Smith (1982).

and Bruce R. Wardlaw, written commun., 1975–1979, to J. F. Smith, Jr.). Local recrystallization of the Pennsylvanian limestone is also evident.

IGNEOUS ROCKS

Igneous rocks in the area of the Black Pine Mountains comprise a few small, altered intermediate to mafic dikes, remnants of Tertiary ash-fall beds and tuffaceous sedimentary strata, and rhyolitic ash-flow tuffs; lithoidal rhyolites crop out in the topographic expression of a rhyolite dome about 5 km southwest of the mountains. The radiometric age of these glassy intrusive and extrusive rocks in the dome was determined by C. W. Naeser, using the fission-track method on zircons, as 8.3 ± 1.7 m.y. (Williams and others, 1976). Dikes of presumably Tertiary age are poorly exposed in the mining district. Two mafic dikes in an artificial cut in the NE¼ sec. 34, T. 15 S., R. 29 E. do not exceed 1 m in width. They were intruded along faults that strike north and have vertical dips. The dikes are extensively weathered and do not form continuous exposures. Contacts between the dikes and the country rocks are sharp, and no prominent thermal effects were observed in the host sedimentary strata.

The mafic dikes are porphyritic and have an intersertal texture, which is locally obliterated by alteration. The principal constituents of the dikes are plagioclase as phenocrysts and pyroxene and biotite in the groundmass. Secondary minerals or oxidation products include quartz, calcite, muscovite, pyrite, magnetite, hematite, rutile, and trace amounts of chlorite, penninite, and epidote. Plagioclase with the composition of labradorite occurs as twinned subhedral crystals, which are commonly less than 1 mm long. The interior of the plagioclase crystals is commonly completely replaced by quartz, calcite, and minor amounts of sericite, and the margins are also locally embayed by quartz. Subhedral crystals of pyroxene have a glomeroporphyritic texture in places. Biotite is extensively leached of iron, and it is commonly completely altered to muscovite. Silicification preceded calcification in the dikes, and both quartz and calcite occur as microveinlets or irregular replacement masses throughout the intrusives.

GENERAL STRUCTURE

Low-angle faults, along which younger rocks have been moved over older ones or over rocks of partly equivalent ages, form the most prominent structural features in the Black Pine Mountains. They are more prevalent than the steeper normal faults, which may, however, be more abundant than can be shown on the geologic map, as their recognition is hampered by poor exposures in many places and by the lack of traceable key beds. Normal faults seem to have no preferred orientations.

Both large- and small-scale folds appear to be common in the Black Pine Mountains, but delineation of trends is difficult in many parts of the area because bedding attitudes differ in short distances. The folds, whose axial trends are not shown on figure 2, comprise anticlines and synclines of principally north and northeast trends.

MINERAL DEPOSITS

VEIN DEPOSITS

The vein deposits are characterized by quartz veins that fill fractures chiefly in Pennsylvanian carbonate rocks. These veins are commonly elongated, steeply inclined tabular bodies that exhibit pronounced variations in thickness and lateral continuity. Calcite and minor amounts of barite are common gangue minerals associated with the quartz. Isolated pods and stringers of ore contain tetrahedrite (freibergite), sphalerite, jamesonite, minor pyrite, and uncommonly cinnabar. Secondary oxidation products include smithsonite, hemimorphite, azurite, malachite, scorodite, bindheimite, and various oxides of antimony and iron. These secondary minerals generally are lacking within 23–30 m of the surface, and supergene processes evidently were not important factors in enriching the ore (Anderson, 1931).

