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# COBALT-COPPER DEPOSITS OF THE BLACKBIRD DISTRICT LEMHI COUNTY, IDAHO

by

J. S. Vhay

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Strategic Minerals Investigations Preliminary Report ~~PRESS RELEASE~~
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# DEPARTMENT OF THE INTERIOR

## INFORMATION SERVICE

Geological Survey

For Release APRIL 28, 1948.

REPORT RELEASED ON BLACKBIRD COBALT-COPPER DEPOSITS IN IDAHO

Director W. E. Wrather of the Geological Survey announced today that a preliminary report on the cobalt-copper deposits of the Blackbird district, Lemhi County, Idaho, has been released for limited distribution.

The presence of cobalt in this region has been known since about 1901. Some cobalt ore was produced during World War I, but the potential importance of the district has only recently been demonstrated by comprehensive investigations of the Geological Survey and Bureau of Mines started in 1942, and by exploration by private interests that started in 1943. The cobalt deposits of the Blackbird district now appear to be among the more important of the country.

Cobaltite and the copper mineral chalcopyrite, the principal ore minerals are associated with pyrite and pyrrhotite. The ore deposits occur in shear zones, and their shape is dependent to a considerable extent on folds and shear zones in the country rock.

The report, consisting of a mimeographed text and three large-scale maps, describes in some detail the geology of the area and the mineral deposits. A limited number of copies of the report are available as Strategic Minerals Investigations Preliminary Report 3-219, titled "Cobalt-copper deposits of the Blackbird district, Lemhi County, Idaho", from the Director, U. S. Geological Survey, Washington 25, D. C., or from the Geological Survey office at 707 Peyton Building, Spokane, Washington.

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Plates in Library flat drawers 48-0001 - 4/18.25

P.N. 36882

Addendum to Blackbird open file (3-219)

Indicated on plate 1 are a few corrections:

The long dashed blue line indicates the approximate location of a major fault in the area, southwest of which is the "West Fork" structural block, which was not recognized when the report was written (although its typical structure is mentioned in the last two sentences on page 11). The rock type in this block is generally a very fine-grained, thinly laminated, slaty or phyllitic rock, with cleavage dipping moderately (35°-60°) eastward (upper part of West Fork, and the few observations along Musgrove Creek, plate 1). It is a weak rock structurally, which probably accounts for the insignificant copper deposits on French Gulch (plate 3A) and similar deposits on Ostrander Creek and the gulch west of Indian Gulch (on Blackbird Mountain quadrangle).

The boundary between the Blackbird and Haynes Stellite blocks north of Blackbird Creek and in Little Deer Creek is probably in error, but it is relocated at only one place in blue on plate 1 (just below the Long Dike trenches).

Below are indicated some errors in the text of 3-219; errors resulting from the facts that, a) the differing structure and lithology of the West Fork block (discussed above) were not recognized sufficiently, b) the "porphyroblastic gneiss" at the north end of plate 1 was misidentified as igneous rock ("granitic rock" of the Idaho batholith on the legend of plate 1), whereas now it is believed fairly certainly that it is merely a strongly recrystallized part of the Belt sedimentary section that was of such composition that it could recrystallize to a gneiss during the metamorphism which formed either quartzite or quartz-biotite schist out of other Belt rocks. Quartz monzonite of the Idaho batholith is present in the extreme western part of the quadrangle. The intrusive contact comes into the quadrangle about where Yellowjacket Creek crosses the west edge of the quadrangle, crosses the road northwest of Quartzite Mountain about 0.8 mile from the west edge, crosses Big Deer Creek about 2.2 miles from that edge, approaches Clear Creek about a mile from that edge, and then apparently turns almost due west and leaves the quadrangle just north of Clear Creek.

The suggested changes in the report are listed below:

Page 1, paragraph 1, delete "a part of the Cretaceous Idaho batholith cuts across the northern part of the district, and" . . .

Page 2, paragraph 1 under geology, after ". . . granitic rocks of the Idaho batholith" add "along the west edge of the Blackbird Mountain quadrangle."

Page 3, paragraph 2, change "granite" to "gneiss."

Page 3, paragraph 3, delete "Granite of the Idaho batholith . . . (to) . . . district; other" . . .; make "igneous" "Igneous."

Page 3, paragraph 4, delete "granite" (first line); delete the whole sentence "In the southeast part . . . sandstones"; delete ", which probably was related to the intrusion of the Idaho batholith,"; after ". . . quartz-biotite schist" add "; higher grade metamorphic rocks, containing either garnet or chloritoid or both minerals, are present in the north part of the Blackbird and Lookout blocks. To the west, bordering the quartz monzonite in a zone in places over 3 miles wide, the rocks are granulite and hornfels containing cordierite and epidote." Delete the whole sentence "Near the granite . . . one another." (Unfortunately, in condensing the descriptions of the rock types, the quartz monzonite was combined with the porphyroblastic gneiss; also combined were the descriptions of the contact metamorphic rocks, containing cordierite and/or epidote with the regionally metamorphosed garnet-chloritoid rocks.)

Page 4, paragraph 2, delete sentence "This change probably . . . the granite."

Page 4, paragraph 3, change the sentence "The block is about 2 miles . . (. . south edge of pl. 1)" to read "The block is about 2 miles wide and extends south from the gneiss about 5.6 miles, pinching out about at the West Fork of Blackbird Creek." Delete "or cordierite."

Page 5, paragraph 1, delete "calcareous" (used twice). The sentences "In the western . . . (down to) . . . muscovite schists" actually are describing some of the rocks in the West Fork block which I discussed above.

Page 5, paragraph 2, delete "; minor amounts of cordierite may be present." Change "granite" to "gneiss."

Page 6, Lookout structural block. The granulite containing cordierite, epidote present also, (was seen around Blackbird Mountain) lies in the contact metamorphosed area, that continues westward towards the quartz monzonite.

Page 6, first paragraph under "Igneous rocks." This whole mishmash might as well be deleted! (See my remarks in parenthesis at end of discussion under page 3, paragraph 4.)

Page 8, paragraph 3, change ". . . between granite and country rock" to ". . . between gneiss and garnetiferous quartzite."

Page 11, bottom paragraph, change "granite" to "gneiss."

Page 16, paragraph 2, change "granite" to "gneiss."

Page 17, bottom paragraph, change "cobalt chalcanthite" to "bieberite."

Page 18, paragraph 3, insert "a" before "few islands of cobaltite."

Page 18, paragraph 5. It is suspected that the "bull quartz" is more likely the result of recrystallization of quartzite or possibly metamorphic differentiation.

Page 20, paragraph 1. The vivianite is a late primary hydrothermal mineral, rather than "secondary."

Page 21, paragraph 2, change "Calera" to "7100" and "Chicago" to "7200."

Page 21, paragraph 6, change "injection" to "recrystallization or metamorphic differentiation." In last sentence of this paragraph change "carbonate" to "calcite" and "ludlamite" to "iron phosphates."

Page 24. "Adits on French Gulch." These are in the unfavorable West Fork block type of lithology.

J.S.V.

Fall, 1968

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ILLUSTRATIONS



Folio in library, map filing case.

COBALT-COPPER DEPOSITS OF THE BLACKBIRD DISTRICT

LEMHI COUNTY, IDAHO

by

J. S. VHAY

ABSTRACT

The Blackbird district is in east-central Idaho, about 20 miles west-southwest of Salmon. The area is one of deeply weathered, flat-topped upland surfaces cut by several steep-walled valleys, which are tributary to the canyon of Panther Creek. Most of the area has a heavy vegetative cover, and outcrops are relatively scarce except in the walls of the steeper valleys. The rocks of the district consist mostly of metamorphosed sedimentary rocks of the pre-Cambrian Yellowjacket formation (Belt series); a part of the Cretaceous Idaho batholith cuts across the northern part of the district, and acid porphyry dikes and metamorphosed basic rocks cut the Yellowjacket rocks.

Structurally, the sedimentary rocks are divided by faults into three, roughly north-south blocks. The center one (Blackbird structural block) appears to have been more tightly squeezed than the others into relatively tight folds, with the development of widespread schistosity (flow cleavage). The rocks of the two outside blocks are in more open folds. In general they are nonschistose, except for the north end of the western block, where there are schistose rocks cut by several north-dipping thrust faults. The northern parts of the central and western blocks contain considerable garnet, chloritoid, and cordierite.

The Blackbird structural block is cut by a number of mineralized shear zones. Those dipping moderately northeast and striking northwest, and those dipping steeply and striking north and northeast, appear to be most important. The mineralized rock contains chalcopyrite, cobaltite, pyrite, and pyrrhotite in a gangue of quartz, biotite, tourmaline, ankerite, and muscovite; the deposits were formed mostly by replacement of the shear zones. In addition, the block is cut by north-dipping thrust faults of west to northwest strike, and a number of high-angle faults.

The district was first prospected about 1893; considerable development was done at the Brown Bear mine in 1899-1902, at the Haynes-Stellite in 1917-1920, and at the Uncle Sam mine in 1938-1941. During World War II, the U. S. Bureau of Mines explored in the district with bulldozer and diamond drill, and the U. S. Geological Survey mapped the district and logged the drill cores. The Howe Sound Co. also did some diamond drilling

in the district, and in 1945 the Calera Mining Co., Blackbird Division (subsidiary of Howe Sound Co.), started underground development at the Calera adit. Although the district has had very little production to the present, it is believed that a large tonnage of copper-cobalt ore exists in the district which should permit mining to be continued over a long period.

The report contains brief descriptions of all the accessible workings in the district, of which the most important are Calera, Brown Bear, Uncle Sam, and Hawkeye mines. In the Calera adit, about 1,700 feet of the mineralized zone, ranging in width from 3 feet to 40 feet and averaging about 15 feet, have been explored (August 1946); the zone lies on a wide northwest-striking shear zone dipping moderately ($60^\circ \pm$) northeast. The Brown Bear adit is in a wide, mineralized, north-south shear zone in which are higher-grade pods plunging $25^\circ$ to $35^\circ$ north. The Uncle Sam mine explores a relatively narrow north-south shear zone in which are two or three north-plunging ore shoots. The Hawkeye mine is in a broad zone of mineralized schist in which are several north-plunging lenses of ore.

# INTRODUCTION

The Blackbird district is in Lemhi County, east-central Idaho, about 20 miles west-southwest of Salmon. Discovered about 1893 by prospectors from the nearby placer camp of Leesburg, it was first prospected for gold and copper, and in the period 1899-1902 considerable work was done in the Brown Bear area, but no production is recorded. Cobalt was discovered about 1901; claims in the Haynes-Stellite area and on the West Fork of Blackbird Creek were staked for cobalt, but there was little interest in this metal until the period 1917-1920 when the Haynes-Stellite deposit was explored, and 55 tons of concentrates containing 17.74 percent cobalt was produced from 4,000 tons of ore. From 1938 to 1941 the Uncle Sam mine was worked; U. S. Bureau of Mines Minerals Yearbooks (1939-1940) report a total of 3,657 tons of ore and concentrates shipped, containing 461 ounces of gold, 332 ounces of silver, and 163,485 pounds of copper. The district was investigated by the U. S. Geological Survey at intervals during the period 1942-46 as part of its wartime search for strategic minerals; this report and accompanying maps summarize the results of this study. From 1942 to 1945 the U. S. Bureau of Mines explored the deposits with bulldozer and diamond drill. In 1943 the Howe Sound Co. took an option on a group of claims in the district, and drilled in the Brown Bear area. Both exploration programs indicated large tonnages of ore, and in 1945 the Howe Sound Co. began the Calera adit to explore the Chicago zone.

The district, about 15 miles south of the junction of Panther Creek and the Salmon River, is drained by Blackbird, Little Deer, and Big Deer Creeks, tributaries of Panther Creek. Altitudes range between 4,500 and 9,000 feet. The streams occupy steep-sided canyons cut into an old erosion surface whose altitude ranges between 7,500 and 8,500 feet. The main roads in the district are one along Panther Creek and another along Blackbird and Meadow Creeks. The district can be reached from Challis by a road over Morgan Creek Pass, and from Salmon over Williams Creek Pass, a distance of 44 miles. In severe winters the only practicable route is down the Salmon River and up Panther Creek, a distance of about 81 miles from Salmon. The nearest railheads are Darley, Mont., 115 miles, and Mackay, Idaho, 106 miles.

