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MINERALIZATION IN THE BEAR RIVER RANGE, UTAH-IDAHO

by

John C. Chappelle

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Geology

Approved:

UTAH STATE UNIVERSITY  
Logan, Utah

1975

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Finally, and most of all, I want to thank my wife, Peggie, for her patience, encouragement, and assistance.

John C. Chappelle

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## ABSTRACT

Mineralization in the Bear River Range, Utah-Idaho

by

John C. Chappelle, Master of Science

Utah State University, 1976

Major Professor: Dr. Donald R. Olsen

Department: Geology

The purpose of this thesis is to describe the occurrences, interrelationships, and possible origin of the metallic mineral deposits of the Bear River Range. In this study, 21 mineral deposits containing minerals of lead, iron, copper, manganese, and zinc with quartz and carbonate gangue minerals, are described and classified as low temperature epigenetic hydrothermal deposits. The deposits predominantly occur in Cambrian limestone and dolomite formations located below formations with a high shale content. The deposition occurred as fracture filling and replacement along fractures associated with Tertiary Basin and Range normal faults and joints which generally trend northerly in the range. No zoning of the deposits was observed. No obvious source for the mineralizing solutions was observed; however, the presence of iron and magnesium minerals in all of the deposits may suggest the possibility of a metamorphic origin. The deposits are dated as post-Eocene.

(71 pages)

## INTRODUCTION

### Purpose and Scope

The purpose of this thesis is to examine and discuss the metallic mineral deposits of the Bear River Range, Utah-Idaho, excluding the vanadium extracted from the Phosphoria Formation. The location of the study area is shown in Figure 1. Mineralization was observed underground in only 16 deposits. In the remaining deposits, caving of the mines made in-place observations impossible. Samples were taken from all of the deposits either from the mines or from the dumps. Maps were made of the Blackstone mine in St. Charles Canyon, Idaho, and the main tunnel of the Lucky Star mine in Blacksmith Fork Canyon, Utah, to show the typical depositional relationships. Possibly some deposits were not included in the study because the author was not aware of their existence.

The author has attempted to determine the possible interrelationships of the deposits and to learn the origin of the metals in the deposits and the type of deposit. Descriptions of the individual deposits include structural and stratigraphic controls, ore and gangue mineralogy, type of deposit, and paragenesis.

### Previous Work

Hayden (1872) mentioned the presence of mineral deposits in the Bear River Range and concluded that "... these mines would never become profitable." Gale (1909) studied the copper deposits in Triassic

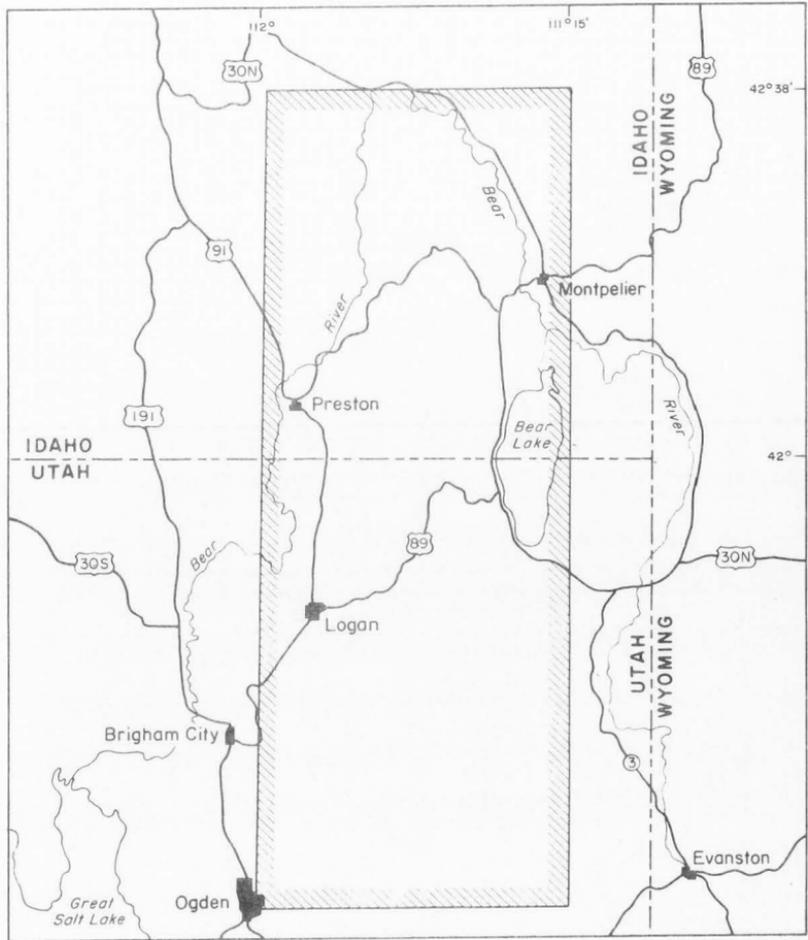


Figure 1. Index map to the study area.

formations east of Montpelier, Idaho, and attributed their deposition to the reduction of copper in ground water by carbonaceous material in the rocks. The source of the copper was thought by Gale to be the local strata. Richards (1910) investigated the lead and copper deposits along the eastern side of the range. He described the general location and mineralogy of some mines and prospects, several of which were already closed at the time of his observations. Richards did not identify stratigraphic or detailed structural controls or propose a source for the mineralizing solutions; however, his descriptions of the workings are of value because the majority of the mines he visited are now inaccessible. Butler, Loughlin, Heikes and others (1920) briefly mentioned several claims in the Bear River Range, giving general locations and mineralogy.

Mansfield (1927) included descriptions of deposits on the eastern slope of the Bear River Range in Idaho. Due to their minor economic importance and the state of ruin on many mines, Mansfield drew heavily on Richards' (1910) descriptions of the deposits, supplemented by field observations, in compiling his discussion. Mansfield applied Gale's (1909) theory on the origin of the copper deposits east of Montpelier to the copper deposits of the Bear River Range except he concluded that reduction was caused by disseminated bituminous material. Mansfield favored the theory that local strata were the source for the lead and copper of the deposits; however, the possibility that an unexposed igneous body was the source was also mentioned.

Crawford and Buranek (1943) and Bullock (1970) described the Mineral Point iron deposit. They attributed it to replacement of carbonate rocks by solutions with a high-iron content ascending along faults and fractures in the noncarbonate rocks. Peterson (no date), in an unpublished Utah State University senior research report on the Mineral Point iron deposit, also described the structure and emplacement of the deposit.

Olsen (1958) studied the deposits of the Bear River Range, Utah, as far south as the LaPlata district and concluded:

... it seems most probable that they were deposited by upward migrating solutions derived from the Precambrian basement by metamorphism of the basement near the east edge of the Cordillerian geosyncline. Emplacement of the minerals followed the formation of Tertiary faults and joints over the Precambrian basement, and upward migration of the weak mineralizing fluids.

Mullens and Izett (1964) mentioned the zinc deposit at the entrance to Blacksmith Fork Canyon and identified the associated formations. They made no examination or explanation of the origin of the deposits.

#### Procedures

Field work for this study was accomplished June through September, 1972, and May through July, 1973. Initially, a search of the available geologic literature and the mining claim records was conducted in each county involved. Because of the vagueness of the location descriptions encountered in the mining records, the mining claims were used to determine the general areas where mineral deposits had been found.

Then, a canvass was made of local communities to determine the location of mines and prospects. Where mineralization was noted, samples for laboratory examination were taken from dumps and from workings where possible. The stratigraphic distance from the formation contacts was determined with a Jacobs staff and Abney level (Kottlowski, 1965). Underground mapping was done with a 50-foot steel tape and Brunton compass as described by McKinstry (1948).

Thin sections and polished sections were prepared from samples by standard techniques. Samples for section preparation were selected to show mineralogy and depositional relationships. Thin sections were examined with a Zeiss Standard K petrographic microscope with daylight-filtered light. Recognition of individual carbonate minerals was accomplished by using staining techniques outlined by Warne (1962). Polished sections were examined under an American Optical Spencer microscope with a vertical illuminator and filtered white light. Identification of ore minerals was accomplished utilizing procedures outlined in Short (1931) and Cameron (1961). Microscopic characteristics determined from examination of polished and thin sections included mineralogy, paragenesis, depositional textural relationships, types of wall rock, and wall-rock alteration. Spectrographic examination of samples for trace metals was done on a Vreeland direct-reading spectroscope.

## GENERAL GEOLOGY

Stratigraphy

The Bear River Range contains about 23,000 feet of sedimentary strata representing all of the Paleozoic Era. The strata represent miogeosynclinal deposition in the Cordilleran geosyncline.

The Tertiary Period is represented by 300 to 500 feet of conglomerate and tuff. Lake deposits are found along the eastern and western edges of the range and to a lesser extent within the range. Brief descriptions of the stratigraphic units are included below. Emphasis in these descriptions is placed on the lateral variation of thickness and lithology to facilitate future location of the deposits and provide a basis for examination of the deposits with respect to their stratigraphic positions. Detailed stratigraphic descriptions are included in the references cited.

Precambrian rocks

Mutual Formation. The Mutual Formation consists predominantly of pale red-purple to light grayish-purple quartzite with hematite and sericite. The quartzite is predominantly medium-to-coarse-grained with minor cross-bedding. Bedding thickness is within the range 0.45 to 4.2 feet. Bright (1960, p. 17) reported 10,671.5 feet of undifferentiated Cambrian and Precambrian quartzites. The lower two thirds of this section appears to represent the Mutual Formation, based on his descriptions.

### Cambrian System

Brigham Formation. The Brigham Formation consists predominantly of light-brown and gray quartzite with some pink and greenish-brown quartzite. It is medium-to-coarse-grained with scattered well-rounded quartz-pebble conglomerate in thin beds. The upper approximately 200 feet is predominantly quartzite with interbeds of olive-green, greenish-brown, and micaceous and arenaceous shales that are 1 to 3 inches thick. Scolithus is common in the upper part of the formation, especially in the beds of greenish-brown quartzite (Williams, 1948, p. 1132). The amount of shale in the upper part of the formation decreases rapidly to the north and east (Maxey, 1958, p. 668). Davis (1969) measured 3,413 feet of the Brigham Formation exposed west of St. Charles, Idaho. Williams (1948) measured 4,800 feet on Flat Creek in the Preston Quadrangle.

Langston Formation. The Langston Formation, from Blacksmith Fork Canyon southward, consists of two thick-bedded dolomite members separated by a thin-bedded limestone member. The dolomite members are crystalline, light-to medium-gray, weathering to a brown surface (Williams, 1948, p. 1132; Hafen, 1961, p. 16). To the north of Blacksmith Fork Canyon, the lower dolomite member thins and the Spence Shale Member and Naomi Peak Limestone Member are present. The Spence Shale Member consists of up to 200 feet of black, green, and gray fissile shale with thin interbeds of tan siltstone and silty shale in the upper part. The Naomi Peak Limestone Member is a thin-bedded fossiliferous fine-crystalline light-to medium-gray limestone.