The Silver Hills, Hazel Pine, and Ruth mines evidently were the largest producers of vein-deposit ore in the Black Pine mining district (Anderson, 1931, p. 134–139). The Silver Hills mine, which has the most extensive workings, was inaccessible during my investigation in 1976; it is the best example of a typical quartz vein deposit in the district. Production from this mine, which ceased in 1932, probably did not exceed 900 t (metric tons) of ore. This estimate was made by combining analytical data published by Anderson (1931) with production figures compiled by the Idaho Bureau of Mines (Campbell, 1924, 1925, 1926, 1932). Lead, silver, gold, and copper, in order of decreasing dollar value, constitute the most important metals in the ore from the Silver Hills mine. Small shipments of siliceous silver ore with lesser values of gold, lead, and zinc were made from the Hazel Pine mine between 1915 and 1917 (Gerry, 1917, 1918, 1919, 1920). About 12 t of zinc carbonate ore was shipped from the Ruth mine in 1915 (Gerry, 1917), and a minor, but unknown, amount of smithsonite ore was also produced from other claims before 1921 (Siebenthal, 1917; and Gerry, 1918, 1919, 1920).

DEPOSITS OF DISSEMINATED GOLD

Fine-grained disseminated gold occurs in altered Pennsylvanian silty carbonate rock. In 1943, the Virmyra Mining Company located 20 claims near the Tolman mine (fig. 2) in the Strevell 15-minute quadrangle. These claims were called the Virginia group (Campbell, 1943). This property was leased and mined by the Duvall Company from 1949 to 1955 (McDowell, 1949, 1950, 1951, 1952, 1953, 1954, 1955). Workings at the mine consisted of a crescent-shaped, generally east trending open cut, which was almost 180 m long and 90 m wide by 35 m deep, and of four short drifts into the north face of the pit. The ore was processed in a small mill erected near the mine in 1950 (McDowell, 1950). No published production data are available. Several companies have conducted drilling programs in the area and have explored an area of several square kilometers since the early 1960's, but no published data on the results are available. Samples on which most of the following discussion is based were collected from the Duvall Company pit and the immediate vicinity.

HOST ROCKS FOR DEPOSITS OF DISSEMINATED GOLD

Pennsylvanian strata of predominantly sandy and calcareous siltstones and silty limestone and claystone in lenses constitute the host for the deposits of disseminated gold. Siltstone is the most common rock type in what appears to be the principal area of altered rock. These siltstones are thinly laminated red-brown to yellow-brown rocks that are poorly sorted and commonly contain a few percent of very fine to fine quartz sand. The siltstones consist primarily of subangular to subrounded grains of quartz with variable amounts of interstitial clay. Small quantities of calcite occur as localized patches of granular cement. Magnetite, hematite, goethite, and leucoxene, the main accessory minerals, range in diameter from 0.01 mm to 2 mm and occur as trains or small clusters distributed along the bedding planes. The siltstones contain numerous subrounded to lenticular microcavities, which were formed by partial to complete dissolution of magnetite during diagenetic alteration of the sediments. These solution cavities, which range from 0.1 mm to 2.5 mm across, in places contain relict grains of magnetite and commonly are filled with chalcedony. In some cavities, both chalcedony and magnetite have been partially replaced by irregular patches of calcite.

Thin lenses or beds of green to gray or black dense limestone, generally less than a few meters in thickness, are interbedded with the clastic sedimentary rocks. These limestones are mostly silt bearing, partly silicified, partly recrystallized, fossiliferous micrites. Clastic components are randomly dispersed in the micrite matrix. Opaque iron oxides have been partly dissolved, but oxidation and liberation of iron were not as pronounced in the limestones as they were in the clastic rocks. Pseudo-spar or recrystallized calcite as well as fine-grained silica developed during the postdepositional alteration of the sediments.

Massive green to greenish-gray claystones are exposed along the lower part of the north side of the Duvall Company open cut. These claystone units are generally less than 7 m thick. Illite and mixed-layer illite-montmorillonite are the principal constituents of the claystones. Magnetite, hematite, and quartz silt occur in small quantities as accessory constituents. Iron oxide forms a conspicuous yellow-brown coating along the numerous microfractures in these beds. The claystones commonly contain elongated microcavities, which have been filled to varying degrees with chalcedony, in turn locally replaced by incipient calcite crystals. Alteration in the claystones is further characterized by the random development of irregular patches of replacement quartz in the rock matrix.