Information on the district is found in the following publications:

1. Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho U. S. Geol. Survey Bull. 528, pp. 71-72, 159-165, 1913.

2. Hess, F. L., Cobalt: Mineral Resources U. S., 1917, Pt. 1, pp. 899-901, 1921.

3. Anderson, A. L., A preliminary report on the cobalt deposits in the Blackbird District, Lemhi County, Idaho, Idaho Bur. Mines and Geology Pamph. 61, 1943.

4. Reed, G. C., and Herdlick, J. A., Blackbird cobalt deposits, Lemhi County, Idaho: U. S. Bur. Mines Rept. Inv. 4012, Feb. 1947.

5. Anderson, A. L., Cobalt mineralization in the Blackbird district, Lemhi County, Idaho: Econ. Geology, Vol. 42, pp. 22-46, 1947.

## GEOLOGY

The rocks of the Blackbird district are metamorphosed sedimentary rocks of the Yellowjacket formation of Belt age (pre-Cambrian) which have been intruded by granitic rocks of the Idaho batholith. The Yellowjacket rocks cannot be readily separated into stratigraphic units but can be broadly grouped into three adjacent north-trending structural units which in this report are designated from east to west respectively as the Haynes-Stellite structural block, the Blackbird structural block, and the Lookout structural block (pl. 1).

Throughout most of the district natural outcrops are poor and widely scattered. On most of the flatter upland surfaces the weathering is very deep and vegetative cover is heavy. Elsewhere talus or vegetative cover obscures the bedrock, except in the deeper canyons and on some of the south-facing slopes, where outcrops are fairly good partly because of the north-plunging structures. Much of the detail shown on plate 2 was mapped in bulldozer trenches along the temporary roads, or projected from the diamond-drill holes.

Most of the ore deposits of the district occur in the central Blackbird structural block. The rocks of this block are predominantly schistose and have been bent into folds, tight in places, most of which plunge 30° to 40° N. The rocks have been cut by faults, by basic dikes, and by numerous shear zones. Three principal directions of shearing have been developed:

(1) North-south shears with steep dips.

(2) Northwest shears with moderate northeast dips.

(3) Northeast shears with steep dips.

The mineralization was controlled mainly by the shear zones, but in part by the north-plunging folds, and has resulted in veins and lenses formed by replacement. The main minerals of the ore zones are chalcopyrite, cobaltite, pyrite, pyrrhotite, quartz, biotite, and siderite.

East of the schistose Blackbird structural block, and separated from it by a fault zone, is the Haynes-Stellite structural block. The rocks in this block are mainly nonschistose, well-bedded quartzites intercalated with some phyllite. The rocks are in relatively open, north-plunging folds and are cut by faults and breccia zones, many of which have been healed by the introduction of silica and fine-grained tourmaline. The mineral deposits of this block consist almost solely of very fine grained cobaltite in the tourmalinized breccia zones.

West of the Blackbird structural block and also separated from it by a fault is the Lookout structural block. As in the Haynes-Stellite structural block the rocks of the Lookout structural block are relatively nonschistose except in the extreme north end of the district. They generally consist of well-bedded quartzites and quartz-biotite granulites, in places spotted with cordierite. The structure is more variable than in the other two structural blocks and some folds have a southerly plunge. At the north end the rocks are somehwat schistose, and are garnetiferous near the granite. The only known ore deposits in the Lookout structural block are at the north end in the schistose or garnetiferous rocks.

Granite of the Idaho batholith occurs at the north end of the Blackbird district; other igneous rocks of the district consist of metamorphosed basic rocks, and unmetamorphosed acid porphyry. The metamorphosed basic rocks include a few gabbro dikes and numerous bodies of mafic rocks which now consist largely of biotite or biotite and feldspar and are too narrow to show on the maps. The acid porphyry dikes which are found in the Lookout structural block and along the fault zone separating the Lookout from the Blackbird structural block, are quartz-feldspar porphyry or relatively fine grained soda granite or quartz monzonite.

## Metamorphosed sedimentary rocks

All the rocks of the area other than the granite, porphyry, gabbro, and basic dikes, were originally sediments of about the same age as the Yellowjacket formation of the Belt series described by C. P. Ross 1/ in the Casto quadrangle to the southwest. Before metamorphism they were well-bedded sandstones, shales and mixtures of the two. In the southeast part of the area (Musgrove Creek) there were also some calcareous sandstones. During metamorphism, which probably was related to the intrusion of the Idaho batholith, the rocks became quartzite, quartz-biotite granulite, biotite schist and phyllite, and intermediate types of micaceous quartzite or quartz-biotite schist. Near the granite body garnet, chloritoid, and cordierite were developed either singly or in association with one another. In most of the area the bedding is still preserved and locally retains such features as mud cracks, ripple marks, and cross bedding, which indicate that the sediments were deposited mostly in shallow water.

1/ Ross, C. P., Geology and Ore Deposits of the Casto Quadrangle: U. S. Geol. Survey Bull. 854, pp. 15-20, 1934.

The Blackbird structural block is differentiated mainly on a pronounced development of flow cleavage that produced schistose rocks containing various proportions of quartz and biotite; even the nearly pure quartzites have been sheared in many places to such an extent that they may be slightly fissile when weathered. The Haynes-Stellite and Lookout structural blocks on the other hand, have mainly nonschistose rocks, though the rocks in the northern part of the Lookout structural block are also somewhat schistose, and the garnetiferous rocks of this block are similar to those at the north end of the Blackbird structural block. However, the rocks of the three structural blocks into which the Yellowjacket formation is divided also may have differed originally in lithology, in that those of the central (Blackbird) block were somewhat thinner-bedded and more argillaceous.

Haynes-Stellite structural block.--Most of the rocks of the Haynes-Stellite block are well-bedded quartzites and biotitic quartzites that are interbedded with thin layers of phyllite in which the small biotite crystals seem to lie parallel to the bedding. Variable but generally small amounts of alkali feldspars are present. Ripple marks and cross bedding are observable at a few places. The rocks are cut into angular blocks by numerous joints. Some schist is developed in local sharp folds at a few places in the southern part of the structural block. At the north end in the valley of Little Deer Creek, the quartzite becomes more glassy and is bleached to a lighter color in spots and bands; under the microscope it is seen to contain more muscovite than usual, some cordierite, and a little garnet. This change probably is due to the nearness of the granite. West of Little Deer Creek there is considerable slightly fissile (weakly schistose) quartzite which might be confused with some of the quartzite in the Blackbird block; distinction in this place, however, was made on the presence of garnet in the rocks of the Blackbird structural block and its absence in the fissile quartzite of the Haynes-Stellite structural block. The rocks of the Haynes-Stellite structural block in general are more quartzitic and somewhat thicker-bedded than those of the Blackbird structural block. They are nonschistose except for the phyllites in which the mica lies parallel to the bedding.

Blackbird structural block.--The Blackbird structural block is the most important from the standpoint of economic geology, as almost all the mineral deposits occur within it. It is characterized principally by the presence of schistose rocks; even the quartzites, except for the purest, are foliated and somewhat fissile. In most places where the rocks do not show schistosity in the outcrop, the microscope will show that the micas are fairly well oriented at an angle to the bedding. The block is about 2 miles wide and extends south from the granite of the Idaho batholith at least $7\frac{1}{2}$ miles (to the south edge of pl. 1). On plate 1, the Blackbird structural block is divided into two parts, the northern part characterized by the presence of garnet, chloritoid, hornblende, or cordierite, or associations of several of these minerals, and the southern part by the presence of different proportions of quartz and biotite with small amounts of alkali feldspar, and locally considerable muscovite.

The rocks of the southern part of the Blackbird block as exposed on the West Fork of Blackbird Creek are predominantly thin-bedded and consist of quartz-biotite schists and micaceous quartzites. Bedding is visible almost everywhere except where the rocks were so tightly contorted that it was destroyed. In the western (upper) part of the creek, the rocks usually are light-colored and contain considerable muscovite. Farther southwest, along Musgrove Creek and in French Gulch, there are also calcareous quartzites and calcareous muscovite schists. Along Blackbird Creek in the central part of the block, along Meadow Creek, and in the upper parts of Little Deer Creek, the rock is also for the most part thin-bedded, but there is more variation in the rock types, which range from nearly pure quartzite to nearly pure biotite schist. Bedding is usually well preserved, but in a few places, as on the west side of Hawkeye Gulch (pl. 2), it has been destroyed in the more schistose layers. Locally on the crests of tight folds, the rock is a quartz-biotite schist with blobs of the more quartzitic layers scattered through it as though they were pinched off in the folding. Peculiar rock types, apparently the result of contact metamorphism, occur in a few places next to basic dikes or gabbro. Along the gabbro contact above the Uncle Sam mine, the sedimentary rocks have been locally feldspathized and resemble granite. Next to some of the basic dikes, considerable hornblende was formed in the biotite schist and was then itself altered to a white mixture of quartz and clay. Where the bedding is tightly folded, as in the area between the Uncle Sam mine and Hawkeye Gulch, the rocks are all strongly schistose, but on the limbs of the broader folds, as between the Calera and Chicago adits, the outcrops do not usually show much schistosity, except where cut by zones of slip-shear cleavage. The diamond drill cores and exposures in the Calera adit show the presence, at least in this area, of some beds of very thinly laminated rock resembling siltstone, which consists mostly of muscovite, with some quartz and biotite. If further work shows that the siltstone is a definite stratigraphic horizon in the section, structural interpretations will be helped considerably, as to date no recognizable key beds have been found in the area.

The metamorphic rocks in the northern part of the Blackbird block, as well as those at the north end of the Lookout block, are characterized by the presence of garnet or chloritoid. The common rocks are garnet-quartz-biotite schist or chloritoid-quartz-biotite schist; the garnet and chloritoid may both be present in some places. Much of the biotite has been replaced by chlorite; minor amounts of cordierite may be present. Locally there is a hornblende-quartz-biotite schist. Some muscovite is usually present. Bedding, usually destroyed in the garnet-chloritoid-biotite schists, is observable only in the more quartzitic layers. In the purer quartzite layers, there may be no metamorphic minerals, though in places bands of garnet mark the bedding planes in slightly impure quartzite. An almost massive quartzite with small garnets evenly distributed throughout occurs locally, especially close to the granite contact. The contact between the garnet-chloritoid rocks and the quartz-biotite rocks to the south is gradational in places, the garnets becoming smaller and smaller. In many places, however, and especially on the northeast side of Meadow Creek, the contact is probably a thrust fault, although on the maps it is shown as a gradational contact. The actual contact was seen at only one place, a small adit about 390 feet

ESE. of Cobalt triangulation station, where the garnetiferous rock overlies the quartz-biotite rock on a fault dipping about 50° N. (see pl. 3A). In the north end of the Lookout block the garnetiferous rocks are apparently thrust out over the nongarnetiferous rocks.

Lookout structural block.--The Lookout structural block consists of both schistose and nonschistose rock types but is mainly well-bedded, nonschistose quartzite and quartz-biotite granulite with various proportions of quartz and biotite. White spots of cordierite are widespread in most types of rock. In the Big Deer Creek area, much of the rock is a bedded schist wrinkled by a late cleavage which dips northeast. On the ridge west of the Sunshine prospect there is an area where the rocks contain small garnets and another area of wrinkled schist; these rocks may be outliers either of the Blackbird structural block or of the garnetiferous and schistose rocks of the north end of the Lookout structural block.

## Igneous rocks

The igneous rocks in the district include granite, quartz-feldspar porphyry, gabbro, and basic dikes. The predominant igneous rock is the granitic rock of the Idaho batholith (Cretaceous age). This is principally a massive, medium-grained granite, though in places it is coarse-grained and porphyritic. Ross 2/ reports rock of quartz monzonite composition to

2/ Ross, C. P., op. cit., pp. 35-37.

the southwest, and some of the rock in the Blackbird area may be similar. Locally, near the contacts, the granite has linear and planar structures, but for the most part it is massive. Along the contact there is some feldspathization of the country rock, which produces a fine-grained rock closely resembling the granite.