Thin beds of medium-grained gray calcareous or dolomitic sandstone that weather brown may be found at the base of the Naomi Peak Limestone Member in places (Maxey, 1958, p. 671). Both the Naomi Peak Limestone Member and Spence Shale Member thin to the east and north. They are absent in Bloomington Canyon (Keller, 1963, app. 2) and Co-Op Canyon (Oriel and Armstrong, 1971, p. 29). The upper dolomite member thins to the north and west, and it is absent in Oneida Narrows (Bright, 1960, p. 40-65). The brown-weathering dolomites of the Langston Formation are excellent stratigraphic markers. The formation is 485 feet thick at High Creek (Williams, 1948, p. 113) and is 274 feet thick west of St. Charles, Idaho (Davis, 1969, p. 6).

Ute Formation. The Ute Formation was described by Williams (1948, p. 1133) as being thin-bedded silty and sandy limestone interbedded with light-green shale. The limestone contains irregular wavy laminae of fine sand and silt which weather with strong relief. The laminae are frequently oolitic. Maxey (1958, p. 672) stated that the formation is generally uniform in thickness and lithology throughout the Bear River Range. Oriol and Armstrong (1971, Plate 5) indicated that the shale content decreased toward the northeast. The formation thickness is 665 feet in Blacksmith Fork Canyon (Williams, 1948, p. 1133) and 480 feet west of Garden City, Utah (Richardson, 1941).

Blacksmith Formation. The Blacksmith Formation contains massive-bedded fine-to medium-grained light-to medium-gray dolomite with some fine crystalline to aphanitic limestone beds. Dolomite comprises the major part of the formation in the southern part of the area (Williams,

1948, p. 1133; Hafen, 1961, p. 19) but decreases northward. Only 23 feet of dolomite are present west of Liberty, Idaho (Maxey, 1958, p. 672, after Walcott, 1948, p. 8), and dolomite is absent in Oneida Narrows (Bright, 1960, p. 40-65). Medium-to thick-bedded fine-to medium-crystalline dark-to medium-gray limestone comprises the major part of the formation in the northern part of the Bear River Range. The formation is 450 feet thick in the south and 900 feet thick in the northwestern part of the range.

Bloomington Formation. Four members make up the Bloomington Formation: (1) the basal Hodges Shale, (2) the lower limestone member, (3) the Calls Fort Shale, and (4) the upper limestone member. The Hodges Shale Member is olive-green calcareous shale with thin interbeds of light-to dark-gray limestone in the south and is micaceous siltstone and claystone with thin beds and nodules of limestone in the north. The lower limestone member consists of thin-bedded oolitic dark-gray limestone irregularly interbedded with thin beds of olive and brown siltstone and shale. The Calls Fort Shale is very similar to the Hodges Shale but is thinner. The upper limestone member is distinct only in the northern and western parts of the range. Northward in the Logan Quadrangle, the shale content of the lower unit decreases and the bedding thickness increases (Williams, 1948, p. 1134). In the LaPlata region, the members are not distinguishable (Hafen, 1961, p. 20). The Bloomington Formation is 1,500 feet thick in the Logan Quadrangle (Williams, 1948, p. 1130) and 534 feet thick in St. Charles Canyon (Davis, 1969, p. 6).

Nounan Formation. The Nounan Formation is thin-to medium-bedded fine-to medium-crystalline light-gray dolomite with thin-bedded fine-crystalline to aphanitic dark-gray limestone in the upper third. The limestone beds are fossiliferous and unevenly bedded and have shaly or silty partings. Williams (1948, p. 1134) and Hafen (1961, p. 21) stated that some of the lower dolomite beds are oolitic in the LaPlata region. The formation thins to the east from 1,125 feet at High Creek (Williams, 1948, p. 1134) and 1,145 feet at LaPlata (Hafen, 1961, p. 21) to 950 feet in the Randolph Quadrangle (Richardson, 1941, p. 12)

St. Charles Formation. The St. Charles Formation contains three members: (1) the basal Worm Creek Member, (2) a lower carbonate member and (3) an upper carbonate member. The Worm Creek Member has two beds of medium-bedded medium-grained light-gray quartzitic arkose according to R. Q. Oaks, Jr. (personal communication) separated by medium-gray sandy dolomite and overlain by dolomite with interbedded shale. The Worm Creek Member thickens rapidly northward from 90 feet in the James Peak Quadrangle (Hafen, 1961, p. 22) to 900 feet in the Soda Springs Quadrangle (Oriel and Platt, 1968, Sheet 2). The upper and lower carbonate units are dolomite and are distinguished by color and resistance to weathering. The lower dolomite is light-gray and less resistant to weathering than the upper more massive, dark-gray dolomite. The formation is 75 feet thick at High Creek (Williams, 1948, p. 1133) and 950 feet thick in St. Charles Canyon (Mansfield, 1927, p. 156).

### Ordovician System

Garden City Formation. The Garden City Formation consists of interbedded shaly limestone, crystalline limestone, and compact crystalline limestone, which becomes more massive crystalline limestone with a high chert content near the bottom and it has some coarsely crystalline dolomite near the top (Ross, 1953, p. 23; Williams, 1948, p. 1135; Hafen, 1961, p. 26). The Garden City Formation is highly fossiliferous and ranges in thickness from 1,290 to 1,800 feet in the Bear River Range.

Swan Peak Formation. The Swan Peak Formation is composed of three members: (1) the lower member consists of calcareous sandy gray siltite containing predominant quartz grains, and overlain by black shale with interbeds of silty quartzose sandstone, and limestone, (2) the middle unit contains interbedded pale-green shale and yellowish-brown orthoquartzite, and (3) a purple orthoquartzite (Schulingkamp, 1972, p. 9-19). The formation has thicknesses of 171 feet at Swan Peak (Schulingkamp, 1972, p. 116-117) and 739 feet in Copenhagen Basin, Idaho (Schulingkamp, 1972, p. 103-104).

Fish Haven Formation. The Fish Haven Formation is a massive-bedded medium-to dark-gray crystalline dolomite. It is a conspicuous cliff-former. The formation is 125 feet thick in the James Peak Quadrangle (Hafen, 1961, p. 50) and 500 feet thick in southeastern Idaho (Mansfield, 1927, p. 51).

### Ordovician and Silurian Systems

Laketown Formation. The Laketown Formation is a medium-to dark-gray very fine to coarse-crystalline medium-to very thick-bedded dolomite with chert nodules and seams. Thickness is between 1,100 and 1,400 feet in the area (Budge, 1966, p. 14).

### Devonian System

Water Canyon Formation. The Water Canyon Formation is divided into two members: (1) the Card Canyon Member and (2) the Grassy Flat Member. The Card Canyon Member is an argillaceous dolomite that weathers light-gray. It contains local intraformational breccia. The bedding is medium to thick in the lower part and is laminated in the upper part. The Grassy Flat Member contains interbedded silty dolomitic sandstone that weathers light-to dark-brown, and argillaceous dolomite. Both are thin-bedded. The remainder of the member is an arenaceous dolomite that weathers brown, and medium-grained calcareous dolomite and medium-grained calcarenite with six to eight feet of limestone breccia near the top. The formation thins to the north, east, and south of the Logan area. The Water Canyon Formation is from 221 to 861 feet thick in the range (Williams and Taylor, 1964, p. 38-53).

Hyrum Formation. The Hyrum Formation contains thin-to thick-bedded fine-to medium crystalline gray dolomite with interbeds of limestone, sandstone and dolomitic sandstone. In Blacksmith Fork Canyon it is 932 feet thick (Williams, 1971, p. 221).

Beirdneau Formation. Yellowish-gray dolomitic sandstone and medium-gray arenaceous dolomite compose the bulk of the Beirdneau

Formation. The lower part of the formation has calcareous dolomite with interbeds of dolomitic sandstone, and arenaceous dolomite. The top of the unit is silty or argillaceous dolomite with some limestone. The thickness of the formation is from 500 to 1,000 feet in the range (Williams, 1971, p. 225-226).

#### Devonian and Mississippian Systems

Leatham Formation. The Leatham Formation consists primarily of pale-brown to dark-gray shale with brown silty sandstones, and nodular limestone. The Leatham is from 75 to 100 feet thick (Holland, 1952, p. 1719).

Lodgepole Formation. The Lodgepole Formation contains about 30 feet of calcareous, fissile shale at its base. This is overlain by dense thin-to medium-bedded limestone with interbeds of calcareous siltstone. Interbedded cherty limestone and dolomitic limestone mark the top of the formation. The total thickness is 45 feet thick in Logan Canyon (Williams, 1948, p. 1130) and it is about 1,000 feet in Randolph Quadrangle (Richardson, 1941, p. 21).

Little Flat Formation. The Little Flat Formation contains alternating beds of calcareous sandstone and gray limestone. The calcareous sandstone is predominant near the base and decreases toward the top of the formation where limestone is predominant. It is approximately 900 feet thick (Williams and Yolton, 1945, p. 1145).

Great Blue Formation. The basal unit of the Great Blue Formation is predominantly black to gray silty limestone and calcareous sandstone with some black shale and dark-gray limestone. It is overlain by

grayish-olive argillaceous limestone, interbedded with crystalline limestone. The top of the formation is predominantly crystalline limestone with abundant chert. It is 1,820 feet thick at Dry Lake, southwest of Logan, Utah (Williams and Yolton, 1945, p. 1145).

Manning Canyon Formation. The Manning Canyon Formation is predominantly black to gray silty limestone and calcareous sandstone with some black shale and dark-gray crystalline limestone. It is 900 feet thick at Dry Lake, southwest of Logan, Utah (Williams and Yolton, 1945, p. 1145).

#### Pennsylvanian and Permian Systems

Oquirrh Formation. The lower part of the Oquirrh Formation contains thick-bedded dark-gray limestone with calcareous sandstone interbeds. Above the basal limestone member, medium-gray calcareous sandstone and dark-gray limestone alternate. The sandstone content is about 50 percent in the center of the formation and 90 percent at the top. The Oquirrh Formation is approximately 6,700 feet thick in the Wellsville Mountains west of Logan, Utah, but only the basal 1,735 feet is present in Blacksmith Fork Canyon (Williams, 1948, p. 1144).

#### Tertiary System

Wasatch Formation. The Wasatch Formation consists predominantly of a red conglomerate of sandstone, limestone, and chert pebbles and cobbles with occasional boulders of quartzite. A basal limestone is present in the southern part of the range. The limestone may be oolitic, pisolitic, stromatolitic, or compact. The Wasatch Formation

thickness is from 0 to 530 feet in the area (Williams, 1948, p. 1144-1147).