Variable amounts of carbonaceous material occur as minor constituents in the Pennsylvanian siltstones and limestones, which are exposed in the open cut. Two types of carbonaceous material—graphite and organic matter—were recognized in these sediments. Carbon analyses determined from samples of each rock type (table 1) indicate that carbonate rocks contain slightly higher amounts of organic matter than do the noncalcareous clastic rocks, which presumably are more permeable and more susceptible to oxidation.

OCCURRENCE OF THE GOLD

Finely divided gold and pyrite are the principal metallic minerals in the deposits. They seem to be disseminated chiefly in siltstone, which is commonly oxidized to some degree, and are associated with a gangue that includes calcite, barite, and quartz. Most of the gold grains are submicrometer in size, as shown by electron microscope, and are commonly less than 0.5 μm in diameter. They are disseminated within the clay or silt matrix of the clastic rocks or in the micrite groundmass of the limestones. Some gold is associated with the organic matter in both the clastic and carbonate sedimentary rocks; a seam of carbonaceous siltstone, generally less than 1 m thick, contains the highest concentration of gold in the rocks sampled. The highest gold content of samples from this siltstone was 70 ppm (2.25 oz troy/t). In general, however, no positive association between gold content and the amount of organic matter in the sedimentary rocks could be demonstrated. Oxidized siltstones stratigraphically above this carbonaceous zone contain between 5 and 10 ppm (0.16 and 0.32 oz

TABLE 1.—*Analyses showing the relationship between organic carbon and gold content in altered rocks from the Duvall Company open cut (site of Tolman mine on fig. 2), Black Pine Mountains, Cassia County, Idaho*

[Total carbon determined by thermal conductivity by V. E. Shaw; carbonate carbon determined gasometrically and organic carbon determined by difference, by P. H. Briggs; gold determined by atomic absorption, by J. D. Hoffman; <, less than]

Sample No.	Field No. BS-	Total C	Carbonate C (percent)	Organic C	Au (ppm)
1	19	10.09	7.74	2.35	0.05
2	22	.18	.04	.14	1.5
3	26	.12	<.01	.12	9.5
4	32	9.56	9.18	.38	.35
5	34	.12	<.01	.12	.20
6	35	3.89	3.71	.21	6.5

SAMPLE DESCRIPTIONS

1 Black, carbonaceous, argillaceous, silty limestone; abundant thin calcite veinlets. North side of open cut.

2 Brown argillaceous siltstone; few thin calcite veinlets; rare thin quartz veinlets; trace barite. Adit on north side of open cut.

3 Yellow-brown argillaceous siltstone; moderate amounts of iron oxide; rare thin calcite veinlets. Adit on north side of open cut.

4 Dark-gray, brecciated, silty limestone; abundant calcite veinlets; moderate pyrite; minor barite. Adit on north side of open cut.

5 Red-brown argillaceous siltstone; rare calcite veinlets. Adit on north side of open cut.

6 Gray brecciated siltstone; minor amounts of iron oxide; rare pyrite. Adit on north side of open cut.

troy/t) of gold (table 2). Samples of fault gouge and breccia contain as much as 36 ppm gold (1.15 oz troy/t) (table 2, No. 4).

ASSOCIATED SULFIDE MINERALS

Pyrite occurs commonly in the oxidized rocks, but it does not generally constitute more than 1 percent of the host rock. The pyrite is not readily seen in these rocks because of its small grain size, as most grains are less than 10 μm in diameter; a few grains noted were as large as 20 μm.

Tetrahedrite is the only base-metal sulfide that was identified in the gold-bearing strata, but it was not observed to be associated closely with the gold. The tetrahedrite occurs sparingly as minute grains disseminated in calcite veinlets. Green copper stains in close proximity to tetrahedrite occur uncommonly and in limited areas only.