The quartz-feldspar porphyry is a fine-grained, granular, light-colored dike rock with phenocrysts of quartz, alkali feldspar, and biotite, averaging about a millimeter in size but as large as a centimeter in places. As seen under the microscope the phenocrysts commonly are rounded quartz, with orthoclase, oligoclase, and biotite, in order of decreasing abundance. Some of the biotite is altered to clay and sericite. The groundmass is usually a granular mixture of quartz and orthoclase, some biotite and very little albite. In some thin sections most of the quartz and orthoclase phenocrysts have wide microgranular reaction borders. The porphyry dikes may be about the same age as the granite (Cretaceous) or they may be Tertiary; in either case, they were intruded after the country rock had been metamorphosed into schistose rock.

The gabbro and the basic dikes, on the other hand, are pre-metamorphism in age; they may be pre-Cambrian or an early phase of the Cretaceous intrusion. The gabbro is a dark, relatively coarse grained rock, massive in appearance except near its contacts, where it may be somewhat schistose. The gabbro occurs as dikes. The one east of the Uncle Sam mine ranges in thickness from 30 to 60 feet. Under the microscope it is seen to be strongly altered; part of the alteration may have taken place during metamorphism, and part may be due to hydrothermal solutions. The feldpsar has been albitized and largely replaced by zoisite and some biotite. The dark mineral, probably originally a pyroxene, is now principally a mixture of soda amphibole (glaucophane) and brown biotite, in many places reticulated; a little hornblende is present, and some chlorite and carbonates, the latter consisting apparently of both siderite and calcite.

The so-called basic dikes, ranging in thickness from 1 to 10 feet, are not shown on the surface maps. There are several on the hillside between the Uncle Sam mine and Hawkeye Gulch. Others are found along Meadow Creek, especially in the trenches 800 to 1,200 feet east of the Calera tunnel. One or more were cut in almost every diamond-drill hole. The original mineral composition of these rocks is not known other than that the rocks were rather basic. They were completely reconstituted during metamorphism, the feldspars being albitized, and the other minerals altered mostly to biotite. The biotite is usually oriented, though some of the rocks do not have a foliated appearance. Some of them are now essentially biotite schists, whereas others are rather fine-grained, dark, granular rocks. Under the microscope one very definite characteristic is the presence of reddish-brown to dark-brown biotite, as compared with the greenish-brown biotite of the normal country rock and the green hydrothermal biotite of the veins. The highly schistose dikes consist of the reddish-brown biotite with variable but usually small amounts of quartz; many of them have porphyroblasts of carbonate, usually calcite, but in places siderite. Some specimens show considerable chlorite, generally around the carbonate; others have a fair amount of muscovite, usually in large unoriented crystals. The granular basic dikes are of two types, both consisting essentially of alkali feldspar and the reddish-brown biotite. In one type the feldspar occurs for the most part as large blobs consisting of groups of crystals (mostly albite or oligoclase) with considerable biotite scattered throughout; the groundmass consists either of biotite plus some feldspar or almost entirely of biotite; variable amounts of quartz, chlorite and zoisite may be present. The second type contains much more feldspar, usually coarser grained, which is albitized and shot with biotite; some chlorite, quartz, zoisite, and carbonate are usually present.

In a few trenches and drill cores a soft, light-colored dike rock was seen. Under the microscope the rock appears to have been a trachyte but now consists of clay minerals. Such rocks are probably Tertiary in age and related to the Challis volcanics found a few miles south.

## Structure

The most important structural features of the district are believed to be the three main structural blocks. Only the central or Blackbird block appears to have structures that favor the formation of important mineral deposits. The three blocks differ greatly structurally, though there are not much data on the two outside blocks. In the Blackbird structural block, and to a lesser extent the Lookout block, there are numerous tight folds, with overturned limbs locally. The central block has many shear zones also, both broad and narrow; in this block and the north part of the Lookout structural block are several low-angle thrust faults. All three blocks are cut by a number of high-angle faults. Because of the lack of recognizable key beds in the Yellowjacket formation in this area, much of the data on the displacement on faults and on the magnitude of folds are inconclusive.

### Major structural features

The rocks of the three blocks originally may have differed somewhat lithologically, as pointed out above, but later structural and metamorphic changes have increased the differences markedly. In general the two outer blocks, the Lookout and the Haynes-Stellite, have relatively open, more-or-less irregular folds, contain few schistose rocks except for the north end of the Lookout block, and are relatively poor in mineral deposits. The rocks of the Blackbird block, on the other hand, are folded and crumpled and, in places are tightly folded. Nearly everywhere they are schistose, with the schistosity so strongly developed in places that bedding is no longer visible. Not only are all the important mineral deposits restricted to the Blackbird structural block, but most of the shear zones in the block are at least slightly mineralized.

<u>Fault between Lookout and Blackbird structural blocks</u>.--The boundary between the Lookout and the Blackbird structural blocks appears to be a steeply dipping fault zone, along which, in most places, are one or more quartz-feldspar porphyry dikes; the porphyry dikes are usually on the west side of the fault and may be several hundred feet away from the zone. The fault (or faults) are not exposed, except perhaps on the north side of Big Deer Creek. Here there is a broad zone, about 1,000 feet wide, in which are numerous steeply dipping faults, two, and in places three, porphyry dikes, and considerable mineralized rock. Several adits have been driven into the mineralized rock; a map of one of these (adit on Tinkers Pride (?) claim) is shown on plate 3B. North of this the only evidence of faulting is the fairly straight boundary between granite and country rock. From south of Big Deer Creek to Blackbird Creek, the fault was mapped on the basis of the change from garnetiferous schists to the east to non-garnetiferous quartzite or phyllite to the west and on the presence of the porphyry dikes. The fault is mapped as crossing West Fork of Blackbird Creek along a porphyry dike,

which separates fairly massive quartzite on the west from a rock that is cut by a slip-shear cleavage dipping east at a moderate angle. On Musgrove Creek, in the southwest corner of plate 1, a similar change from nonschistose to schistose rock occurs along a fairly wide porphyry dike, but the change does not lie in line with the fault on West Fork. This offset may be due to a change in direction of the fault, or to a west shift on some cross fault in the unmapped area between the two creeks. The west boundary of the Blackbird structural block thus appears to be a relatively straight, high-angle fault zone. The direction of movement is not known, but is probably both downward and southward on the east side.

Fault between Blackbird and Haynes-Stellite structural blocks.--The boundary between the Blackbird and the Haynes-Stellite structural blocks is more variable in character and probably consists of at least two faults. North of Blackbird Creek, and especially in Little Deer Creek valley, there appears to be a low-angle fault dipping westward, but from the south side of Blackbird Creek to the south of West Fork of Blackbird Creek the boundary is apparently a high-angle fault. On the north slope of the West Fork valley there is a fairly abrupt change from the jointed quartzite and phyllite of the Haynes-Stellite block to strongly sheared, crumpled schist. A fault is inferred to separate these two rock types, and from its trend it would seem to be steeply dipping. On the ridge north of Slippery Gulch the change from quartzite to schist appears to lie on a plane dipping eastward at 65° to 75°. Both here and on West Fork the dip of the Haynes-Stellite rocks turns to the northwest near the fault, suggesting that the west side of the fault moved either down or to the south.

Just north of Little Deer Creek, about 2,000 feet east of the Dewey prospect, the fault between the quartzite of the Haynes-Stellite block and the schist of the Blackbird block is exposed. Here it is an irregular fault dipping on the average about 40° NW. with massive quartzite dipping about 65° NE. beneath, and vertically dipping schist containing stringers and pods of sugary quartz above. Along the fault pods of bull quartz show that mineralization occurred at least in part after the faulting. The fault was approximately located north of Little Bob Gulch between garnetiferous schist and quartzite, and on the ridge south of the Dewey prospect between mineralized schist and bedded quartzite. Elsewhere the fault was only doubtfully located, mostly because of the lack of outcrops. North of the ridge north of Little Bob Gulch, the fault was interpreted to be between garnetiferous schist and nongarnetiferous rocks.

Structural features of the Haynes-Stellite structural block.--In the Haynes-Stellite block the strike of the northward-dipping beds ranges from N. 70° W., through west to N. 70° E. The changes of strike probably represent folds, but few definite folds were seen that could be followed any distance. Anticlines on West Fork of Blackbird Creek and on Slippery Gulch just east of the fault separating this block from the Blackbird block, may be in part drag structures along the fault.

Most of the fault zones in the Haynes-Stellite block are characterized by the presence of fault breccia which has been extensively replaced by tourmaline and to which some quartz probably has been added; fine-grained cobaltite has been introduced into parts of these tourmalinized zones to form the cobalt deposits of the Haynes-Stellite block. Some of the faults also contain veins of massive white quartz. Some of the breccia zones, as the one at the mouth of West Fork of Blackbird Creek, are over 200 feet wide and have such irregular boundaries that only an approximate idea of their strike could be obtained. In other places, as on the north side of West Fork canyon from 5,000 to 7,000 feet west of its mouth, the tourmalinized rock is in relatively narrow bands apparently formed along minor faults. Most of the faults in this block have moderate to steep dips, but no definite structural patterns for them were worked out, nor is anything known regarding the amount or kind of displacement that has taken place on them.

Structural features of the Lookout structural block.--The southern half of the Lookout block has not been sufficiently mapped to show the structure. Outcrops are scarce and poor, but they do indicate that the structure is fairly complicated. For some 1,500 feet west along the ridge from the Sunshine prospect the bedding appears to be overturned, and some garnet is present in the rocks near a shear zone. From there to the west edge of the map the few outcrops examined indicate that the beds are in fairly tight, south-plunging folds. Northward, down the South Fork of Big Deer Creek, and north of Big Deer Creek, the beds appear to lie in structures plunging northeast or north. In the area north of Big Deer Creek the rocks are divided by north or northeast-dipping thrusts into several masses in each of which the structure may be different from that in the adjacent ones, though in all of them the plunging structural features seem to dip from 15° to 25° in a direction between N. 15° E. and N. 15° W. West of Indian Creek the contact of the garnet schist with the nongarnetiferous rocks is a thrust fault dipping 26° N. On the ridge east of Indian Creek, the apparent continuation of this fault was observed to dip 60° NE., but this steep dip may not be representative as there seems to be an outlier of the garnet schist on top of the hill at the south end of this ridge (about 2,000 feet south). Too few observations were made in the garnet schist block to work out much structure, but the beds have steep dips in places and are probably rather tightly folded, and are cut by other north-dipping thrust faults.

Structural features of the Blackbird structural block.--Most of the detailed mapping in the district was concentrated on the Blackbird structural block; within the block the greatest amount was done along Meadow Creek and the north side of Blackbird Creek as far east as Hawkeye Gulch; this embraces the area explored by bulldozer trenches and diamond-drill holes and is shown on plate 2. In the western half of this area, the main folds are fairly open, and their axial planes are nearly vertical. East from a north-south line approximately through Cobalt triangulation station, the folds become increasingly tighter and closer together, and the axial planes dip more and more to the west. Hawkeye Gulch probably marks the line of a westward-dipping thrust fault. All the folds have a plunge between 30° and 45° N. In addition to the large folds, the beds in many places are crumpled into minor folds whose amplitude ranges from a few inches to over 10 feet, and which may be relatively open or tight. They are especially common on and near the crests of the anticlines and the troughs of the synclines. These minor folds may be in part due to movements on the slip-shear cleavage (see below).