Salt Lake Formation. Light-colored tuffs, tuffaceous sandstone, and conglomerate comprise the Salt Lake Formation. These are lake deposits which accumulated along the margin of the range and into the valleys (Williams, 1948, p. 1147). The formation locally is absent in the mountains and is nearly 9,000 feet thick in Cache Valley (Adamson, 1955, p. 56-59).

#### Quaternary System

Lake Thatcher Formation. The Lake Thatcher Formation is a sequence of lake and fluvial beds deposited during Late Pleistocene time in Gem Valley, Idaho, to the north of Oneida Narrows. The formation consists of beds of gravel, sand, silt, and clay, most of which are marly with several intercalated tufa and travertine deposits. Bedding thicknesses can be found from a few millimeters to over 10 feet. The formation thickness is a minimum of 590 feet at the center of the basin and is absent at the valley margins (Bright, 1963, p. 22-23).

#### Igneous rocks

Cub River Diabase. The Cub River intrusive rocks are predominantly diabase with minor syenodiorite and andesite intruded as dikes and sills into the tuff of the Salt Lake Formation in the foothills of the Bear River Range east of Preston, Idaho. The intrusive outcrops are in an area approximately 2 miles wide and 10 miles long with a north-northwest trend (Willard, 1972, p. 15-19).

Gem Basalt. The Gem Basalt contains four flows of slightly to very vesicular fine to medium-grained, dark-to very dark-gray porphyritic olivine basalt. The total thickness is approximately 167 feet. The flows originated at volcanic cones near Alexander, Niter and Grace, Idaho; and possibly from the Blackfoot lava field (Bright, 1963, p. 31-34).

#### Structure

The Paleozoic rocks of the Bear River Range are folded into three broad folds which were formed during the late Mesozoic-early Tertiary Laramide Orogeny. These major folds are the Logan Peak syncline, the Strawberry Valley anticline, and the Fish Haven syncline. The Logan Peak syncline is a broad fold trending north-northeast near the western side of the range. The axis of the syncline plunges southwest to the north of Logan Peak and is nearly horizontal to the south where it is cut by the East Cache fault east of Paradise, Utah. The Strawberry Valley anticline is located east of the Logan Peak syncline. The anticline axis trends northeasterly and is horizontal where exposed. The Strawberry Valley anticline is covered by the Wasatch Formation over most of the area, except upper Blacksmith Fork canyon and southward in Weber County, Utah. Richardson (1941, Plate 1) indicates that the Strawberry Valley anticline trends to the east of the Fish Haven syncline. The Fish Haven syncline is a small shallow syncline on the eastern side of the range just south of the Utah-Idaho state line. It trends north-easterly. The eastern side of the range is marked by the

overthrust of Paleozoic strata onto Mesozoic strata along the Paris thrust fault. The Paris thrust dips gently to the west under the Bear River Range.

The Bear River Range is located in the zone of overlap of Laramide structures and Tertiary Basin and Range structures. The Laramide structures of the Bear River Range are broken by numerous steeply dipping north-striking normal faults. The western-most of these faults is the East Cache fault which is located along the western margin of the range. Another is located along the eastern margin of the range. The Cache Valley and Bear Lake Valley grabens collapsed relative to the Bear River Range horst along these two faults.

Throughout the range two sets of intersecting fractures are found which have strikes of N.  $10^{\circ}$  to  $30^{\circ}$  E. and N.  $30^{\circ}$  to  $50^{\circ}$  W. These fractures are mostly vertical or dip steeply to the west. Such structural patterns have been assumed to imply deformation based on a general N. to S. compression. If this is the case, the deformation may have been pre-Laramide because Laramide compression is thought to have been W. to E. Occasional east dips are found.

## MINERAL DEPOSITS

Twenty-one deposits or groups of deposits were found in the study area. Due to the variations in the names given to individual deposits in mining records, geologic literature, and current use, descriptions are given under the name of an associated geographic feature. Where the name of a mine is widely recognized and accepted, it is noted in the description. Each description includes the location, stratigraphic and structural controls, mineralogy, and paragenesis. None of the deposits described appear to have any economic potential in the near future.

DescriptionsAmazon Hollow, Cache County, Utah

The Amazon mine is located in the E. 1/2 sec. 17, T. 14 N., R. 4 E., south of U. S. highway 89. It is visible from the highway approximately 1 1/4 miles east of Beaver Mountain. The workings consist of two tunnels, two shafts, and an open pit in fine-crystalline medium-to dark-gray dolomite of the Blacksmith Formation within 55 feet of the contact between the Blacksmith and Bloomington Formations. The bedding strikes N. 23° W. and dips 10° E. Williams (1948, Plate 1) mapped high-angle faults approximately three-quarters of a mile to the west and to the northeast. The high-angle fault to the northeast trends approximately northwest. Small faults paralleling this northwest-trending fault can be seen in a road cut on U. S. highway 89 east of the mine and

in the northern tunnel. Each of these small faults shows the western block to be down relative to the eastern block. Predominantly vertical fractures trending N. 15° to 55° E. and N. 50° to 85° W. were observed in the workings. Mineralization, in the northern tunnel, was controlled by a fault which trends N. 81° W. and the fractures intersecting it.

Galena, pyrite, dolomite, ankerite, barite, siderite, calcite, and cerussite were observed. Olsen (1958, p. 10) reported the presence of sphalerite, magnetite, and one grain of chalcopyrite in a polished section. These were not observed by the author; however, many of the pods of hematite were not pseudomorphs after pyrite and may be the results of the alteration of magnetite or of chalcopyrite. The initial phase of mineralization was the recrystallization of the host rocks and the introduction of iron, forming ferroan-dolomite, followed by deposition of dolomite and ankerite fracture filling. Calcite and siderite were later deposited in and near the dolomite-ankerite vein. Siderite was only observed in pods in the host rock with calcite. Calcite was deposited in the dolomite vein. Galena and pyrite were deposited during the last stages of calcite deposition.

#### Birch Creek, Franklin County, Idaho

On the north side of Birch Creek in SE 1/4 sec. 15, T. 14 S., R. 41 E., southeast of Mink Creek, Idaho, is the mining claim of Mr. A. C. Wardell and Mr. Roy Taylor of Clifton, Idaho. A small prospect pit has been dug along a normal fault in the Brigham Formation. The fault strikes N. 45° E. and dips 62° SE. The displacement could not be determined. The quartzite strikes N. 37° W. and dips 15° E. Minor

pyrite and chalcopyrite were deposited simultaneously as a fracture filling along the fault plane. The pyrite and chalcopyrite were altered to hematite containing remnants of the primary minerals. The leached copper was redeposited as malachite and azurite.

Blacksmith Fork Canyon,

Cache County, Utah

Approximately 8 1/2 miles from the junction of the left and right forks of the Blacksmith Fork River, on the north side of the Left Fork, is a group of tunnels collectively referred to as the Lucky Star mine. The area can be divided into the upper and lower workings. The lower workings consist of a tunnel near the road and a shallow shaft above. Both are located along a large fault trending N. 25° to 51° W. and dipping steeply to the west, according to Olsen (1958, p. 13). Only iron oxide stain was noted in the shaft. The lower tunnel is now caved. The lower workings are located in an apparent slump or possible down-faulted block of the upper Langston Formation and seem to have the same general stratigraphic location as the upper workings.

The upper workings consist of three tunnels and a shaft that are located from 100 to 200 feet below the contact between the Langston Formation and the overlying Ute Formation. The shaft, in excess of one hundred feet deep, is at the entrance to the western tunnel and blocks entrance to the tunnel. The other two tunnels are accessible. Figure 2 is a map of the larger of the two tunnels.

The Lucky Star mine is close to a high-angle fault mapped by Williams (1948, p. 1154) and named the Lucky Star fault. The south-

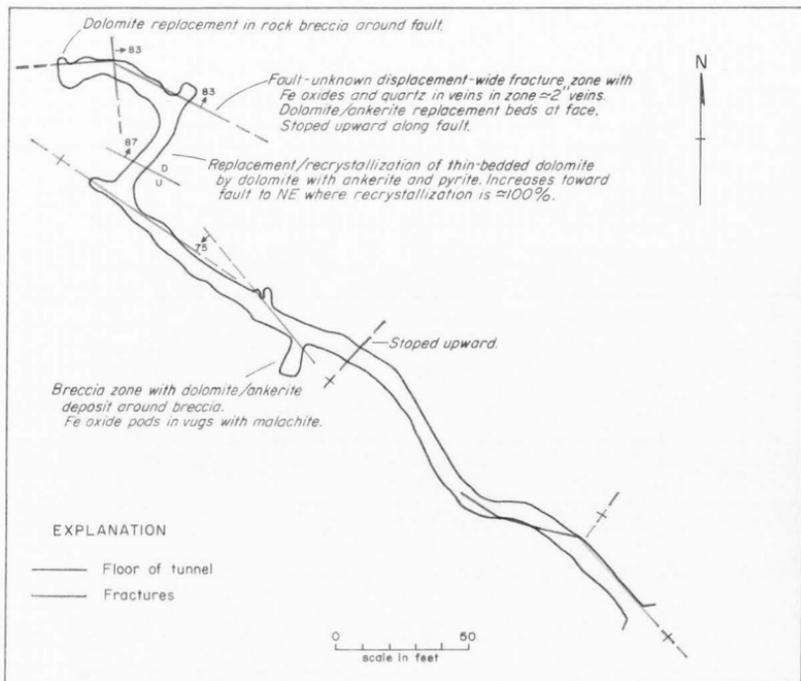


Figure 2. Lower level of the Lucky Star mine

eastern portion of this fault trends approximately N. 60° W. It crosses the canyon with a trend of approximately N. 30° W. and follows the draw immediately west of the lower workings. The western side of the fault is down and the stratigraphic throw is approximately 500 feet. The majority of the fractures associated with the mines and mineralization trend N. 60° to 70° W. and N. 40° to 45° W. and dip vertically or steeply westward, paralleling the Lucky Star fault and probably genetically associated with it. Bedding strikes 35° to 69° E. and dips 4° to 11° W.

The author observed pyrite, chalcopyrite, galena, quartz, dolomite, ankerite, cerussite, malachite, and iron oxides. Olsen (1958, p. 14) also observed tetrahedrite and covellite in polished sections of the ore minerals. Examination of samples and mine workings reveals the following paragenesis: (1) quartz and pyrite replacement of the host rock from three to six inches away from fractures, (2) quartz, pyrite, and minor chalcopyrite deposition in open fractures; the tetrahedrite and covellite appear to be contemporaneous with the chalcopyrite according to Olsen (1958), (3) galena deposition just prior to the end of the deposition of quartz in the fractures as evidenced by galena inclusions in quartz crystals, and (4) deposition of dolomite and ankerite with a decrease in ankerite during deposition. The initial occurrences of the dolomite were as a replacement of quartz and later as a fracture filling. Replacement of the quartz by dolomite is evidenced by isolated quartz fragments in optical continuity within the dolomite.