TABLE 2.—*Analyses of altered and unaltered rocks from the Duvall Company open cut (site of Tolman mine on fig. 2) and vicinity, Black Pine mining district, Black Pine Mountains, Cassia County, Idaho*

[Numbers in parentheses indicate sensitivity limit of method used. G, undetermined amount of the element is present above number shown; L, undetermined amount of the element is present below sensitivity limit; N, element looked for but not found; ND, not determined. Elements were determined by semiquantitative spectroscopy unless otherwise noted. Analysts for samples: semiquantitative spectrographic analyses by Steve Sutley and J. Motooka; gold analyses by J. D. Hoffman and J. Sharkey[1]; antimony analyses by C. A. Curtis, J. Sharkey, and J. Viets[1]; arsenic analyses by J. Sharkey[2]; mercury analyses by J. G. Viets and J. G. Frisken[3]. All elements shown under sample TM-9 were determined by semiquantitative spectroscopy by Chris Heropoulos. Fe, Mg, Ca, Ti in percent; others in parts per million]

Field No.---	BS-18	BS-19	BS-23	BS-24	BS-32	BS-34	BS-44	BS-51	BS-52	BS-53	BS-54	BS-55	BS-56	TM-9	BS-43	BS-50
Sample No.--	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fe (.05)	1.5	0.15	10	2	0.07	2	10	1	7	10	3	3	1.5	2	0.05	7
Mg (.02)	.2	1	.1	.05	3	.3	1	.1	.5	.5	.3	.5	.5	.2	.7	1
Ca (.05)	5	10	.5	1	G20	.5	10	.5	.5	.2	1.5	.2	7	1	20	15
Ti (.002)	.2	.02	.2	.3	.05	.2	.3	.2	1	1	.3	.5	.2	.5	.01	.2
Mn (10)	20	50	200	L	200	10	500	150	20	20	10	20	300	15	50	100
Ag (.5)	1	.5	10	7	.5	2	5	2	2	5	1.5	2	1.5	10	.7	3
As (1)	1,200	60	800	2,400	100	80	200	3,300	200	1,600	200	3,300	200	7,000	L10	300
Au (.05)	.05	.05	19	36	.35	.2	L.05	1	.2	7	2.5	6	.4	70	L.05	1.5
Hg (.01)	10	.65	G50	G50	10	1.2	.3	40	13	G50	6.5	G50	7	ND	2.5	13
B (10)	100	15	70	50	20	200	100	50	300	300	100	200	70	70	L	70
Ba (20)	150	N	G5,000	G5,000	700	150	150	G5,000	200	200	300	200	G5,000	30,000	70	200
Be (1)	1.5	L	1	1.5	N	1.5	1	L	2	L	N	1	1	1.5	N	L
Bi (10)	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Cd (20)	N	N	N	N	N	N	N	N	L	L	L	L	L	N	N	N
Co (5)	5	N	7	L	N	L	70	L	L	L	N	L	10	N	N	5
Cr (10)	150	30	500	700	70	150	1,500	150	1,000	700	700	1,000	200	300	L	150
Cu (5)	15	N	100	50	L	50	150	30	100	200	20	70	50	50	L	100
La (20)	50	N	50	50	L	30	70	L	100	70	70	50	30	70	N	70
Mo (5)	10	N	5	N	N	7	N	N	10	L	L	5	N	N	N	L
Nb (20)	N	N	L	L	N	L	L	L	L	L	L	L	N	N	N	L
Ni (5)	100	5	300	150	20	70	1,000	70	200	150	100	150	150	70	5	200
Pb (10)	L	N	30	20	L	15	20	30	20	30	10	10	10	30	30	30
Sb (.01)	40	5	100	5	30	15	10	60	10	N	5	5	5	300	N	25
Sc (5)	10	L	L	L	5	10	15	N	20	10	5	7	L	5	N	5
Sn (10)	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Sr (100)	100	500	G5,000	G5,000	1,000	100	700	1,000	L	200	500	300	2,000	2,000	2,000	2,000
V (10)	150	15	70	100	100	200	150	50	700	500	500	1,000	150	150	L	100
W (50)	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Y (10)	30	L	10	10	30	30	20	15	70	15	15	15	N	15	10	20
Zn (200)	1,000	N	300	500	N	700	N	300	1,000	500	300	500	700	500	N	500
Zr (10)	100	N	50	70	20	100	200	70	150	100	70	100	30	200	15	70

[1]Analyses by atomic absorption.
[2]Analyses by colorimetric method.
[3]Analyses by instrumental detector.