A main anticlinal crest occurs about 400 feet west of the Brown Bear shaft, and can be traced 4,500 feet S. 12° E. to the north side of Blackbird Creek where the crest is broadened and intensely crumpled. A syncline lies in the first gulch west and there seems to be another highly crumpled anticlinal crest on the south face of the ridge farther west (pl. 1). East of the Brown Bear anticline a complementary syncline is exposed as a crumpled zone extending south from Cobalt triangulation station as far as the gulch going east from the Calera adit; it is also present on the north slope of Blackbird Creek as a broad crumpled zone (approximately 600 feet west of the mouth of Meadow Creek). In the area around and north of the Bohannon adit and as far east as the Uncle Sam mine the fold structure is not clear; numerous crumpled zones and areas of relatively steep dip suggest that one or more folds is present. Just west of the Uncle Sam mine is the crest of an anticline whose axial plane dips about 75° W., and in the area between the Uncle Sam mine and Hawkeye Gulch are at least six tight anticlines whose eastern limbs stand vertically or are overturned to the west and whose axial planes dip westward at successively lower angles from 75° in the westernmost fold to 55° on the fold just west of the Gulch. The crests and troughs of the folds are tightly crumpled and slip-shear cleavage has increased the crumpling. There are a number of north- to northeast-striking, high-angle thrust faults associated with the folding. This faulting is best exposed in the first part of the lower Uncle Sam level (see pl. 3B). omit

For the rest of the district, detailed mapping was insufficient to show the fold structures, but similar close folding is probably present in the valley of Little Deer Creek west of the Dewey prospect, on Slippery Gulch, and probably on the West Fork of Blackbird Creek west of the fault separating the Blackbird from the Haynes-Stellite structural block.

In the southern and central parts of the Blackbird structural block the direction of plunge of the folds (and also of the intersection of cleavage and bedding) is consistently within a few degrees of north, but farther north, mostly in the garnetiferous rocks, there is apparently a downward convergence of plunges so that on the east side the plunges are as much as N. 65° W. and on the west side swing eastward in direction as much as N. 80° E. Closer to the granite, along Big Deer Creek, the plunge is again nearly north. Lack of good outcrops, insufficient mapping, and the fact that bedding is in many places destroyed by the schistosity, combine to make it impossible to give a complete explanation of this structure. Another structural feature which cannot be explained yet is the anomalous, low eastward dips of the axial planes and cleavages on the West Fork of Blackbird Creek west from a point about 3,500 feet west of the bounding fault. Outcrops are poor between the West Fork and the main fork of Blackbird Creek to the north, so it is not known where or how the change in attitude takes place.

The rocks of the Blackbird block are cut by numerous faults and shear zones. Before discussing these it might be wise to point out the distinction that has been made between a fault and a shear zone and why an attempt has been made to separate them on the maps. In general, it may be said that a fault is a plane or relatively narrow zone containing gouge or breccia along which there has been appreciable movement. A shear zone, on the other hand, is a relatively broad zone composed of many closely spaced shear planes which produce a schistosity in the rock without appreciable movement on any single plane, but the cumulative effect of which may have produced considerable differential movement of the bounding blocks. Viewed from a distance therefore, they are essentially the same; in detail the movement on a shear zone is distributed through a thickness of rock thereby made schistose, whereas a fault is essentially a single definite break. A further difference in the Blackbird district is that faults are either unmineralized or are post-mineral in age, whereas most of the shear zones either are the loci of major ore deposition or of at least slight mineralization. It may very well be that if a pre-mineralization fault has been well-mineralized, it would be mapped a shear zone, but it is believed that even if this is so, the distinction between faults and shear zones is useful. It is true that where outcrops are poor, it may be difficult to differentiate the two, especially where a boundary between two rock types may be mapped on the basis of float only. There are also places where one or more faults are present in a shear zone, but where only the shear zone is mapped.

Plate 2 covers most of the area on which mapping was detailed enough to show many of the shear zones and faults. The shear zones represent the major structural control of the known mineral bodies, and almost all of them are at least somewhat mineralized. These shear zones are of three general types:

(1) Those which strike northwest, dip 50° to 75° NE., and are relatively broad.

(2) Those which strike north and dip steeply either east or west; these are, in general, narrower and some are related rather closely to the fold structures.

(3) Those which strike northeast and dip steeply either east or west; only a few of these are known and most seem relatively narrow.

Of the northwest shear zones, the best-known one is the Chicago zone which extends along the east side of Meadow Creek between a point a little east of the Brown Bear shaft and the gulch east of the Calera adit; within it is all the ore so far exposed (November 1946) in the Calera adit (see pl. 2 and 3A). The shear is shown as being over 200 feet wide in places, because some of the drill cores showed sheared rock throughout this width, but it may actually consist of two or more parallel shear zones, with less sheared rock between. Underground structures in the shear zone have dips ranging from less than 40° to over 80°, but the average dip is probably between 60° and 65°. The shear zone (shown on pl. 2) includes some areas of relatively unsheared quartzite and phyllite, but steep dips, local crumpling, and mineralization suggest that there has been shearing throughout the entire width. The northwest shear is cut here and there by northwest-striking, low-angle faults, and in other places by north-south faults, both pre-mineralization and post-mineralization in age. A northwest-striking shear zone, which may be an extension of the Chicago zone, lies farther southeast between the Uncle Sam and the Hawkeye zones. Another northwest-striking shear zone east of the Chicago zone is exposed in two of the trenches roughly 450 feet and 600 feet south of Cobalt triangulation station. This zone has only weak gossan here, but a possible extension visible in a trench 600 feet southeast shows abundant quartz and gossan. Another possible northwest shear zone with a steeper dip may extend from the Ella shaft southeast to the trench about 500 feet northwest of the Bohannon adit; a few scattered occurrences of gossan or sheared rock between these two points suggest the possibility of such a zone.

Shear zones striking north (those within 20° of north are included in this group) are the most numerous in this area. Some of them, especially those around and east of the Uncle Sam mine, are closely related to the folding, and represent thrusts on the steep limbs, and zones of strong slip-shear on the crests of some anticlines. Others, such as the Uncle Sam zone, cut through the folds, and are, in general, wider and more continuous. Three of the larger shear zones with a northerly trend, the Brown Bear, the Uncle Sam, and the Hawkeye zones, have appreciable mineralized rock. The Brown Bear shear zone (see pl. 2 and 3A) is a broad zone, the boundaries of which are imperfectly known, in which the slip-shear cleavage dips between 80° E. and 80° W. The Uncle Sam zone is much narrower, dips steeply either east or west, and in many places has one or more faults along it. The mineralization and shearing of this zone are seen in trenches along the strike as much as 2,100 feet north from the lower adit, and the shearing and mineralized rock of the Anaconda Gold prospect in Little Deer Creek half a mile farther north appear to be a continuation of the Uncle Sam zone. The Hawkeye shear zone, exposed in two adits and in bulldozer trenches, looks like a fairly broad schistose zone in which mineralization is widespread. To the south of the adits, however, no single broad zone is identifiable; instead, there are a number of relatively narrow shear zones distributed across a zone of tight folding between the gabbro dike and Hawkeye Gulch; much of the rock between the shear zones is cut by intense slip-shear cleavage. Other north-south shear zones which have not yet been proved to carry appreciable ore, but which are mineralized to some extent, are the ones respectively 500 feet and 1,000 feet east of the Calera portal. The one at 1,000 feet east, as exposed in a number of trenches, shows considerable gossan both as stringers and as small lenses, and at depth may contain considerable ore.

Only a few northeast-trending shear zones are known. Two of them occur in the trenches approximately 1,000 and 1,200 feet east of the Calera portal; both of these are rather heavily mineralized. Two others are in the headwaters of the north branch of Little Deer Creek, about 1,000 feet and 1,500 feet north of the Anaconda Gold prospect; they are characterized mostly by quartz and gossan, and apparently are northeast-striking shear zones with steep dips.

The most important faults in the area shown on plate 2, aside from those which follow the shear zones, strike between west and northwest, and dip north or northeast at angles between 30° and 55°. Some of these low-angle faults, such as the one in the Brown Bear workings, and the ones near the Chicago adit, are definitely post-mineral in age; others are either post-mineral in age or, if pre-mineral, were impervious to the mineralizing solutions. Among the latter are the two southeast and south of Cobalt triangulation station, the wide one at the north end of the gabbro dike striking north-northwest, and two others approximately 100 feet and 500 feet southwest of there. Other faults of post-mineral age, generally of rather small displacement, can be seen on plates 2, 3A, and 3B, and usually have rather steep dips.

## Minor structural features

A number of minor structural features, although relatively unimportant in themselves, were very useful in deciphering the structural problems in areas of poor outcrops. Tight crumpling (in part drag folding) 1 to 10 feet in amplitude, is common on the crests of anticlines and in the troughs of synclines. Where it occurs on the limbs of folds, it is open and of small amplitude, generally less than 1 foot. In areas of widespread crumpling, it is difficult to locate the axis of a broad fold, but such crumpling is usually an aid in mapping the structure, for the axial planes and plunges of the crumples appear to parallel those of the major folds.

A cleavage, which is here termed "axial-plane cleavage," is also useful for indicating the position of folds. This is a slaty cleavage or schistosity, best developed in mica-rich beds, which approaches parallelism to the axial plane of a fold in a nearly pure mica bed; in the quartzitic beds the "axial-plane cleavage" is a joint inclined to the axial plane at a fairly large angle and intersecting it parallel to the plunge of the fold. In the beds of all intermediate compositions, the angle between the cleavage and the axial plane ranges between 0° and the angle in the quartzitic beds. In its development 3/

3/ Shenon, P. J., and McConnel, R. M., Use of sedimentation features and cleavage in the recognition of overturned strata: Econ. Geology, vol. 35, pp. 430-44, 1940.

in a quartzitic bed between two more micaceous ones, the "axial-plane cleavage" is "S" or a reversed "S" in shape, the tips of the "S" joining the cleavage in the micaceous layers and thus approaching parallelism with the axial plane of the fold. The "S" cleavage is thus useful, where outcrops are scarce, in telling in what part of a fold an outcrop lies, and usually, though not always, in determining whether a bed is overturned or not. A question of nomenclature arises from the fact that the "axial-plane cleavage" in a micaceous bed is undoubtedly flow cleavage (i. e., the micas in the rock are parallel to the cleavage) whereas the "axial-plane cleavage" in the impure quartzite would probably be called fracture cleavage (i. e., as Leith says, "Fracture cleavage is a capacity to part along closely spaced parallel surfaces of fractures.... (which) are not determined by a parallel arrangement of mineral particles.") However, as the angles of the cleavage in the rocks of intermediate compositions in this area seem to show a complete gradation between the two extremes and as the few micas in the slightly micaceous quartzites seem to be oriented parallel to the cleavage in those rocks, it is felt that this cleavage in the rocks of all compositions is a type of flow cleavage formed during folding. In this report the term "axial-plane cleavage" is used to cover this cleavage in all types of rock because of the questionability of the use of "flow cleavage" for the structure in the more quartzitic beds. The intersection of the "axial-plane cleavage" with the bedding gives the plunge of the fold; individual intersections give different readings but the average of a number of readings gives a close approximation to the plunge. The intersections of the cleavage in the more quartzitic beds seem to be usually closer to the plunge than those of the more micaceous beds.

Slip-shear cleavage is a younger structure than the "axial-plane cleavage"; that is, it seems to have formed after the beds were folded, probably at the time some of the shear zones were formed. It probably was initiated as a fracture cleavage, but now appears in part to be a flow cleavage, in that the micas all through the rock are parallel to it where it is strongly developed. It differs from "axial-plane cleavage," with which it may be confused in a single micaceous bed, by cutting all beds in the same direction irrespective of their compositions or place in different parts of a fold. As slip-shear cleavage increases in intensity, it seems to grade into the shear zones, thus suggesting that the slip-shear cleavage has been formed by some of the same stresses which caused the shear zones. Small movements on the slip-shear cleavage have here and there increased the apparent effect of crumpling (shear folding), and where the shearing is especially intense, it has broken up the more competent quartzitic beds into separate masses which are now completely enclosed in schist. At least some of the dikes in the Uncle Sam area seem to have been intruded after folding and the formation of the "axial-plane cleavage," but before the formation of the slip-shear cleavage. The intersection of slip-shear cleavage with bedding also gives a plunge structure; in areas where both types of cleavage could be seen it was found that the two plunges were usually different, but no regular or systematic difference has been discovered.