City Creek Canyon, Cache County, Utah

Four tunnels are located on the north side of the left fork of City Creek Canyon east of Richmond, Utah. The tunnels are located in an area cut by three high-angle faults striking approximately north and dipping steeply westward. The two westernmost faults are normal faults and the eastern fault is a reverse fault. All three faults have minor displacement.

Mineralization was limited to dolomite of the Langston Formation between the central and eastern faults. The Langston Formation strikes N. 13° E., dips 36° W. and is in fault contact with the Ute Formation to the east and west. Mineral deposition was along a fracture in the Langston Formation and as a partial replacement of the formation. The paragenesis is similar to the deposits in the right fork of City Creek except for the absence of barite and much less quartz. Due to the small amount present, the paragenetic position of quartz is debatable in the deposits on the left fork.

The lack of mineralization in the Ute Formation is thought to be caused by the shale interbedded with the limestone. It restricted the flow of mineralizing solutions along bedding planes.

Two lead mines are located on the north side of the right fork of City Creek in NW 1/4 sec. 4, T. 13 N., R. 2 E., east of Richmond, Utah. Olsen (1958, p. 12) referred to these as the Egan claims. The workings consist of an upper and lower tunnel. Only the upper tunnel is open.

The lower tunnel was described by Olsen (1958, p. 12) as having several hundred feet of workings following faults and joints striking

N. 30° N. to N. and dipping 25° to 30° W. Olsen noted no metallic mineralization in the lower tunnels.

The upper tunnel is located in the Cambrian Langston Formation. There, thin-bedded, sandy dolomite is cut by a normal fault striking N. 20° W. and dipping 35° to the west. An open fracture, 6 to 10 inches wide, parallels the fault approximately two feet away. Deposition is in the form of bedding replacement in the thin-bedded dolomite. Medium-to thick-bedded dolomite outcrops in this area show only calcite veins in fractures. Possibly, the replacement zone represents a bedding-plane thrust fault.

Hydrothermal minerals include quartz, barite, dolomite, ankerite, siderite, pyrite, calcite, and galena. Olsen (1958, p. 12) noted the presence of sphalerite containing scattered specks of pyrite. These were not noted by the author. After a period of initial fracturing, quartz was deposited as small euhedral crystals projecting into open spaces around breccia. Next, barite was deposited along bedding surfaces and in fractures on the earlier quartz. Pyrite deposition may have started late in the barite phase; however, it was also deposited with dolomite and ankerite following barite deposition. Following deposition of minor dolomite, and ankerite, a second period of fracturing occurred, which was followed by deposition of calcite and galena in fractures in the dolomite. Calcite was deposited as a replacement of barite and possibly as an open-space filling. The bladed forms of the original barite are evidenced in hand specimens. Isolated grains of barite, in optical continuity, are separated by calcite.

The High Creek stratigraphic section of Maxey (1958, p. 651-655) shows 45 feet predominantly of shale with thin-bedded limestone and limestone nodules in the lower Bloomington Formation. Presence of the shale is thought to be the cause of the spread of mineralizing solutions along bedding planes lower in the section and the resulting bedding replacement.

#### Cleveland, Franklin County, Idaho

An old manganese mine is located on the McGregor ranch east of Cleveland, Idaho, in the NE 1/4 sec. 30, T. 12 S., R. 41 E. The mine is located in sediments of Pleistocene Lake Thatcher (Bright, 1960, p. 201). It is completely caved. Hewett (1928, p. 211-218) examined the deposit while it was being mined, and Hale (1952) described the deposit in a report for the J. R. Simplot Company. The Hale report was not available; however, it was extensively quoted by Bright (1960). This description is based on the observations of Hewett, Hale, and Bright, as well as the author, and discussions with Mr. Leroy Smith of Preston, Idaho, who originally worked the mine with his father.

The manganese ore was predominantly wad with small masses of psilomelane and pyrolusite, all of which were deposited in tufa and travertine. The ore was deposited as a vertical pipe-shaped body approximately 15 feet in diameter with horizontal beds of ore which radiate from the pipe and thin outward. The lenticular beds were approximately 6 feet thick at the pipe. Diamond drill cores, taken during the Hale examination, showed that the ore beds had thinned to 1 to 3 inches laterally and that three beds were present. According

to Mr. Smith, the cores were taken all around the deposit and were cut to Paleozoic bedrock.

The manganese was undoubtedly deposited by fault-controlled hot springs along the shores of Pleistocene Lake Thatcher. The hydrothermal solutions were probably contemporaneous with the Gem basalts extruded to the immediate north as proposed by Bright (1960, p. 203).

Copenhagen Canyon, Bear Lake

County, Idaho

An old lead mine once operated by the family of Mr. C. D. Skinner of Liberty, Idaho, is located near the top of a low ridge on the northern side of Copenhagen Canyon in the NW 1/2 sec. 34, T. 28 N., R. 42 E. Mr. Skinner stated that one body of galena approximately 15 x 15 x 8 feet was found in a vertical fracture and that it thinned outward to a small vein which disappeared. Work was stopped because of the expense of equipment and labor and the poor prospect of a profitable discovery. All of the original workings are collapsed and inaccessible.

The site is located in the upper Blacksmith Formation, predominantly in the medium-bedded fine to coarse-crystalline dark-blue-gray limestone, 220 feet below the Hodges Shale Member of the Bloomington Formation. The bed strikes N. 29° W. and dips 23° SW. Nearly vertical fractures, striking N. 60° W. and N. 35° E., were observed in the area. Oriel and Platt (1968, Sheet 1) mapped two parallel north-trending normal faults approximately three-quarters of a mile to the east in the Brigham Formation.

Minerals deposited included dolomite, ankerite, calcite, quartz, pyrite, galena, fluorite, and opal which indicate low temperatures during deposition. Initial mineralization included local dolomitization of host rock and deposition of bands of dolomite and ankerite in optical continuity in the open fractures, implying continuous deposition from a solution of changing composition. Calcite was deposited on the dolomite in open spaces. The dolomite and calcite are cut by fractures filled with coarse-grained quartz and pyrite. Some masses of fine-grained quartz are present. Quartz showing rhombohedral cleavage is present as a replacement of the fine-grained carbonate and possibly rock breccia. Galena, fluorite, and opal followed quartz and were deposited on the growth surfaces of the coarse-grained quartz.

Deadman Gulch, Cache County, Utah

The author did not learn of the Deadman Gulch iron deposit until after the 1973 field season and consequently the site has not been visited. The following description is taken from Bullock (1970, p. 17-19).

The deposit is located in sec. 28, T. 14 N., R. 4 E., 3.9 miles southeast of Beaver Mountain. Iron mineralization consisted of small pockets of magnetite and hematite replacing limestone beds in the Bloomington Formation. Bullock (1970, p. 17) stated that faulting did not seem to be a structural control for mineralization. The hematite is blue-black to reddish in color and is relatively hard. The magnetite is black, massive, and pure. Economic potential is very small.

Dry Canyon, Bear Lake County, Idaho

On the southern side of Dry Canyon in the NE 1/2, sec. 17, T. 15 S., R. 43 E., west of St. Charles, Idaho, is a collapsed mine named the Idaho Gem. The Idaho Gem is a lead mine located in the upper part of the Cambrian Blacksmith Formation immediately below the Bloomington Formation. The mineralization was in thin-bedded medium-gray limestone that strikes N. 25° W. and dips 27° W. The mine is collapsed and has not been active since 1910 (Mansfield, 1927, p. 343). Minor amounts of galena were noted in the dump. Examination of the dump revealed an assemblage similar to the near-by Blackstone mine except for sphalerite and fluorite, which are present in the Blackstone. In outcrops near the mine entrance, dolomite, ankerite, calcite, and galena mineralization is in the rocks adjacent to fractures striking N. 50° E. and N. 70° E. and dipping vertically and 73° NW respectively.

Hodges Canyon, Rich County, Utah

Numerous prospects and one known mine are located in Hodges Canyon southwest of Garden City, Utah, in sec. 36, T. 14 N., R. 4 E. The area is referred to as Lead Hill in mining claims registered in the county records. An old mine and several prospect pits located in the upper Langston Formation are on the western side of a hollow extending northward out of Hodges Canyon. The hollow contains a north-trending high-angle fault which has the western side down. Olsen (1958, p. 11) noted faults in the Langston Formation striking N. 22° E. and N. 46° W. with dips of 73° SE. and vertical respectively. These faults were not observed at the surface by the author; however,

predominantly vertical faults and fractures striking from N. 30° E. to N. and N. 25° to 60° W. were observed in the mine tunnel. The tunnel exposes only minor quartz veins containing limonite pseudomorphs after pyrite. On the ridge above the tunnel, approximately 70 feet below the contact between the Langston and Ute Formations, are several prospect pits. The beds strike N. 20° to 26° E. and dip 4° to 17° W. The prospects are in the brown-weathering dolomite of the Langston and expose the following minerals: barite, quartz, dolomite, ankerite, malachite, and limonite pseudomorphs after pyrite. After a period of fracturing, a vein of dolomite with thin bands of ankerite was deposited and later fractured. Following a second period of fracturing, quartz replaced portions of the host rock and the dolomite vein and filled open fractures in the dolomite. Pyrite and possibly chalcopyrite deposition began during the first stages of quartz deposition. They were deposited as euhedral crystals and irregular masses around breccia fragments. Chalcopyrite was not identified; however, presence of a Cu-Fe primary mineral is indicated by the selective association of malachite with certain iron oxide remnants. Barite filled late-formed fractures.

Olsen (1958, p. 11) described a shallow pit and short incline in the Langston Formation in Hodges canyon and identified calcite, siderite, barite, quartz, pyrite, chalcocite, and malachite. The malachite was the product of alteration of chalcocite which had replaced primary pyrite.

#### Hyrum Canyon, Cache County, Utah

In SE 1/4, sec. 30, T. 10 N., R. 2 E., on the southern side of Hyrum Canyon, east of Paradise, Utah, several prospects and a small lead

mine identified as the Morning Star mine by Olsen (1958, p. 16) exist in a dolomite of the Mississippian Great Blue Formation, just below the upper contact with the Pennsylvanian-Permian Oquirrh Formation. The mine, now caved, is located 75 feet below the contact. Mullens and Izett (1964, Plate 1) have mapped a northeast-trending high-angle fault with the eastern side down, approximately a quarter mile west of the mine. One normal fault, with approximately 15 feet of displacement, trending N. 45° E. and dipping 70° SE., was observed in the outcrops. This is probably the fault at which the mine terminates according to Olsen (1958, p. 16-17). Olsen (1958, p. 16) also observed a series of strong fractures and faults trending N. 25° to 43° E. and dipping vertically which were exposed in the mine. The observations correspond to the fractures observed in the surrounding cliffs. Olsen's statement that the mine follows an apparent bedding-plane fault is supported by a thick calcite vein which contains breccia of adjoining rock units formed parallel to bedding at the entrance of the prospect and no bedding replacement or deposition parallel to bedding can be observed elsewhere.