SAMPLE DESCRIPTIONS

1 Yellow-brown, slightly sandy siltstone; much iron oxide; minor calcite veinlets. South side of open cut.
2 Black, carbonaceous, argillaceous, silty limestone; abundant thin calcite veinlets. North side of open cut.
3 Gray, vuggy, brecciated siltstone; moderate amounts of iron oxide; minor barite. Adit C. (Of four adits in the northwest and north side of the open cut, C is the third one from the southwest end.)
4 Yellow-brown brecciated siltstone; much iron oxide; fault gouge. Adit C.
5 Dark-gray, brecciated, slightly silty limestone; abundant calcite veinlets; moderate pyrite; minor barite. Adit C.

6 Red-brown argillaceous siltstone. Adit C.
7 Brown, altered mafic dike; moderate number of calcite veinlets; much iron oxide; abundant pyrite. Slightly north and above main open cut.
8 Green, argillaceous siltstone; minor amounts of iron oxide; minor barite. North side of open cut.
9 Red-brown argillaceous siltstone; much iron oxide. North side of open cut.
10 Green-brown argillaceous siltstone; moderate amounts of iron oxide. North side of open cut.

11 Red-brown, sandy, argillaceous siltstone; much iron oxide. North side of open cut.
12 Greenish-gray, brecciated, calcareous siltstone; moderate amounts of iron oxide; abundant calcite veinlets; few quartz veinlets; rare barite veinlets. North side of open cut.
13 Brown-red, sandy, argillaceous siltstone; much iron oxide. North side of open cut.
14 Carbonaceous siltstone. Bottom of west wall, Adit C.
15 Fossiliferous silty limestone; unaltered Pennsylvanian limestone. Altitude 2,048 m (6,720 ft), 0.3 km northwest of open cut.
16 Light-gray, slightly sandy, calcareous siltstone; minor thin calcite veinlets; minor amounts of iron oxide; unaltered siltstone. About 0.2 km south of open cut.

Trace amounts of cinnabar are widely dispersed in the more porous zones in the gold-bearing sediments. This mineral was also observed as very sparse microscopic crystals or anhedral grains along fractures within brecciated barite veinlets.

Although base-metal sulfides and cinnabar are very sparse as minerals in the oxidized sediments, anomalous amounts of mercury, arsenic, and antimony occur in the samples from the open cut (table 2). The four samples containing 6–36 ppm gold also contain more than 50 ppm mercury and from 800 to 3,300 ppm arsenic. The sample (table 2, No. 14) with the greatest gold content, 70 ppm, contains 7,000 ppm arsenic and 300 ppm antimony; the mercury content of this sample was not determined. These elements and tungsten are associated with gold deposits elsewhere in the Basin and Range province and may be considered as geochemical prospecting indicators in the search for mineralized rock containing gold. Tungsten was not detected (<50 ppm) in the samples in table 2. Anomalous amounts of arsenic, tungsten, and mercury are associated with gold at the Getchell mine north of Winnemucca, Nev. (Erickson and others, 1964); and anomalous amounts of arsenic, mercury, antimony, and tungsten occurred with the gold at the Cortez mine south of Carlin, Nev. (Wells and others, 1969).

GANGUE MINERALS

Barite is locally conspicuous in the mineralized rock, although it constitutes only a minor part of the host sediment. Barite occurs in several forms: bladed crystals in cavities or porous zones; veinlets or discontinuous wispy streaks of finely crystalline barite; and irregular patches that replace matrix carbonate, quartz silt, or clay. No positive correlation is apparent between the occurrence of barite and gold in the mineralized rocks, and sediments that contain anomalous concentrations of barium are not necessarily enriched in gold, although the three samples with the highest gold content are among those with the highest concentrations of barium (table 2).