A true fracture cleavage, which in many places produced a wrinkled schist, is found in the north end of the Lookout structural block. It usually dips to the northeast at moderate to low angles and may be related to the thrust faulting found in the Big Deer Creek part of that block.

## ORE DEPOSITS

A definition of what constitutes ore in the district will be difficult until the methods and costs of recovery of the copper, cobalt, and gold have been worked out. Consequently only a few of the more heavily mineralized zones may be considered to be "ore bodies," and most of this chapter deals more properly with mineralized rock. During the war some calculations of "ore reserves" were made by the Geological Survey, using a cut-off of 0.4 percent "cobalt equivalent," the cobalt equivalent being the sum of the cobalt present plus one-eighth of the copper. It is not known what figure will be used by operators in the district, but presumably the 0.4 percent figure is too low. The term "mineralized rock" as used in this report refers not only to rock which contains cobalt and copper, but also to rock into which only the gangue minerals, quartz and hydrothermal biotite, have been introduced; almost any zone of mineralized rock is a potential locus for shoots of ore-grade material.

### General features

Mineralized rock is widespread in the Blackbird structural block, relatively scarce in the Lookout and Haynes-Stellite structural blocks, and almost nonexistent in the granite area. In the Blackbird block the mineralized rock seems to have been formed almost exclusively by the hydrothermal replacement of favorable parts of shear zones, and perhaps also of older faults. Some of the younger minerals may have been deposited in fractures, but on the whole, replacement of country rock or of older hydrothermal minerals along shear zones appears to have been the dominant process.

The presence of hydrothermal alteration and ore minerals in shear zones of all attitudes indicates that all directions of shear had been initiated before mineralization began. The principal shear zones previously described under "Structure" therefore are the principal loci of mineralization. Diamond drilling and underground development have indicated the presence of mineralized rock bodies, some of them of ore grade, along the following shear zones:

(1) The Chicago zone, of northwest strike and moderate northeast dip, on which drilling and underground work have indicated mineralized rock with a minimum length of 2,500 feet to widths of 3 to 30 feet, probably averaging 10 to 15 feet; in places there may be two or more parallel overlapping bodies of mineralized rock.

(2) The Brown Bear shear zone, of north strike and vertical or steep dip, in which are located several north-plunging lenses of fairly high-grade material; in addition, many small stringers of mineralized rock disseminated in the shear zone throughout a minimum width of 100 feet, and probably for a length of at least 500 feet.

(3) The Uncle Sam shear and fault zone of north strike and steep dip, along which low-grade material is exposed underground and on the surface for nearly 2,000 feet and in which occur at least three mineralized bodies of probable ore grade with widths up to 10 feet.

(4) A broad belt on the west side of Hawkeye Gulch, where there are a number of distinct shear zones, between which the rock is strongly cut by slip-shear cleavage; the shear zones contain lenses of mineralized rock, and the intervening schistose rock contains stringers of mineralized rock. The latter are in places abundant enough to form probable ore-grade material across widths of more than 30 feet.

These four shear zones are the only ones so far proved by diamond drilling and underground workings to contain mineralized rock of probable ore grade. Some mineralized rock occurs in the St. Joe workings, as indicated by the dump, and was also cut by nearby drill holes, but it is not known on what type of structure it occurs. Many other shear zones, in addition to the four described above, may contain shoots of ore-grade material. This is suggested by the occurrence of gossan and, more rarely, of ore minerals in float, on dumps of caved workings and pits, in bulldozer trenches, and in outcrops.

The controlling features in the formation of shoots of higher-grade material within the mineralized shear zones are not completely understood, but in most places a shoot is more continuous in the direction of the plunge of linear structural features than along the strike or down the dip. In the Uncle Sam mine the stope above the lower level (pl. 3B) appears to be at the intersection of the north striking shear zone with a north-northeast-striking zone of thrust faulting which occurs in the overturned east limb of an anticline. The shoot which outcrops east of the dump between the two levels seems to lie on the intersection of the main shear with faults dipping 65° E., and several small shoots just east of there appear to lie on favorable beds in the crests of minor folds; all these shoots appear to have their greatest continuity either down the plunge of the shear-faults intersection or down the plunge of the folds. Not much is known about the lenses of higher-grade material in the Brown Bear and Hawkeye shear zones, but it is believed that these also are plunging lenses. The material of probable ore grade in the main level of the Calera mine (pl. 3A) is more continuous along the strike and presumably up and down the dip than elsewhere in the district, but even here it is believed that the continuity of the shoots of mineralized rock is parallel to the plunge of linear structural features.

## Mineralogy and paragenesis

The mineralized rock contains the metallic minerals pyrite, pyrrhotite, cobaltite, chalcopyrite, safflorite, a little arsenopyrite, chalcocite and covellite; gold is present from a trace to a few hundredths of an ounce per ton, but is rarely seen even under the microscope. Among the nonmetallic minerals are quartz, biotite, tourmaline, chlorite, muscovite, carbonates (calcite, and ankerite or siderite), and vivianite, and a little apatite and ludlamite. In the zone of oxidation, hematite and goethite, cobalt chalcanthite, erythrite, heterogenite (?), pitticite (?), native copper, cuprite, malachite, jarosite, nontronite, and several unidentified minerals are found.

Pyrite ($FeS_2$) occurs in several different forms. Some is rather dull in hand specimens, and under the microscope shows concentric cracks or lines of impurities; the brighter material occurs both as separate crystals and as large irregular masses. Under the microscope there also is seen to be a late type occurring as many very small stringers cutting all the older minerals. Pyrrhotite ($Fe_{1-x}S$) is generally found only as large irregular masses in the more massive sulfide material and closely associated with chalcopyrite.

The ore minerals are chalcopyrite, cobaltite, safflorite, and gold. Chalcopyrite ($CuFeS_2$) occurs both as scattered grains and veinlets, and as fairly large irregular masses usually associated with quartz or intimately mixed with other sulfides. Cobaltite ((Co,Fe)AsS) occurs as separate grains scattered through the country rock, as grains in other ore minerals, and as irregular masses. Where scattered as very fine grains in biotite schist, it may be invisible to the naked eye, even though the specimen is fairly high grade; where it occurs as solid masses of fine-grained material, it has a dull pinkish-grey color and looks more like quartzite than high-grade ore. The coarser-grained cobaltite is silvery-colored and usually shows numerous good cleavage faces. Safflorite ($(Co,Fe)As_2$) is less common than cobaltite, but in a few places occurs in considerable amounts. In hand specimen it looks softer and has a duller-grey color as compared with the cobaltite; under the microscope it usually appears to be replacing the cobaltite grains as small veinlets, or occasionally as fairly large masses in which few islands of cobaltite remain.

A little arsenopyrite (FeAsS) was seen under the microscope in material from the Hawkeye mine, and considerable crushed arsenopyrite was seen in the bull quartz veins in the trenches near the head of the north branch of Little Deer Creek. No arsenopyrite was recognized in the mineralized rock from the Uncle Sam, Calera, or Brown Bear adits, but it has been reported by others. The sooty chalcocite ($Cu_2S$) and covellite (CuS) are secondary minerals seen occasionally near the bottom of the oxidized zone. Considerable chalcocite is present in the stope over the upper level of the Uncle Sam mine; under the microscope covellite can be seen on the borders of many chalcopyrite grains.

Quartz is the most abundant of the nonmetallic minerals. It occurs in several forms and is associated with all types of mineralized rock except the massive sulfide. In the form of bull quartz it may be the only introduced mineral present; it occurs in silicified schist, as recrystallization veinlets in the country rock, as sugary quartz in many of the veins, and as small stringers with pyrite and calcite in the latest veinlets.

A green biotite is the second most abundant and widespread nonmetallic mineral in the mineralized shear zones. Under the microscope this hydrothermal biotite appears quite different from the greenish-brown to olive-green biotite of the normal country rock and from the reddish-brown to brown biotite of the basic dikes, in that it is a bright-green, is usually coarser-grained, and generally not so well oriented, though it may contain a relict schistosity where it has replaced schist. This hydrothermal biotite is present in almost all the shear zones, and in many places has completely replaced biotite and quartz of the country rock. It would appear, however, that little material was added to the rock during the formation of this biotite; that is, in many places it looks as if the biotite, (and much of the sugary quartz associated with it) had formed mainly by recrystallization of the material in the country rock. Thus, in places where veinlets of quartz and green biotite cut beds of different composition, coarse green biotite is predominant in biotite schist, and quartz is predominant in micaceous quartzite. There has obviously been introduction of the elements composing the biotite where a quartz-biotite schist has been converted to solid green biotite, but the material may have come from a relatively nearby point. Whether the green biotite was formed mostly by recrystallization or mostly by replacement, it is always present along the mineralized zones and seems to be closely associated with the fine-grained cobaltite, present in the country rock along the recrystallization (?) veinlets described above. Cobaltite plus green biotite locally constitutes fairly high-grade ore.

Tourmaline (a complex borosilicate) is widespread in the district, being found in most of the shear zones and in places even in otherwise unaltered country rock. In a few shear zones in the Blackbird structural block it is one of the abundant minerals introduced, and in the mineralized zones of the Haynes-Stellite structural block it is almost the only introduced mineral aside from cobaltite and pyrite. In many places in the latter block the rocks consist of more than half tourmaline, and the resulting dense, hard, black rock is characteristic of the fault zones of that block. Some similar tourmalinized, sheared quartzite occurs in the Lookout structural block north of the Sunshine prospect, and north of Big Deer Creek to the west of Indian Creek. The tourmaline is usually fine-grained and dark in hand specimens. Under the microscope it shows a bluish center and a dark greenish-brown rim. Rarely the tourmaline is coarse-grained enough that individual crystals can be distinguished by eye; this is true in some of the rather massive quartz veins in the headwaters of the north branch of Little Deer Creek.

Chlorite, usually replacing the green biotite but also replacing muscovite and other minerals, is a common minor constituent of the mineralized rock.

Muscovite is present both as coarse-grained masses, and as the fine-grained variety, sericite. It is usually closely associated with masses of ankerite (or siderite).

Several different carbonate minerals are present in the mineralized rock. The commonest is close to ankerite in composition, though there may be some siderite present also. Late veinlets of calcite are present. Ankerite may make up a considerable part of the heavy sulfide type of ore.

A little apatite ($Ca_5(F,Cl)P_3O_{12}$) occurs in the mineralized rock. More common in the Calera adit and in some of the diamond-drill cores is coarse-grained vivianite ($Fe_3P_2O_8 8H_2O$). Usually colorless, or pale green or violet when first found, it turns deep blue within a few hours on exposure to light. Another green iron phosphate, ludlamite ($7FeO.2P_2O_5.9H_2O$), was also seen in the Calera adit. The apatite is a primary mineral. The ludlamite probably is a late primary mineral, as it occurs associated with drusy quartz and pyrite in the north-south fractures which cut the sulfides. The vivianite, commonly in vugs in fault gouge, is probably a secondary precipitate from circulating ground water.

On and near the surface, hematite and goethite are abundant in the gossan. In addition to a number of other oxidized minerals there are two varieties of cobalt bloom. Of these, the relatively insoluble erythrite ($Co_3As_2O_8.8H_2O$) is rare, except on the Sweet Repose dump, where there is a rather large amount. The other, cobalt chalcanthite ($CoSO_45H_2O$), though fairly soluble, is common throughout the district as efflorescences on outcrops, especially on outcrops in the Haynes-Stellite structural block. The black oxide, heterogenite (CoO.OH) was doubtfully identified in a few trenches. In addition to the above cobalt minerals, the oxidation of cobaltite has formed a group of minerals of yellowish to greenish color, which, though containing little if any cobalt, seem to be very good indicators of the former presence of cobaltite; these minerals include jarosite ($K_2O_93Fe_2O_3.4SO_4.6H_2O$), nontronite ($H_4Fe_2Si_2O_9?$), scorodite ($FeAsO_4+2H_2O$), an iron arsenate probably related to pitticite, and perhaps several others. One or more of these minerals occurs in the oxidized zone either as solid masses or as a greenish stain on porous sugary quartz. The usual minerals resulting from the oxidation of chalcopyrite, namely malachite ($Cu(OH)_2CuCO_3$), cuprite ($Cu_2O$), and native copper are fairly common near and at the surface. The depth of oxidation is considerable where cobaltite and chalcopyrite are both present; even on steep slopes, such as at the Uncle Sam mine, oxidation is fairly complete to a depth of more than 50 feet. On the gentler upland surfaces (between altitudes of 7,500 to 8,500 feet) oxidation is presumably much deeper, probably more than 100 feet, though no mining has yet been attempted under such surfaces. Where cobaltite alone is present, oxidation is less complete, and east of the Uncle Sam mine cobaltite was found on some outcrops.