Examination of samples taken from the dump by the author, and by Olsen in 1958, reveal the following minerals: calcite, barite, galena, sphalerite, marcasite, siderite, jarosite, and cerussite. A primary mineral containing iron was deposited initially as a fracture filling. This was followed by a second period of fracturing. Calcite was deposited along fractures cutting the iron-bearing mineral and the host rock after the second period of fracturing. Subsequent to the calcite deposition, a period of barite deposition occurred. This was followed

by simultaneous deposition of galena, sphalerite, and marcasite in an intimate mixture.

Hyrum front, Cache County, Utah

A zinc mine is located in the NW 1/4 sec. 13 and the SE 1/4 sec. 11, T. 10 N., R. 1 E., east of Hyrum, Utah, and approximately one mile south of the mouth of Blacksmith Fork Canyon. The workings include three tunnels and several prospect pits in the lower Great Blue Formation. The workings are located along the East Cache fault zone as mapped by Mullens and Izett (1964, Plate 1). The formations are highly brecciated. Only the northernmost tunnel is open and it is in very dangerous condition.

Mineralization was limited to iron oxide and porous, iron-stained smithsonite along north-northwest-trending fractures which dip steeply to the west or are vertical. No primary minerals could be identified and the deposit is thought to be the result of secondary deposition of smithsonite by means of groundwater alteration of zinc-bearing primary minerals such as sphalerite, or replacement of carbonate rock. It is not presently considered to be an economic deposit.

LaPlata Canyon, Cache County, Utah

The LaPlata mining district is located in the E. 1/2, sec. 11, T. 8 N., R. 2 E. Carr (1972, p. 18) stated that the LaPlata deposits were discovered by a sheep herdsman late in the summer of 1891. A sample taken by the sheep herdsman was reportedly galena with 400 ounces of silver per ton. Development of the area was principally during 1891. A town of over 60 buildings was built during that year.

Pockets of up to 80 percent galena were found in clays along faults. Over 250 tons of ore averaging 76 percent lead with 10 ounces of silver per ton was reported shipped to Salt Lake City during 1892. By the end of the summer of 1891, the major deposits were mined out and all except a few small operations had closed. The last operations stopped during a sharp decrease in the price of silver during 1893 and 1894.

Workings consist of two tunnels, two shafts, and numerous prospect pits. The two shafts are located on the eastern side of the canyon near the road connecting LaPlata Canyon and Red Rock Creek. Both shafts are in the Cambrian Ute Formation on the northern side of a high-angle fault that trends west. The fault is down on the north side (Hafen, 1961, Plate 1). The northern shaft is located in the Ute Formation 285 feet below its contact with the Blacksmith Formation. The southern shaft is 380 feet below the base of the Blacksmith Formation and is closer to the east-west trending fault. Both shafts are collapsed. Approximately 0.3 mile north of the shafts, on the western side of the canyon, a tunnel is located. It is located in the Blacksmith Formation 340 feet above its base. The tunnel was flooded, except for the upper 100 feet, when visited. A series of fractures, trending N. 50° W. and dipping 65° NE., was noted in the upper part. Calcite pods along bedding surfaces were the only mineralization noted in the upper part of the tunnel. A second and more extensive tunnel is located approximately 0.25 mile northwest of the first tunnel on the contact between the Blacksmith and Bloomington Formation. The tunnel is collapsed and could not be examined; however, no metallic

mineralization could be found on the dump. Beds strike N. 47° to 60° E. and dip 19° to 29° W. Minerals identified in the LaPlata dumps include pyrite, galena, quartz, dolomite, ankerite, calcite, malachite, and cerrusite.

Pyrite and dolomite with bands of ankerite were deposited after an initial period of fracturing. Pyrite deposition occurred in the host rock and in the veins during the initial dolomite deposition. Dolomite-ankerite deposition was followed by fracturing and by calcite deposition along the fractures in the dolomite. Galena was deposited following the calcite deposition. The last period of fracturing was followed by deposition of quartz with pyrite and possibly chalcopyrite along the fractures. Quartz replaced part of the Ute and Langston Formations near the fault associated with the southern shaft and was deposited in veins in the host rock. Malachite is associated with some pods of iron oxide in the quartz, indicating a primary mineral containing copper and iron or a secondary replacement mineral containing copper. In general, lead, quartz, and copper mineralization were weak. Mineralization consisted primarily of the vein and replacement rock carbonates and pyrite.

#### Maple Creek, Franklin County, Idaho

In Maple Creek canyon, east of Franklin, Idaho, three tunnels and several prospect pits exist in light-blue-gray limestone of the upper Blacksmith Formation. The southern tunnel is collapsed. The central tunnel was filled with water, except for the upper 100 feet,

when visited, and the northern tunnel was open and accessible. Beds strike N. 5° E. and dip 30° E.

The mineral assemblage found included quartz, pyrite, chalcopyrite, dolomite, ankerite, azurite, and malachite, and is associated with joints and faults trending from N. 5° to 65° E. and dipping from vertical to 50° W. Coulter (1956) mapped a major north trending normal fault, approximately 1 1/4 miles to the west, and the Frankline Basin fault, a normal high-angle fault, approximately 2 miles to the east. All of the mineralized zones are within 100 feet of the base of the Hodges Shale Member of the overlying Bloomington Formation.

Limestone beds of the upper Blacksmith were selectively dolomized after an initial period of fracturing. The dolomitization occurred simultaneously with or before deposition of a vein of banded dolomite and ankerite in fractures and bedding planes. A second period of fracturing followed the deposition of the dolomite-ankerite vein. Quartz partially replaced the host rock and was deposited in fractures in the dolomite. Coarse-grained dolomite-ankerite vein material was replaced by the quartz to a much less extent than the finer-grained rock. Deposition of pyrite and chalcopyrite followed the vein-quartz deposition. Weathering of chalcopyrite by carbonate-rich ground water produced malachite and azurite. Examination of the workings and hand specimens show some of the quartz as bladed masses apparently replacing barite; however, no barite remnants were found.

The thick shale unit in the lower Bloomington Formation apparently caused the ascending solution to spread along the bedding and into the

pore space of susceptible units in the underlying Blacksmith Formation. This allowed the dolomitization and silicification of the host beds and ore-mineral deposition in fractures and along bedding surfaces.

Mineral Point, Cache County, Utah

Approximately 9 miles east of Avon, Utah, in the NE 1/2, sec. 25, T. 19 N., R. 2 E., is a north-northwest trending ridge named Mineral Point. Both iron and copper deposits are known on the ridge. Near the top of the ridge, two tunnels, a shaft and numerous prospect pits are located on an iron deposit formed along a fault which has placed the Brigham and Langston formations in juxtaposition laterally. The deposit was discovered in 1875 (Bullock, 1970, p. 19). One tunnel, which is caved, is on the eastern side of the ridge in the Brigham Formation. Near the crest of the ridge, approximately 100 yards west of the eastern tunnel, is a collapsed inclined shaft, in a highly brecciated zone of the Brigham Formation, just northeast of a high-angle fault which trends northwest (Hafen, 1961, Plate 1). There is a tunnel on the western side of the ridge in the Langston Formation. This tunnel terminates at the fault contact with the Brigham Formation. Numerous prospect pits are located on both sides of the ridges. The majority of the prospect pits show no mineralization.

Exposures in outcrops in the west tunnel and in diamond drill holes, cut in 1928 by the Columbia Steel Corporation of California (Bullock, 1970, p. 19), show the deposit to be wedge-shaped in cross section. The deposit was formed as a fracture filling in the Brigham Formation and replacement of the Langston Formation.

The mineral assemblage, at the Mineral Point iron deposit, consists of specular hematite, pyrite, quartz, dolomite, ankerite, and calcite. After the initial fractures were formed, quartz was deposited in veins containing abundant grains of euhedral pyrite in the Brigham and Langston Formations. Subsequently the pyrite was removed leaving negative crystals or crystal molds in the quartz. Later, solutions deposited specular hematite in fractures and around breccia fragments in the Brigham Formation and as a replacement body in the Langston Formation near the fault. Subordinate quartz was deposited simultaneously. Veins of dolomite with minor ankerite and later calcite fill scattered fractures in the margins of the deposit in the Langston Formation in the western tunnel, and increase in abundance and in ankerite content as the major fault is approached.

The only major shipment of ore was a 600-ton shipment made by the Supersteel Corporation of America to Pittsburg, Pennsylvania, for testing the ore. Ore estimates for the deposit range from 50,000 to 100,000 tons (Bullock, 1970, p. 19).

The tunnel of the Mineral Point copper mine is located approximately 200 yards northeast of the first switchback where the road from Avon starts to ascend Mineral Point. It is approximately 600 feet long and ends at a fault contact between the Brigham and Langston Formations. This seems to be the same fault along which the specular hematite was deposited higher on the ridge; however, none is noted at this location. The dip of the Langston Formation steepens as the fault is approached indicating that the southwest block is down. Two small

lenticular masses of quartz crystals with grains of pyrite and scattered chalcopyrite were noted at approximately 450 feet and 500 feet from the entrance. The first lens was removed for the most part during tunnel excavation. Deposition is along a fault that strikes N. 35° E. and dips 32° NW. Dolomite and ankerite were deposited in breccia associated with the fault. The second mineralized zone, containing similar mineralization, is in a zone of parallel fractures which strike N. 55° W. and dip 50° SW. No alteration of the wall rock was noted in either zone.

Buranek (1942, p. 3) reported the presence of another shallow shaft from which "rather high values of gold, silver, and copper had been reportedly obtained." This shaft was reported to be located on the major Mineral Point fault, but it could not be found. Buranek reported that assays of samples taken from the Brigham Formation near the fault reported traces of gold and up to 0.30 ounce of silver per ton. He proposed that the reported rich values of gold, silver, and copper in the surface shaft were the result of supergene enrichment.

#### Nounan, Bear Lake County, Idaho

West of Nounan, Bear Lake County, Idaho, copper mineralization occurs on the north side of Co-Op Creek and on the south side of Skinner Creek in the SW 1/4 sec. 17 and NE 1/4, sec. 19, T. 29 N., R. 43 E. The workings consist of a main shaft with numerous peripheral prospects on Skinner Creek and three tunnels in various states of ruin on Co-Op Creek. The Skinner Creek and Co-Op Creek workings

are on the property of Mr. Lee Allerman and Mrs. Leslie Skinner, respectively, both of Nounan.

Mineralization was in the brown-weathering dolomites of the Langston Formation, which Mansfield (1927, p. 345) had identified as the Ordovician Garden City Formation. There, the Langston Formation has been overridden by the Brigham Formation along an imbrication of the Paris thrust fault (Armstrong and Cressman, 1963, Plate 2, and Oriel and Armstrong, 1971, p. 29). Between the two sites runs a north-north-easterly trending, east-dipping, high-angle normal fault. The exact stratigraphic position of mineralized beds within the Langston Formation could not be determined due to the complexity of the structure and the presence of landslides in the area. The Langston Formation strikes from N. 18° W. to N. 2° E. and dips from 51° W. to 28° E.