Secondary silica is noticeable but not abundant in the altered and mineralized rocks. This silica occurs sparingly as thin overgrowths on detrital silt-size quartz grains, as discordant microveinlets, as microscopic replacement patches in the rock matrix, and, locally, in barite.

Calcite has been extensively mobilized in the altered rocks. This mineral occurs principally in veins that are mostly less than 1 cm thick; in some places, only a few veinlets exceed 1 mm in thickness. Some of the larger calcite veins along fractures exhibit a pronounced textural banding in places. Calcite was also noted as small replacement masses in the rock matrix and as incipient crystals replacing quartz and barite.

STRUCTURAL CONTROL OF THE ORE DEPOSITS

Structural features have apparently been important factors in the localization of mineralization in the vicinity of the Duvall Company pit. Both low- and high-angle faults cross the mineralized area and the area nearby. The most prominent structures visible on the northwest wall of the Duvall pit include a well-pronounced subhorizontal fault and shear zone along the lower part of the wall, and several apparently normal steep faults. The prominent low-angle fault essentially defines the backs of three adits in the northwest face of the open cut. This fault is characterized by an undulating surface that in general strikes north-northwest and dips about 35° W. Slickensides along the fault surface in places suggest that the last direction of movement was westward, although major movement in the area was probably eastward. To the top of the pit in part of the hanging wall of this fault, blocks and slabs of limestone as much as about 12 m long and from about 1.5 m to 8 m across are arranged chaotically in tan, pink, and red siltstone and claystone. This jumble of blocks evidently was developed by movement on faults.

More or less paired samples collected across the low-angle fault suggest that gold is more concentrated below the fault than above it, even though this suggestion is based on only six samples and the generalization might not hold for the entire foot and hanging walls. Samples 8, 10, and 12 (table 2) from below the fault contained 1, 7, and 6 ppm gold, and corresponding samples 9, 11, and 13 (table 2) from immediately above the fault contained 0.2, 2.5, and 0.4 ppm gold, respectively. Many steep, normal faults transect mineralized rock mostly above the low-angle fault, and most apparently have small displacement. Fault breccia and gouge collected from several locations contained as much as 36 ppm gold (1/5 oz troy/t) (table 2, No. 4).

CONCLUSIONS

Faults, stratigraphic position, and rock type were important factors in localizing the gold deposits in the Black Pine district. Samples analyzed for this study indicate that oxidized siltstones, which are in a silty limestone part of a Pennsylvanian rock sequence, contain greater concentrations of disseminated fine-grained gold than do other rock types or beds of other ages. Anomalous concentrations of arsenic, antimony, and mercury appear to be associated with gold-bearing rocks. This assemblage of elements, as well as tungsten, is found in other disseminated gold deposits in the Basin and Range province.

The disseminated gold was probably deposited from dilute low-temperature solutions. Fluid inclusions in barite suggest that the temperature of formation was between 125°C and 200°C (C. G. Cunningham, oral commun., 1977). The absence of daughter minerals in the liquid inclusions indicates that the salinity of the fluid was low. Low concentrations of strontium and magnesium determined in barite and calcite, respectively, provide additional evidence for low formation temperature of the deposits. The deposits of fine-grained gold probably formed at depth in a hot spring environment. The Raft River geothermal area is about 20 km west of the mining district. Similar geothermal activity may have formerly occurred in the Black Pine district and served as a source for hot water that mobilized the gold and other metals. Although a few mafic dikes crop out in the district, no surface or geophysical evidence exists to indicate that an intrusive body of any size is buried below or near the district, to have served as a source for the mineralizing solutions.

The age of mineralization in the area is unknown. It certainly is younger than the Permian strata and younger than most of the structural deformation. No good age control, however, is established for the time of deformation in the Black Pine Mountains. In the Raft River Mountains to the southwest, metamorphic deformation was still underway 24.9 ± 0.6 m.y. ago, and extensive eastward movement of allochthonous plates occurred after this deformation (Compton and others, 1977). How closely the deformation in the Black Pine Mountains can be related to that in the Raft River Mountains is still uncertain.

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