Various combinations of the primary and secondary minerals described above form the different types of mineralized rock found in the district. Except for small amounts of chalcocite, practically all the ore minerals are of primary origin, and secondary enrichment is relatively unimportant economically although veins under the flatter upland surfaces might have fairly rich zones of secondary copper enrichment. The more intensely mineralized material can be grouped into six general types:

(1) Silicified schist of the shear zones, ranging from slightly silicified material to an almost solid mass of quartz retaining relict planes of schistosity; this type may be barren or may have sufficient cobaltite to bring it up to ore grade. Some material of this type has been refractured and pyrite and chalcopyrite introduced to produce type 3.

(2) Thorough replacement of country rock by hydrothermal biotite, with or without a certain amount of sugary quartz. This type of rock, like type 1, in many places contains some cobaltite and rarely chalcopyrite; locally the cobaltite is replaced by considerable safflorite. In places a high-grade biotite-cobaltite schist may be produced.

(3) A mixture of quartz, chalcopyrite, pyrite, cobaltite, and safflorite. The quartz may be a combination of early bull quartz or silicified schist plus younger sugary quartz of about the same age as the chalcopyrite and pyrite. This type is common in the Uncle Sam and Chicago zones (Calera adit) and also present in the Hawkeye zone. It may contain considerable safflorite, muscovite, and carbonate.

(4) Heavy sulfide masses, consisting of pyrite, pyrrhotite, chalcopyrite, coarse-grained cobaltite, safflorite; with some biotite, quartz, and carbonate. This type is best exposed in the Calera adit, where some is high grade, but elsewhere, as in parts of the Chicago adit, it is high in pyrite (and perhaps pyrrhotite) and very low in cobalt and copper.

(5) Broad, moderatley sheared zones into which many narrow stringers (1/16 to 4 or 5 inches wide) of cobaltite, pyrite, and chalcopyrite are introduced along the planes of schistosity (or slip-shear cleavage). In the lower Hawkeye adit this type of material is of ore grade. The Brown Bear adit may be another example, but as the adit is almost entirely in the oxidized zone the grade of the material is indeterminate.

(6) Heavily tourmalinized and silicified fault breccia in which very fine-grained cobaltite may be disseminated or in small irregular stringers. The tourmaline is a fine-grained mat which may have replaced more than 50 percent of the rock. This is typical of the deposits in the Haynes-Stellite structural block, and it also occurs in a few places in the Blackbird structural block.

Of course much of the mineralized rock is a mixture of two or more of the first four main types listed above. In the type 5 zones of the Hawkeye mine, there are also lenses of type 3.

The order in which the primary minerals have formed has been provisionally worked out as follows: The oldest mineralized rock is the barren (bull) quartz, formed either by replacement or injection. Silicification and the formation of hydrothermal biotite followed; the relative order between the two processes is not known, and where the biotite formed by recrystallization it is usually accompanied by contemporaneous sugary quartz. Tourmaline was apparently introduced about this time. Fine-grained cobaltite accompanied or followed the quartz, biotite, and tourmaline in many places. After a period of fracturing, quartz and the dull pyrite were formed. Further fracturing was followed by the formation of bright pyrite and chalcopyrite, accompanied by quartz, carbonate, and muscovite; during this period of replacement the earlier, generally fine grained cobaltite was recrystallized into much coarser crystals and large masses, and some chlorite replaced the earlier-formed biotite. Safflorite, replacing some of the cobaltite, and pyrrhotite formed slightly later, though perhaps not separated from the main pyrite and chalcopyrite period by any renewed fracturing. Minor amounts of apatite may have formed at this time. After a period of minor fracturing, small stringers of pyrite, carbonate, quartz, and probably ludlamite were formed.

For some reason the cobalt was able to migrate farther into the walls of the shear zones and fractures than was the copper. Also, cobalt is apparently more widely distributed throughout the district than is copper.

## Reserves

No details can be given on ore reserves in the district. One reason for this is that it is not known yet what cut-off value should be used in determining the minimum ore grade. During the war, and before the drilling program was completed, the Geological Survey made a fairly rough calculation of reserves, using a cut-off figure of 0.4 percent cobalt equivalent (equals cobalt plus 1/8 of the copper value). The combined figure for all the known mineralized zones in the Meadow Creek-Hawkeye Gulch area, including all the inferred ore above an altitude of 6,800 feet, and using assumed values for the grades of some ore zones, came to several million tons with an average grade of about 0.6 percent cobalt equivalent. The cut-off figure of 0.4 percent cobalt equivalent is probably much too low under present costs, but the resulting figure gives some idea of the magnitude of the ore deposits.

## Mines and prospects

### Calera mine

The Calera mine (see pl. 3A) is the newest and largest development in the district. It was started in July 1945 by the Calera Mining Co., Blackbird Division, a wholly-owned subsidiary of the Howe Sound Co., to test the Chicago and Brown Bear mineralized zones. Surface exploration and diamond drilling by both the company and the Bureau of Mines indicated that these zones extend for more than 3,000 feet along the east side of Meadow Creek. Plate 2 gives one interpretation of the structure, based mostly on diamond drilling and underground development in the Brown Bear adit. According to this interpretation the structure consists of two broad shear zones, the Brown Bear, striking north and dipping steeply, and the Chicago zone, striking northwest and dipping at a moderate angle ($60^\circ \pm$) northeast. In the Brown Bear zone the richer mineralized rock is in large lenses plunging $25^\circ$-$35^\circ$ north. In the Chicago zone is a single elongated body in the southern part and several overlapping ones in the northern part.

The main Calera level consists of a 550-foot crosscut which intersects the main mineralized zone 460 feet from the portal. At this point the mineralized zone has a horizontal width of about 40 feet. By August 1946 drifts and crosscuts had driven along the mineralized zone for a distance of approximately 1,700 feet. In general (see pl. 3A) the mineralized rock lies within a broad shear zone which strikes approximately parallel to the average strike of the bedding, but is probably somewhat steeper in dip. In some places, however, the body of mineralized rock seems to follow the bedding approximately, as for example, just northwest of the first crosscut northwest of the main crosscut, where the bedding forms a small syncline plunging $54^\circ$ N. $12^\circ$ E. and the mineralized body nearly parallels it with a similar but more open structure; also in the southeast end of the workings, the mineralized rock nearly parallels, but is more open than, the folds of the bedding. At several places where the mineralized body crosses north-striking shear or fracture zones, the edge of the main body of mineralized rock either follows them, or narrow lenses and stringers extend out along them. There has been some post-mineral movement on north-south fractures and on several northwest-striking faults. Beneath the Chicago adit there appear to be several overlapping mineralized zones; farther north the main mineralized body is cut off by a north-striking, steeply dipping fault along which there is shearing and mineralized rock. Apparently because of a variety of controls of the mineralization, the resulting mineralized body has dips that range from as low as 37° to 80° or higher; the average dip is probably between 60° and 65°. As pointed out above, the mineralized bodies appear to plunge in a northerly direction parallel to the plunging structural features of the wall rock, rather than down the dip of the cleavage or bedding. This relation is very important to the exploration and development of the deposits. Most of the mineralized rock in the Calera workings is a mixture of types 3 and 4 mineralization with lesser amounts of types 1 or 2 along the edges of the main body. Types 1 and 2 also extend out on the north-south shears, or out in the sheared crests and troughs of the folds. It may be said that the heavy sulfide material is found more on the footwall side of the mineralized zones and the type 3 material on the hanging-wall side, but there are many exceptions.

In the winter of 1946-47, the northwest adit was being continued northwest to connect with the old Brown Bear shaft; presumably the southeast drift will be extended eastward to test the ground down the plunge from the mineralized ground exposed in the trenches about 1,000 feet east of the Calera portal.

## Brown Bear adit

The Brown Bear adit (pl. 3A) is almost entirely in a wide shear zone having a northerly strike and a steep dip. The shear zone appears to be offset to the west on the north side of a fault dipping 30°-40° N., which has itself been cut by movement on a north-south fault zone. Much of the wide shear zone has many small stringers of quartz, sulfides, and cobaltite lying on the schistosity planes, and in addition contains larger lenses of rather high-grade material plunging north at 25° to 35°; these appear to lie in the Brown Bear shear zone approximately on its intersection with the Chicago shear zone, which is apparently the older of the two. Except for the northwest end, the adit cuts the shear in the zone of oxidation, so assays are not representative of the grade of the mineralized rock at depth.

## Bohannon adit

The small Bohannon adit (see pl. 3A) shows a little mineralized rock in a north-south shear zone, and also some (perhaps dragged in) on a northwest-striking fault zone. At the Bohannon discovery pit trenches, 500 feet northwest, there is some mineralized rock in lenses parallel to a north-northeast-striking fault, and also some rather high grade cobaltite lying in a northwesterly direction which might be part of a possible zone of mineralization extending toward the Ella prospect (see pl. 2).

Adit 390 feet S. 68° E. of Cobalt triangulation station

The small adit 390 feet S. 68° E. of Cobalt triangulation station (see pl. 3A) is of interest only because it exposes the fault contact between the garnet schist on the hanging wall and the biotite-quartz schist on the footwall side. As the strike of the fault does not seem to agree with the surface expression of the contact between the garnetiferous and nongarnetiferous rocks as mapped by float, the fault is shown offsetting the contact on the surface. However, it may be that this fault is the contact for much of the distance on the east side of Meadow Creek.

North adit on Dewey claim

The north adit on the Dewey claim follows a post-mineral fault zone which apparently cuts off the mineralized lenses exposed in the small caved portal higher up the hillside.

Adits on French Gulch

The upper of the two adits on French Gulch (see pl. 1 and 3A) exposes several small irregular masses of higher-grade chalcopyrite which plunge northeastward. The lower adit crosses one fault zone which has been slightly mineralized, and near its face passes through a zone, possibly the same one that is exposed in the upper adit, but here the zone consists of very small lenses (maximum width 2 inches) of quartz, carbonate, and a very little chalcopyrite, plunging northeastward. No cobalt minerals were seen here.

Uncle Sam mine

The Uncle Sam mine (see pl. 3B) is one of the older workings in the district, first opened about 1900. More recently the lower level was stoped and a raise was driven between the lower and upper levels by the Uncle Sam Mining and Milling Co. which was operating the property between 1938 and 1941.

The lower level starts on a series of north-northeast-striking thrust faults (and shears) on the overturned east limb of an anticline, and about 400 feet from the portal turns into the north-south zone. Some mineralized rock is found in the north-northeast zone, but much more occurs in the steeply west-dipping, north-striking shear and fault zone, and the best widths (as much as 10 feet) and grade appear to lie on the intersection of the north-south shears and the north-northeast thrust zone. The ore, mostly of type 3 with some type 2, was stoped for 60 feet above the level; above this the raise exposes a reversal of dip and a low-grade section in the zone, above which the mineralized shoot of the upper level comes in where the dip turns back to the west. North of the stope on the lower level the main north-south zone continues in the left-hand drift with narrow (1 to 18 inches) lenses of sulfide and quartz along it. The east-branch drift follows a fairly strong fault zone on which are a few lenses of sulfide. The upper level follows the main north-south shear and fault zone. The first raise connects with a stope which broke through to the surface and from which considerable oxidized ore with appreciable gold was removed. Fairly good grade material continues north as far as the basic dike (shown on pl. 3B) but little ore has been removed. This material consists mostly of types 2 and 3 mineralized rock. Beyond this is a narrow lean zone after which considerable quartz with some chalcopyrite and cobaltite comes in with fairly good widths. As almost the whole level is within the shear zone, not much information could be gathered as to what controlled the deposition of the copper and cobalt, but numerous stringers angling out to the northeast suggest that the control here may have been similar to that on the lower level. Another relatively high-grade body which seems to lie at the intersection of an east-dipping shear or fault zone with the main Uncle Sam zone crops out between the two levels east of the dump (see pl. 2); this body appears to plunge at 25° to 30° N.