Minerals deposited in the area include, in order of abundance, dolomite, quartz, ankerite, pyrite, chalcopyrite, malachite, and azurite. In Co-Op Creek canyon, the only accessible working is the upper tunnel, which follows an unmineralized fracture which strikes N. 46° W. and dips 48° NE. Immediately inside the entrance of the tunnel, a short crosscut to the left follows a fracture striking N. 22° E. and dipping 62° NW., the only mineralized fracture in the mine, according to Mr. Fred Minnig of Georgetown, Idaho, who worked the mine as a boy. The mineralization consisted of dolomite deposition, followed by the alternating deposition of dolomite and ankerite in optical continuity. Weathering of the ankerite produced bands of iron oxide in the crystals, which mark periods of fluctuation in the iron

content of the mineralizing solutions. Dolomite-ankerite deposition was followed by a period of fracturing. Quartz, pyrite, and chalcopyrite were deposited in open fractures following this period of brecciation. Outcrops and prospect pits, on the ridge between Skinner and Co-Op creeks contain numerous quartz veins 5 to 18 inches wide with similar mineralogy. In the Skinner Creek area, which is closer to the north-northeast-trending fault, mineralization was similar to that of Co-Op Creek except that it is more intense. The vein dolomite does not contain ankerite growth bands as at Co-Op Creek. Following the deposition of dolomite and a second stage of fracturing, quartz replaced breccia fragments, but it did not replace the coarse-grained vein dolomite. Iron oxide stained the quartz during the replacement of the rock breccia and growth of crystals into open fractures, but staining abruptly stopped during the process of quartz deposition. No chalcopyrite remnants were identified in the samples taken; however, its original presence seems assured based on the presence of copper carbonates and their selective association with iron oxide masses, and its identification in Co-Op Creek samples.

Mineralization, west of Nounan, was characterized by solutions initially high in magnesium and iron with periodic fluctuation in the iron content, followed by silica, copper, sulfur, and iron-rich solutions. Movement of the solutions was seemingly controlled by the north-northeasterly trending normal fault as evidenced by the increased intensity of mineralization closer to the fault. Deposition was observed to be strongest in fractures trending toward the fault.

Paris Canyon, Bear LakeCounty, Idaho

The Hummingbird mine is a copper mine in sec. 1, T. 26 N., R. 42 E., north of Paris Canyon. The area is covered with diamictite described as glacial by Oriel and Platt (1968, Sheet 2). Based on the lithology of limited exposures of underlying formations at the site and in road cuts leading to the mine, the author assumes the mine to be located in gray limestone of the Blacksmith Formation near its contact with the Bloomington Formation. The workings of the Hummingbird mine are completely collapsed; however, Richards (1910, p. 184) provided a description. He stated that the ore body was parallel to the bedding and was presumed to occupy a bedding-plane thrust fault. It was several feet thick and continuous where observed. The vein trends N. 60° W. and dips 40° SW. Richards also stated that the ore body contained brecciated quartz, jasper vein material in which secondary quartz and malachite were deposited contemporaneously, and tetrahedrite.

Tetrahedrite, and jasper were not observed by the author during field or laboratory examination of samples from the mine dump. The minerals identified included dolomite, quartz, pyrite, chalcopyrite, malachite, and azurite. Dolomite was deposited in open spaces following an initial period of fracturing. Masses of fine-grain quartz, containing carbonate grains and surrounded by euhedral quartz crystals, evidence the quartz replacement of breccia and subsequent open space filling. A rapid decrease in the iron content of the solutions, during quartz deposition is evidenced by a sharp boundary between iron-stained

and unstained sections of a single crystal. The iron boundary parallels the crystal faces. Pyrite and possibly chalcopyrite were deposited along fractures in the euhedral quartz and on the crystal faces. The iron oxide which remains shows some pyritohedral outlines and local association with malachite.

St. Charles Canyon, Bear Lake  
County, Idaho

The Blackstone property is located on the southern side of St. Charles Canyon, in the SE 1/2 sec. 17, T. 15 S., R. 47 E., 0.2 mile west of St. Charles campground. It is a lead mine which was operated during the 1890's and was one of the largest in the Bear River Range.

The workings consist of an extensive mine (Figure 3) and numerous prospect pits scattered around the area. Mansfield (1927, p. 343, Figure 37) published a plan view of this mine. The mine is located in medium-gray limestone of the Blacksmith Formation, 289 feet below the Hodges Shale Member of the overlying Bloomington Formation. The strata strike N. 20° W. and dip 16° SW. in the vicinity of the mine. The strata in the mine are broken by faults and fractures trending N. 60° to 80° W. and N. 65° to 85° E. and dipping vertically or steeply to the east.

Mineralization was limited to a thin-bedded dolomitized limestone unit which is 12 feet thick. Mineralization was strongest near west-north-westerly trending faults and joints. Minerals identified include dolomite, ankerite, calcite, galena, sphalerite, fluorite, barite, quartz, and pyrite. Richards (1910, p. 182) reported the presence of

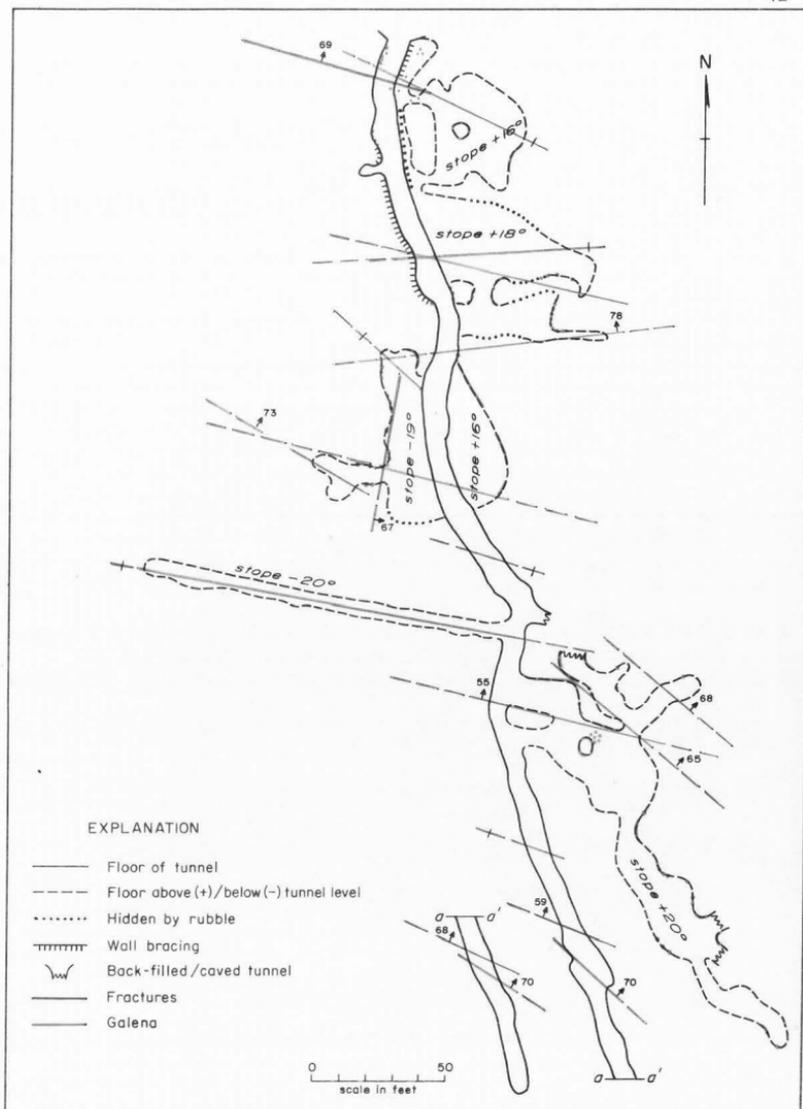


Figure 3. Blackstone mine.

wulfenite in neighboring prospects and stated also that the galena is nonargentiferous. Mineralization started after fracturing of the host rock and introduction of magnesium- and iron-rich solutions, which resulted in recrystallization and dolomitization of the rock and deposited scattered crystals of pyrite in the rock. Next, a banded vein of dolomite and ankerite was deposited in the fractures. This was followed by calcite, then galena. A period of fracturing occurred after the galena deposition. Fracturing was followed by the deposition of barite, fluorite, and sphalerite. This is demonstrated by pods of those minerals connected by filled fractures cutting dolomite, calcite, and galena.

The last apparent stage of fracturing was followed by minor quartz and barite deposition. Samples of the mineralized beds and surrounding beds were taken approximately one mile away where no mineralization effects were observed. These samples were analyzed with an optical spectroscope to determine if local beds could have been a source of the metals in the deposit. The results indicated that they probably were not the source.

#### Smithfield Canyon, Cache County, Utah

On the northern side of Smithfield Canyon east of Smithfield, Utah, in the NE 1/4 sec. 17, T. 13 N., R. 2 E., 467 feet above the contact with the Brigham Formation, two prospect pits are located in the dolomite of the upper Langston Formation. The total thickness of the Langston Formation at High Creek, a few miles to the north, is 484 feet (Maxey, 1958, p. 671). The strata strike N. 37° E. and dip

45° SW. in the area. No major faults can be observed in the immediate area; however, minor calcite-and iron oxide-filled fractures are exposed in the prospect pits. The fractures trend from N. 40° to 60° W. and dip vertically to 70° SW. Pods of iron oxide, along fractures in the rock, locally contain malachite indicating that the primary mineral may have been copper bearing or had been partially replaced by secondary copper minerals. Chalcocite is present as pods in the country rock, and it is altering to malachite.

#### Swan Creek, Rich County, Utah

In NW 1/4 sec. 6, T. 14 N., R. 5 E., west of Lakota, Utah, two old copper mines and several prospect pits are located on the eastern side of the hollow which trends northward from the Swan Creek spring. The location is 0.3 miles from Swan Creek spring. The lower mine is completely caved and the upper mine is partially caved. The mines are located at the contact between the Blacksmith Formation and the Bloomington Formation and extend into the Blacksmith Formation. The upper tunnel is located in a highly brecciated zone, which is cut by many fractures with diverse attitudes, generally northwesterly, with dips to the west. The host rock is a medium-crystalline dark-gray dolomite.

Minerals observed include barite, dolomite, quartz, chalcocite, pyrite, malachite, azurite, and iron oxide. Barite is the predominant mineral. Following a period of fracturing and recrystallation of the wall rocks, dolomite was deposited in open fractures. Dolomitization probably occurred during this period. Quartz replaced scattered fine-grain rock fragments and was deposited in open fractures in the host

rock and dolomite veins. Recrystallized coarse-crystalline dolostone and vein dolomite were not affected by quartz deposition. Euhedral pyrite grains were deposited simultaneously with the quartz. Identification of pyrite is based on the presence of isometric crystal forms in iron oxide masses. Coarse-grained barite was deposited along fractures in the quartz and dolomite. Later, supergene solutions deposited chalcocite, which is currently being replaced by malachite and azurite. Olsen (1958, p. 18) observed covellite replacing pyrite, which was not observed by the author.