## Hawkeye mine

The Hawkeye mine (shown on pl. 3B in its proper relation to the Uncle Sam mine) consists of two adits which crosscut a part of the broad zone of tight folding and shearing lying west of Hawkeye Gulch. In addition to several lenses of types 2 and 3 mineralized rock, the lower adit gives a good cross section of the so-called type 5 mineralized rock, that is, there are many small stringers of ore minerals lying in the planes of schistosity. At one place in the lower adit, assays indicate material of probable ore grade (cobalt equivalent over 0.8 percent) having a width of over 30 feet. Low assays in drill holes to the north and south of the workings suggest that the mineralized rock is rather discontinuous along the strike. Surface exposures (see pl. 2) indicate numerous other mineralized zones besides those exposed in the adits.

## Haynes-Stellite mine, adit to west, and Patty B adit

The Haynes-Stellite mine, the adit about 1,650 feet N. 85° W. of it, and the Patty B adit are all in the Haynes-Stellite structural block. The Haynes-Stellite mine was operated during 1917-1921, when the price of cobalt went very high (as much as $6.00 a pound). The middle and upper level show the typical mineralized rock of this block--a breccia zone (presumably a fault) in quartzite, heavily silicified and replaced by tourmaline, in which is disseminated very fine grained cobaltite in separate grains, small masses, and veinlets. The two upper levels show a fairly definite north (footwall) side of the mineralized rock and a rather indefinite south wall; the mineralized rock is apparently cut off by a north-dipping (?) fault above the lowest level which passes beneath the showings on the upper levels without exposing any mineralized rock. The adit 1,650 feet N. 85° W. of the lowest Haynes-Stellite adit shows only weak silicification, with a little pyrite indicated by gossan, on a small northwest-striking fault. The Patty B adit is in part of a broad, moderately brecciated area with tourmaline and some fine-grained cobaltite present in places.

## Copper Queen adits

At the Copper Queen property there are two adits (see pl. 3B). The upper adit is in schistose rocks, presumably belonging to the Blackbird block, in which there is considerable clay formed by hydrothermal alteration. Gossan and oxidized copper minerals occur along certain beds, mostly the more schistose beds. On the other hand, the lower adit is all in quartzite similar to that found in the Haynes-Stellite block. Mineralization consists of a minor bleaching and alteration of the quartzite to clay and the introduction of a little quartz and pyrite (?), now gossan, on minor fractures. If the determination of the rock types is correct, the Blackbird rocks are thrust over the Haynes-Stellite rocks on a fault dipping west at less than 20°, and the lower adit is in a window eroded through the fault; another possibility is an east-dipping fault between the adits which has dropped a patch of Blackbird rocks into the Haynes-Stellite block. In neither adit were any cobalt minerals seen, and the copper mineralization in the upper adit is unlike anything elsewhere in the Blackbird structural block.

## Adit on Tinkers Pride (?) claim

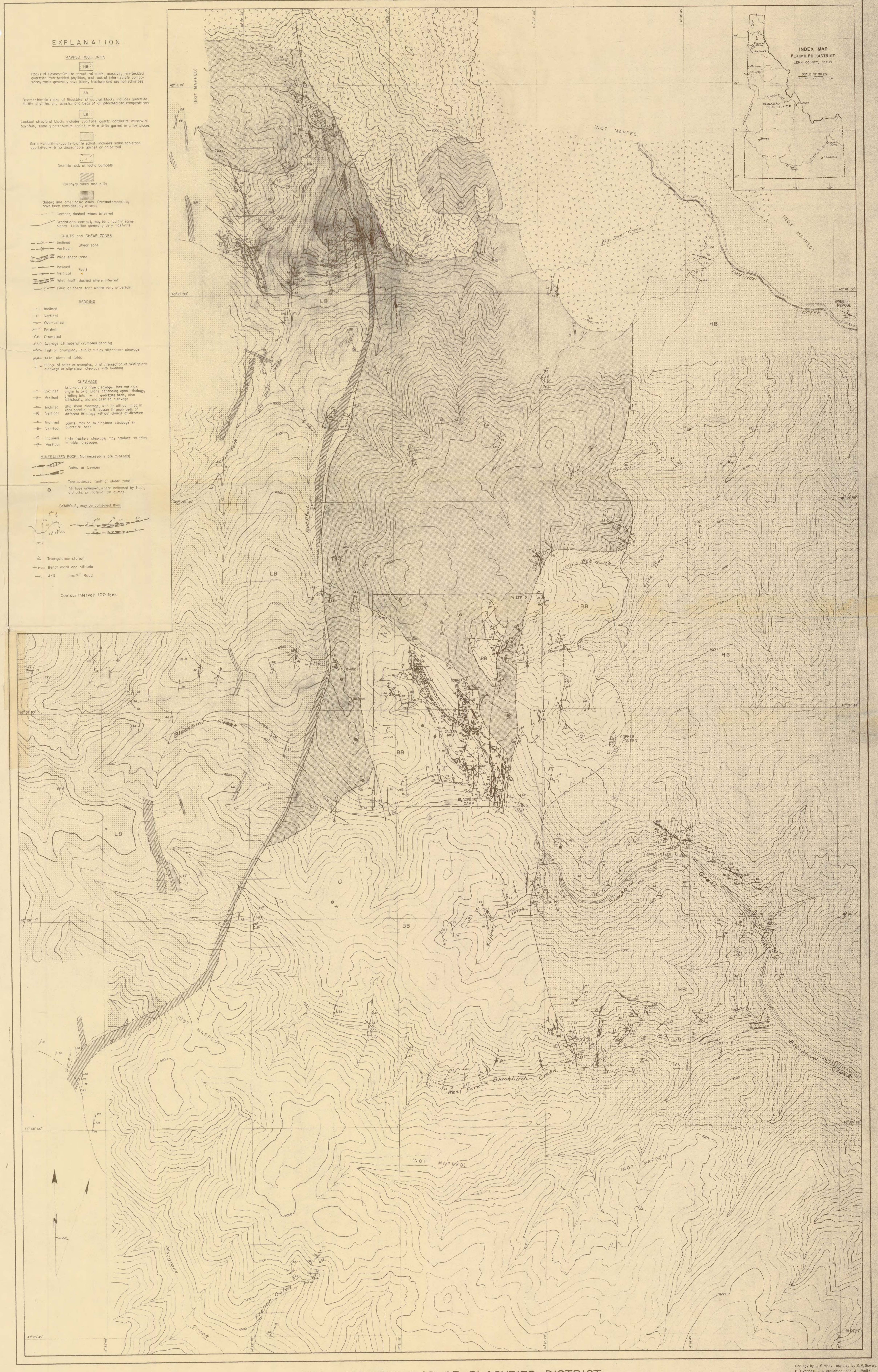
The adit on the Tinkers Pride (?) claim (see pl. 3B) was the only one of a group of adits on the north side of Big Deer Creek still open in 1944. It is in part of a broad zone of shearing and faulting which appears to line up with the fault zone farther south between the Lookout and Blackbird structural blocks. Underground there are a number of shear zones and faults dipping both east and west and striking a little west of north. The country rock is quartzite and garnet schist. There is little high-grade material, but mineralized rock is fairly widespread, and is apparently similar to that found along Meadow Creek; there is some high-grade cobaltite in biotite-rich rock and also considerable pyrite and chalcopyrite in quartz lenses.

## Adit on Indian Creek

The adit on Indian Creek about 7,000 feet from Big Deer Creek exposes a fairly solid chalcopyrite-pyrite vein lying along an altered dike. There are also some lenses of gossan in a crumpled garnet schist. No cobalt minerals were seen underground, but in a new discovery pit about 80 feet N. 35° W. of the portal there is some silicified schist carrying a little cobaltite. Although the mineralized rock is similar to that in the Blackbird structural block in that cobaltite, chalcopyrite, and pyrite are present, the general alteration, including the amount of hydrothermal biotite, is much less intense in the Indian Creek area.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP 3-219
PLATE I



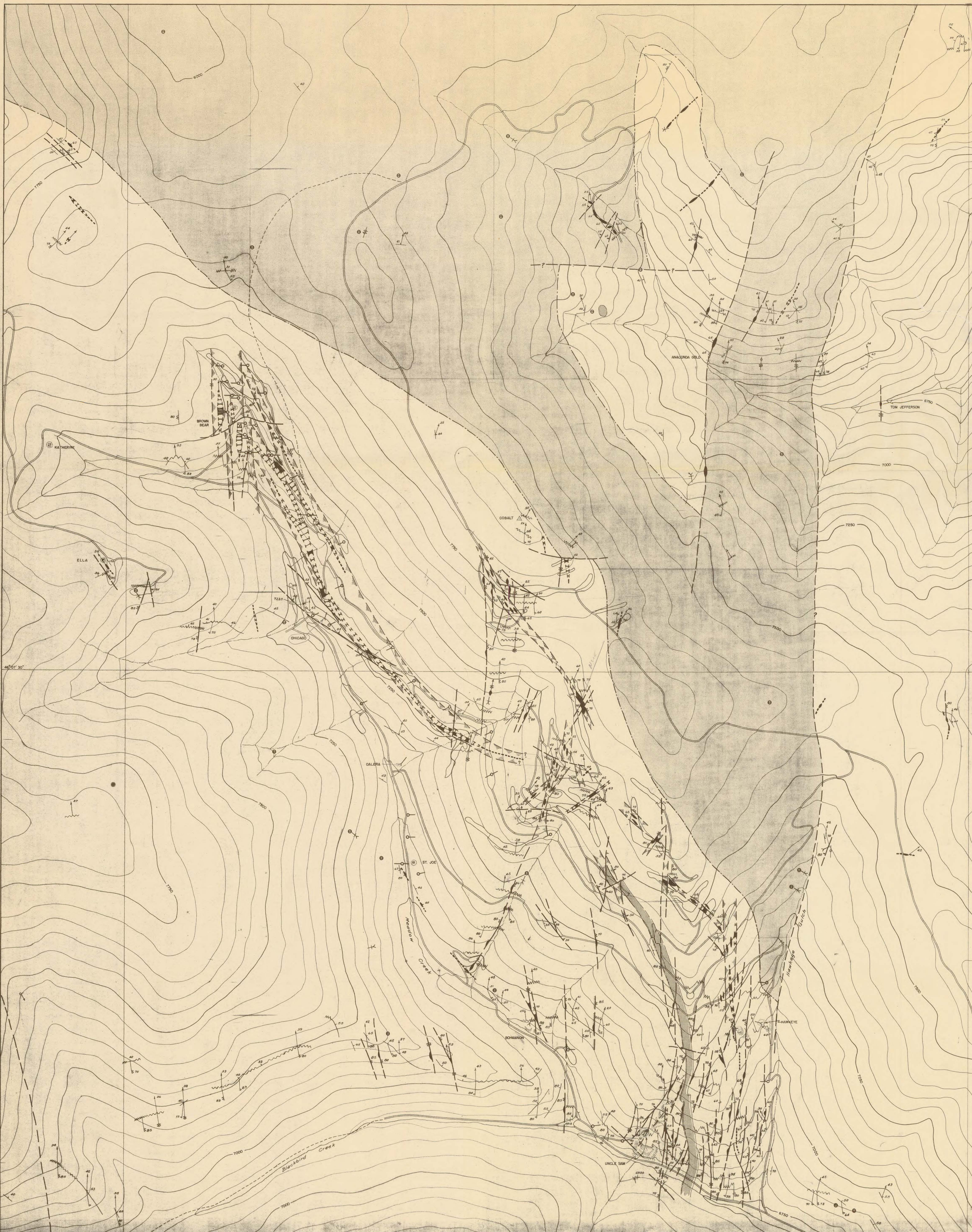

# GENERAL GEOLOGIC MAP OF BLACKBIRD DISTRICT

## LEMHI COUNTY, IDAHO

SCALE 1000 0 1000 2000 3000 4000 5000 FEET

52 x 33

Geology by J. S. Vhay, assisted by G. M. Sowers, D. J. Varnes, J. G. Broughton, and J. L. Weitz.
Topography by Topographic Branch
June 1946




## EXPLANATION

**MAPPED ROCK UNITS:**

Quartz-biotite rocks of Blackbird structural block; includes quartzite, biotite phyllites and schists, and beds of all intermediate compositions

Garnet-chloritoid-quartz-biotite schist of Blackbird structural block; includes some schistose quartzites with no discernable garnet or chloritoid

Gabbro, originally a coarse-grained, labradorite-augite rock, now considerably metamorphosed and hydrothermally altered to oligoclase-soda amphibole-biotite-chlorite-siderite rock. Generally massive, schistose near contacts

Contact (dashed where inferred).

Gradational contact; may be a fault in some places. Location generally very indefinite.

*Note: Numerous basic dikes, 6in. to 10ft. wide, occur in the area, especially in the more disturbed zones; they are pre-metamorphic, have all been considerably altered, and in places changed to biotite-quartz schists; some contain large siderite crystals. They are not shown on this map because of their small size.

**FAULTS and SHEAR ZONES:**

Inclined / Vertical — Shear zone

Wide shear zone

Inclined / Vertical — Fault

Wide fault (dashed where inferred)

Fault or shear zone where very uncertain

**BEDDING:**

Inclined

Vertical

Overturned

Folded

Crumpled

Average attitude of crumpled beds.

Tightly crumpled; usually cut by slip-shear cleavage

**CLEAVAGE:**

Inclined / Vertical — Axial plane or flow cleavage; has variable angle to axial plane depending upon lithology, grading into joints in quartzitic beds; also schistosity, and unclassified cleavage

Inclined / Vertical — Slip-shear cleavage, with or without mica in rock parallel to it; passes thru beds of different lithology without change of direction

19°50'

Contour Interval: 50 feet

SCALE 200 100 0 200 400 600 800 FEET

**MINERALIZED ROCK (Not necessarily ore-bearing):**

Veins or lenses (dashed where inferred, projected from drill holes or mine workings, or uncertain.)

Tourmalinized fault or shear zone

Attitude unknown, where indicated by float, old pits, or material on dumps

Includes following types: massive quartz; silicified schist; quartz and green (hydrothermal) biotite, with or without disseminated cobaltite; heavy sulfides (pyrite, pyrrhotite, chalcopyrite, cobaltite, safflorite) with or without siderite and sericite. Formed mostly in shear zones by replacement of schistose material or of earlier-formed hydrothermal biotite, some formed in fractures in earlier-formed massive quartz or silicified schist

SYMBOLS may be combined thus:

Plunge, of folds or crumples; of intersection of axial plane cleavage or slip-shear cleavage with bedding; or of lineation of minerals; or of ore bodies

Triangulation station

8105 Bench mark and altitude

Diamond drill hole

Trail

Road

Adit — Caved adit

Shaft — Caved shaft

Bulldozer trench

Dump

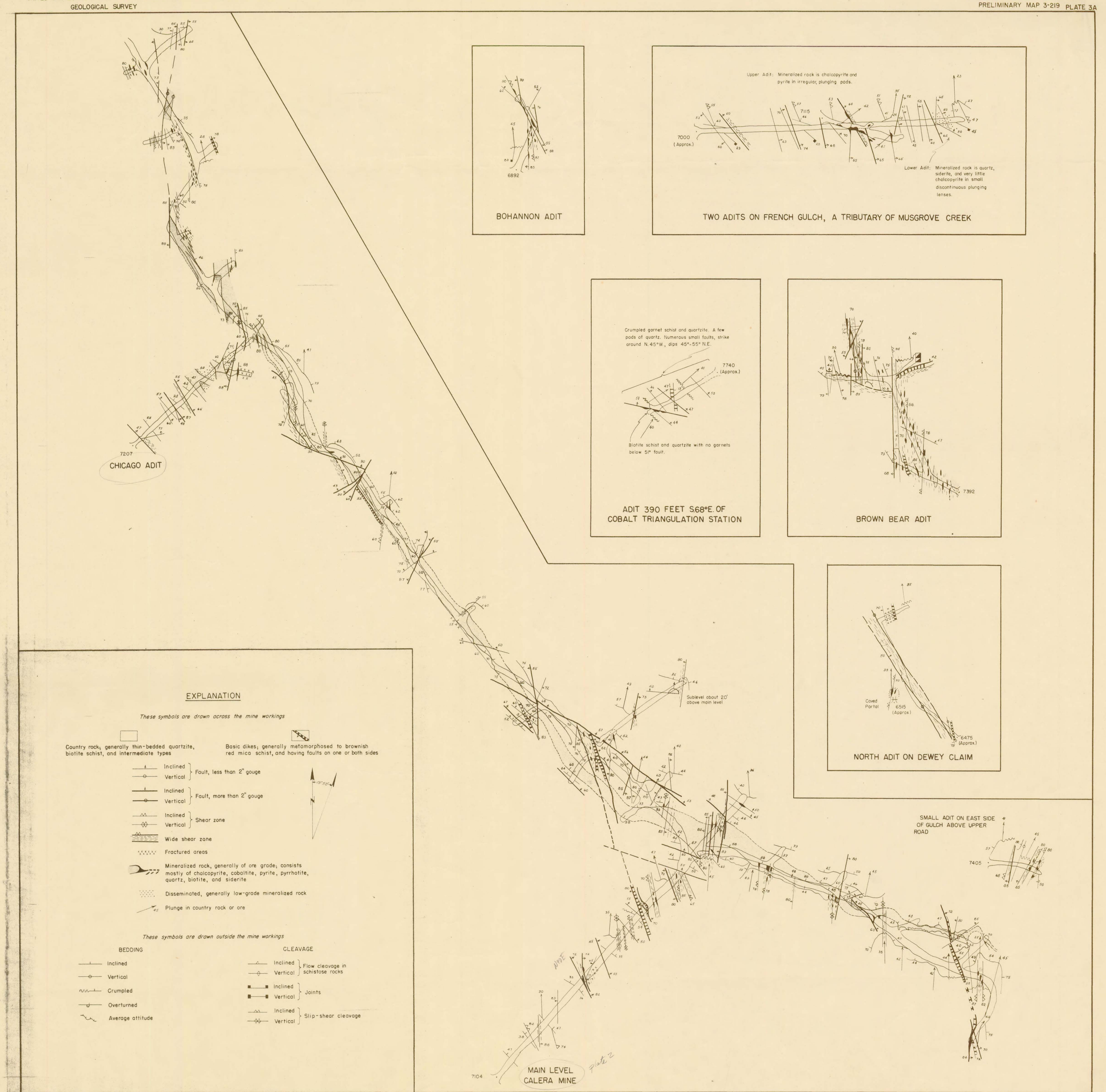
Topography by Topographic Branch, U. S. G. S., adjusted in central part by J. S. Vhay.

Geology by J. S. Vhay, assisted by G. M Sowers, D. J. Varnes, J. G. Broughton, and J. L. Weitz.

June 1946

# GEOLOGIC MAP OF MEADOW CREEK AND VICINITY

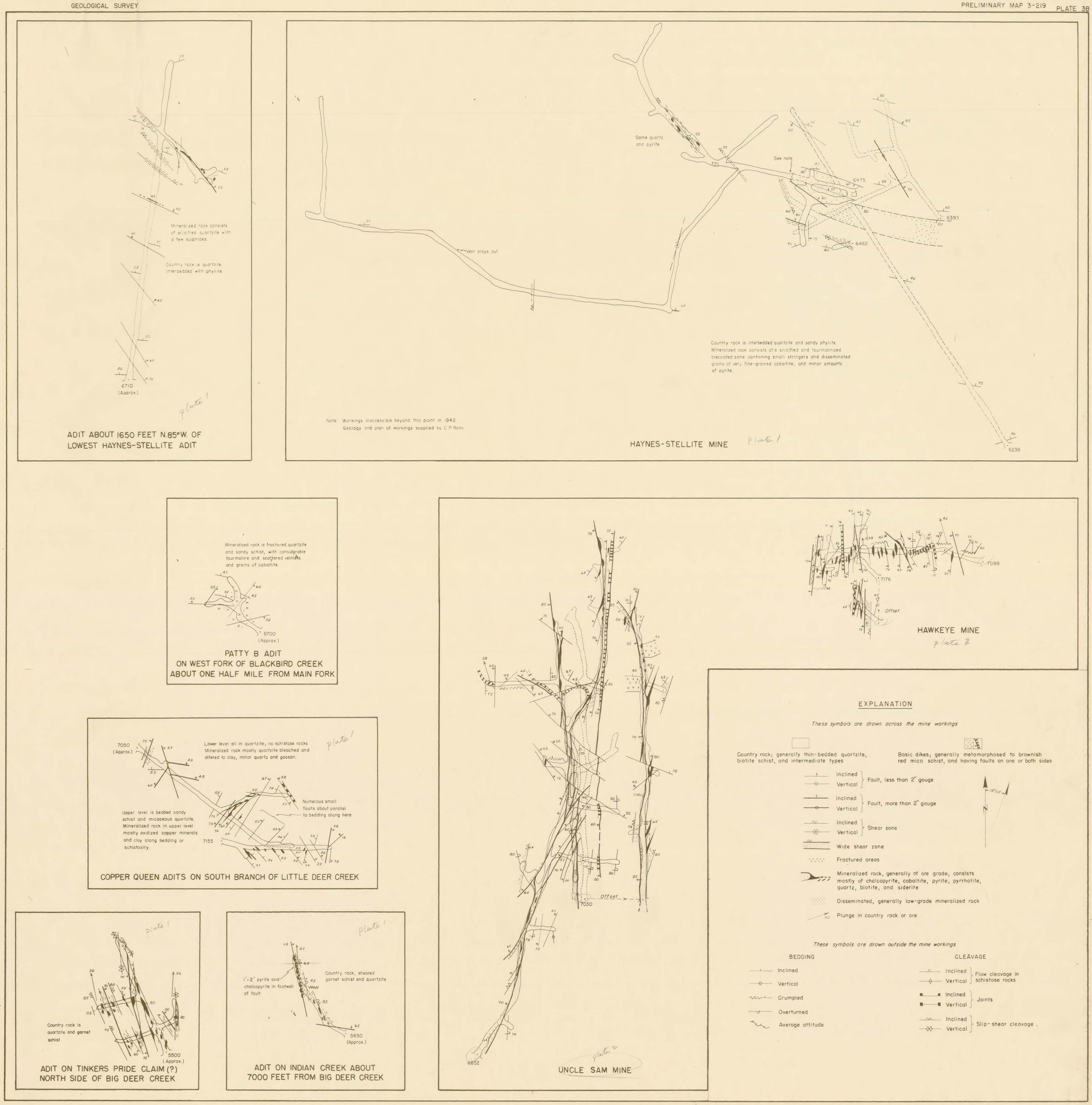
## BLACKBIRD DISTRICT, LEMHI COUNTY, IDAHO




# MINE WORKINGS IN BLACKBIRD DISTRICT
## LEMHI COUNTY, IDAHO

SCALE 0 50 100 150 200 250 FEET

Geology by J. S. Vhay assisted by G. M. Sowers, D. J. Varnes, J. G. Broughton and J. L. Weitz.




# MINE WORKINGS IN BLACKBIRD DISTRICT
## LEMHI COUNTY, IDAHO

SCALE 0 50 100 150 200 250 FEET

Geology by J.S. Vhay assisted by S.M. Sowers, D.J. Varnes, J.G. Broughton and J.L. Weitz.