#### Worm Creek, Bear Lake County, Idaho

In Worm Creek canyon, northeast of St. Charles, Idaho, three tunnels have been excavated on the north side of the canyon approximately 1 mile west of the Cache National Forest boundary. The site is marked on U. S. Geological Survey topographic maps as the Clark mine; however, current claims are titled the Sunset claims.

The three workings are located in the Blacksmith Formation; just below the contact with the overlying Bloomington Formation, 410 feet below the Bloomington Formation and just above the basal contact with the Ute Formation. In these locations the Blacksmith Formation is a fine-to medium crystalline medium-gray limestone which strikes N. 45° W. and dips 15° W. The upper and lower workings have been closed and are inaccessible. The central tunnel is open and in good condition. Examination of the central tunnel and the dumps of the other workings indicate similar mineralization. Numerous prospect pits, scattered throughout the Blacksmith Formation, also reveal similar mineralization.

Minerals deposited in the area include dolomite, ankerite, calcite, galena, pyrite, quartz, and possibly barite. The mineralization started after the fracturing and dolomitization of the wall rock near fractures. Dolomite and ankerite, followed by calcite, and later galena were deposited in a banded vein. Fractures, cutting calcite and dolomite veins, contain fine-grained quartz. Quartz was also deposited on pods of galena. Fine-grained barite was possibly deposited with the quartz, but positive identification could not be made because of the grain size. X-ray identification was not possible because of equipment breakdown. The presence of barite is supported by its confirmed presence in St. Charles Canyon a short distance away in a related deposit.

## MINERALIZATION

Mineralogy

Primary minerals identifiable in the Bear River Range deposits include chalcopyrite, galena, sphalerite, marcasite, pyrite, quartz, dolomite, ankerite, siderite, calcite, barite, fluorite, opal, specular hematite, wad, psilomelane, and pyrolusite. Secondary minerals include chalcocite, smithsonite, malachite, azurite, cerussite, jarosite, hematite, and limonite. Galena and chalcopyrite are found in the same deposit in only two areas, Amazon Hollow and Blacksmith Fork Canyon. In each case, the amount of chalcopyrite is minor. Chalcopyrite characteristically occurs in deposits with substantial quartz, as occurs in the Nounan, and Paris Canyon deposits. Pyrite, dolomite, and ankerite are characteristic gangue minerals in all of the deposits except Cleveland, Birch Creek, Smithfield Canyon, Hyrum Canyon, and the Hyrum iron and zinc deposit. Calcite and barite are present or evidenced to have been present in fifty percent or more of the deposits. Figure 4 shows the distribution of the minerals.

Wall-rock alteration is characteristically minor in all of the deposits. It is limited to silicification, iron and magnesium introduction and minor recrystallization near mineralization. The magnesium and iron introduction was limited to the immediate vicinity of the mineral deposits. No evidence of extensive epigenetic dolomitization of wall rock far from the deposits was observed.

MINERALS		chalcopyrite	galena	sphalerite	tetrahedrite	marcasite	hematite	magnetite	chalcocite	pyrite	wad	psilomelane	pyrolusite	smithsonite	dolomite	ankerite	calcite	siderite	barite	fluorite	quartz	opal
	Amazon Hollow	X	X	X				X		X					X	X	X	X	X			
	Birch Creek	X								X											X	
	Blacksmith Fork Canyon	X	X		X					X					X	X	X	X	X		X	
	City Creek Canyon		X	X						X					X	X	X	X	X		X	
	Cleveland									X		X			X	X	X	X			X	
	Copenhagen Canyon		X				X			X					X	X	X	X		X		X
	Deadman Gulch						X								X	X	X	X				
	Dry Canyon		X							X					X	X	X	X			X	
	Hodges Canyon								X						X	X	X	X				
	Hyrum Canyon		X	X		X									X	X	X	X				
	Hyrum Front		X	X										X								
	La Plata Canyon		X							X					X	X	X	X		X	X	
	Maple Creek		X							X					X	X	X	X		X	X	
	Mineral Point		X					X		X					X	X	X	X		X	X	
	Nounan		X							X					X	X	X	X		X	X	
	Paris Canyon		X		X					X					X	X	X	X		X	X	
	St. Charles Canyon		X	X						X					X	X	X	X		X	X	
	Smithfield Canyon								X						X	X	X	X		X	X	
	Swan Creek								X	X					X	X	X	X		X	X	
	Worm Creek		X							X					X	X	X	X		X	X	

Figure 4. Distribution of minerals by deposit.

Comparison of the paragenetic sequence in the deposits reveals the following general paragenesis: (1) Fe-Mg carbonate and/or quartz, (2) calcite and (3) sulfides. Two periods of fracturing are associated with the mineralization. The first period occurred prior to the first period of mineralization. The second period of fracturing occurred before or during calcite deposition. The regional distribution of minerals was examined, and no regional zoning could be observed in the area.

#### Stratigraphic Controls

Comparison of the stratigraphic location of the mineral deposits reveals that 18 of the 21 mineralized locations are in lower Cambrian strata, 2 are in the Mississippian Great Blue Formation and 1 is a Quaternary hot springs deposit. Of the 18 deposits in the lower Cambrian strata, 16 are in the Langston and Blacksmith formations; the other two deposits are in the Ute Formation. As noted in the description of local stratigraphy, the Langston and Blacksmith formations are predominantly limestone and dolomite. They are overlain by, respectively, the Ute and Bloomington formations which have a high shale content near their bases. Further comparison shows that in 13 of the 16 deposits in the Blacksmith and Langston formations, beds within 150 feet of the contacts with the overlying shaly formations were mineralized; the other three are more than 150 feet from the contact. Figure 5 diagrammatically demonstrates this stratigraphic distribution.

Five of the nine deposits located in the Blacksmith Formation show substantial bedding replacement in thin-bedded limestone beds, e.g.

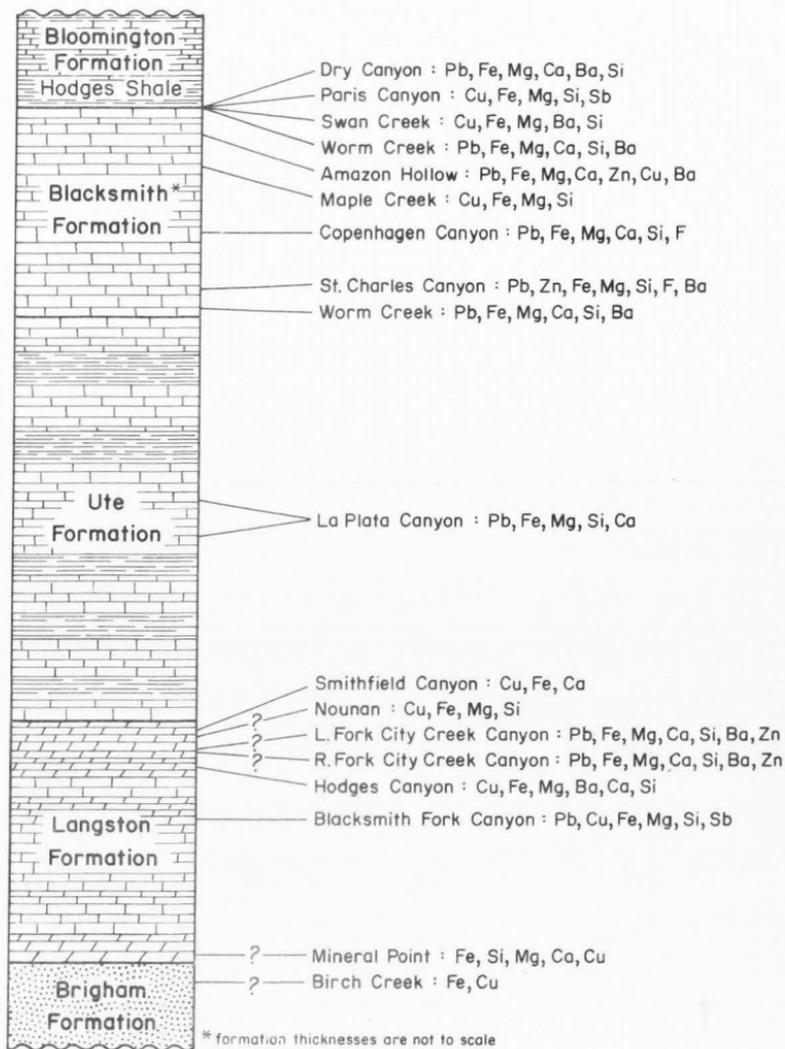


Figure 5. General location of mineral deposits in the Cambrian formations of the Bear River Range.

St. Charles Canyon and Worm Creek deposits. The remaining four do not show substantial bedding replacement. Three of the seven deposits in the Langston Formation show replacement features and these are in thin-bedded units. Therefore, bedding-plane permeability seems to have been important in mineralizing-solution movement.

Insoluble-residue analysis was performed on samples from mineralized and unmineralized beds around one deposit, St. Charles Canyon, Idaho, to determine if differences in the clay content of the beds may have controlled deposition. All beds tested had clay contents in the 13 to 16 percent range. No systematic variations were noted and clay impurity does not appear to have been a factor in mineralization.

#### Structural Controls

Comparison of the orientation of the fractures observed in all of the deposits shows them to be oriented in two sets: N. 30° to 50° W. and N. 10° to 30° E. (Figures 6 and 7). The fractures dip predominantly 55° W. to vertical. The above agrees with the observations of Olsen (1958, p. 4) for the deposits he examined in the Bear River Range, Utah. The orientation of fractures, which are mineralized or appeared to be the sources of mineralizing solutions, is similar to the orientation of all fractures. This indicates that all of the fractures were formed prior to mineralization. Several explanations of the origin of these fractures is possible: (1) they are extension fractures formed along Laramide folds, (2) they are extension fractures resulting from forces associated with Basin and Range faulting, or (3) they are

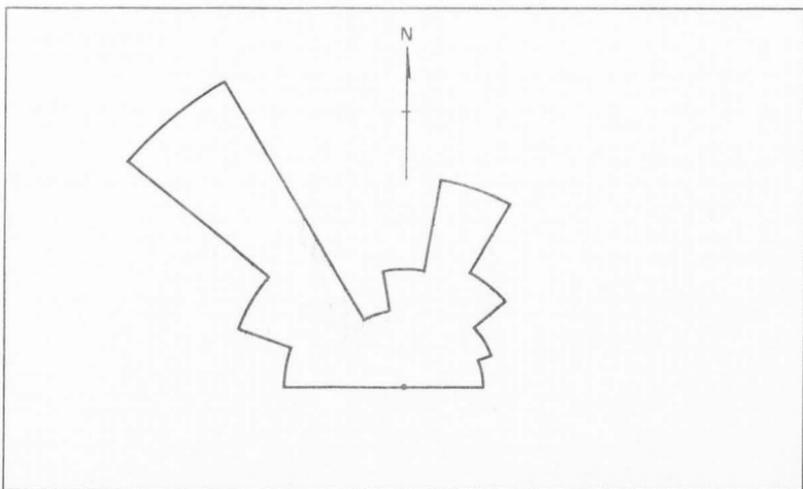


Figure 6. Orientation of fractures in the Bear River Range.

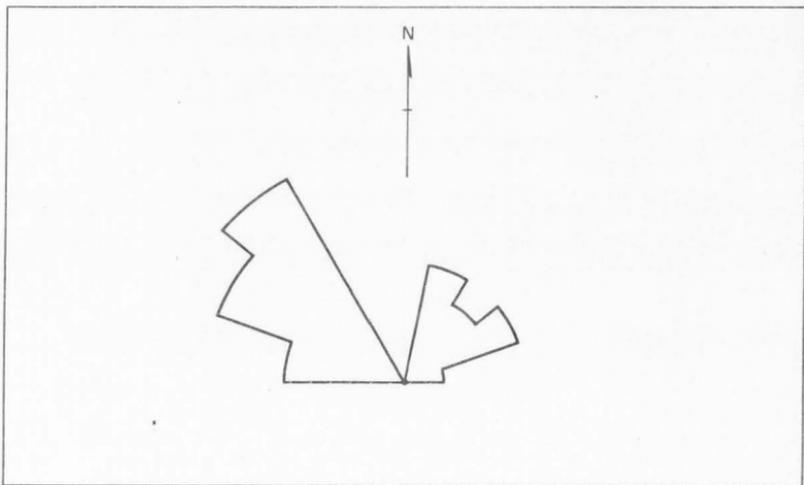


Figure 7. Orientation of mineralized fractures in the Bear River Range.

a reflection of Precambrian structures. No evidence was observed which proves or disproves any of these theories.

Many of the deposits are located in the vicinity of the generally north-striking Basin and Range faults in the area, for example, the Nounan, Blacksmith Fork, and Copenhagen Canyon deposits. In the Nounan, Idaho, deposits, intensification of the mineralization increases as the fault is approached, indicating that here the fault was the source of mineralizing solutions. Similar situations can be observed in the Mineral Point deposits except that the controlling fault is Laramide in origin (Hafen, 1961, p. 47). A consistent pattern of periods of fracturing followed by periods of deposition often with changes in the character of mineralization indicates that the period of deposition is closely related to active faulting over an extended time interval.

#### Depositional Conditions

The mineralogy of the deposits is nondiagnostic but suggests a low to moderate temperature. The majority of the primary minerals in these deposits has been found to be deposited in a wide range of temperature conditions. Some, such as chalcopyrite and quartz, are ubiquitous in hydrothermal mineral deposits. Of the primary minerals found in these deposits only opal and marcasite indicate low temperatures (Krauskopf, 1967, p. 498).

Wall-rock alteration associated with these deposits includes weak recrystallization, silification, pyritization, and dolomitization.

The presence of these types of alteration is not diagnostic; however, the weakness of the alteration and absence of alteration associated with higher temperature deposits indicate low temperatures.

#### Source of Mineralizing Solutions

No clear-cut source of the mineralizing solutions is evident. There are no known igneous bodies located in the area to provide a source; however, there may be an igneous body at depth. Other possible sources include meteoric waters and regional metamorphism.

Mansfield (1927, p. 344) proposed that the deposits on the east side of the range in Idaho were due to the leaching by circulating ground water of the metals disseminated in the surrounding sedimentary rock and redeposition in favorable locations. An alternative source proposed by Mansfield for the copper deposits is an unknown igneous body at depth. The first alternative appears to be based on the concentration of the deposits near the top of the Langston and Blacksmith Formations indicating that they may be the source beds; however, the localization of the deposits appears to be due to damming of mineralizing solutions by the shale in the overlying formations. This resulted in the spread of solutions along fractures and bedding planes and depositions in the upper part of these formations. As noted by Olsen (1958, p. 6-7), it would be expected that if the metals came from the surrounding rock formations, the resulting deposits should be similar in mineralogy and they are not. For example, deposits of galena with predominantly carbonate gangue, chalcocopyrite with predominantly quartz gangue, and specular hematite with quartz are all found in the Langston

Formation. To test Mansfield's source-bed theory, samples were taken from ten beds in the upper Blacksmith Formation near St. Charles Canyon. The sampled beds included the one which was mineralized at the Blackstone mine and beds above and below it. Spectrographic analysis of the samples shows a uniform absence of lead and zinc from all beds except one, which showed traces of zinc, perhaps anomalously so. This indicates that the surrounding beds were probably not the source of the ions deposited at the Blackstone mine unless they were leached clean of their metal content. No evidence of leaching was observed.

Deeply circulating meteoric water along faults is a possible source of mineralizing solutions. Such waters would be heated at depth and could leach metals from the surrounding rock. These solutions would theoretically form mineral deposits as the solutions cooled during upward migration or on encountering environments which alter the chemistry of the solution. This may well be the origin of the Cleveland manganese deposit. No evidence to support or refute this theory was observed.

Mansfield's alternative source of an unknown igneous mass below the area cannot be easily proven or refuted. No evidence is known for any major igneous bodies in the Bear River Range area. Limited geophysical surveys of the Gem Valley, Idaho (Mabey and Armstrong, 1962), Soda Springs, Idaho (Mabey and Oriel, 1970), and Cache Valley, Utah (Peterson and Oriel, 1970; Stanley, 1971), areas reveal no large igneous bodies. The only known intrusive igneous rock, in the area, is the diabase, east of Preston, Idaho (Willard, 1972). No evidence of

extensive hydrothermal activity was noted by Willard near these intrusives. Willard (1972, p. 49) dates the intrusives as late Pliocene. To the east, in the Bear Lake Plateau, Richardson (1941, p. 18) dated a basalt flow as late Tertiary or early Quaternary. None of these igneous rocks seems a likely source for mineralization in the local area. The Keetley-Kamas volcanic area is located to the south. The igneous rocks at Kamas are predominantly andesite with a later diorite intrusive (O'Toole, 1951, p. 10). Several acidic stocks, with associated mineral deposits, are located to the west of the volcanics. Crittenden, Stuckless, Kistler, and Stern (1973, p. 178) stated that intrusion of the stocks began in the late Eocene-early Oligocene (37 to 41 million years ago) with the volcanic activity continuing to 32 to 34 million years ago. The distance to this igneous activity, 90 miles, and the presence of peripheral low-temperature lead deposits indicate that this is not the source of the mineralizing solutions; however, the presence of unobserved igneous intrusive bodies related to Tertiary igneous activity in the region is a possible source of mineralizing solutions.

Goodspeed (1952), Ermolaev (1970), Helgeson (1967), and others have proposed that regional metamorphism is a possible source for hydrothermal solutions and have provided experimental evidence supporting the theory. Goodspeed (1952, p. 146-168) pointed out that sufficient water is available in average sedimentary rocks as water of hydration and connate water to provide adequate hydrothermal solutions to transport the metals found in the Mississippi Valley-type deposits.

Belevtsev (1970, p. 31) stated that pore waters could be released at temperatures as low as 100°C and that bound waters, or waters of hydration, would be released gradually with increasing temperatures up to 600-800°C with a water loss of up to 4-5 percent. Helgeson (1967, p. 333-342) demonstrated that metamorphism of an arkosic sediment, containing interstitial sea water, can concentrate trace elements sufficiently to produce the Mississippi Valley-type lead-zinc deposits. Ermolaev (1970, p. 38) showed in a study of the distribution of uranium, in an area of progressive metamorphism, that rocks lose uranium with increasing temperature and pressure. This demonstrates that for at least one metal, metamorphism does provide a mean of mobilization and removal.

Reynolds (1947), among others, discussed the "basic front" associated with metamorphism. The basic front concept was based on field observations that the iron and magnesium content of rocks increases outward from the center of metamorphic zones. The concept is that iron and magnesium migrate either by solid diffusion or through pore liquids down the temperature or chemical gradient and form enriched Fe-Mg minerals away from the metamorphic center. Tectonic activity could provide fractures which would allow the upward migrating solutions to enter environments favorable for deposition. The widespread presence of Fe-Mg minerals in these deposits would support a metamorphic-origin theory.

The association of the mineralization with Tertiary faulting indicates a possible heat source for deep metamorphic activity. The Tertiary faults are a manifestation of deep-seated crustal disturbance

and are associated with igneous activity to the south of the Bear River Range. The igneous activity suggests that sufficient heat could have been available to metamorphose the lower Precambrian rocks such as the Farmington Canyon complex, or deeper rocks, either regionally or locally. Condie (1966) stated that the Precambrian and Paleozoic rocks of eastern Nevada and northwest Utah were subjected to post-Paleozoic metamorphism. The widespread presence of iron and magnesium minerals in veins cutting the rocks suggests that rocks subject to metamorphic activity were possibly the source of the mineralizing solutions.

In the Sierra Madre mining district in the Wasatch Range ten miles northeast of Ogden are several deposits similar to those of the Bear River Range. Loughlin (Butler, Loughlin, Heikes and others, 1920, p. 225-226) concluded that only iron, lead, zinc, and copper were necessarily brought into the area by mineralizing solutions from a remote source. He proposed that the dolomite, calcite, and quartz may be regarded as of essentially local origin. This does not seem to be the case in the Bear River Range. In several deposits described, the carbonate minerals show sharp changes from dolomite to ankerite, or to calcite. These changes represent rapid fluctuations in the relative amounts of calcium, magnesium and iron in the solutions. The simplest explanation for these fluctuations is a change in the chemistry of the solution entering the area of deposition.

In summary, no unequivocal evidence indicating an origin for the mineralizing solutions is available. Existing evidence supports a metamorphic origin for all of the mineralizing solutions except for those which formed the Cleveland manganese deposit which may have been deposited by deeply circulating ground water.

## CONCLUSIONS

The mineral deposits of the Bear River Range are classified as low-temperature, epigenetic deposits. This classification is based on their relationship to the host rock units, mineralogy, and wall-rock alteration.

The association of the deposits with Tertiary and Quaternary faults obviously places a maximum age limit on the time of mineralization but no minimum limit. The faults cut the Wasatch Formation (Galloway, 1970, p. 85), which is presumed to be early Eocene age. Therefore, mineralization could have occurred from Eocene to the present time.

None of the deposits appear, at this time, to be of economic significance because of low grade and low tonnages. Even those deposits from which ore shipments have been made in the past, have been forced to quit operations because of economic or geologic considerations. The possibility of future operations or reopening of old mines does not seem even remotely good at the present time.

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