Geology and Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR

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THE URANIUM-BEARING NICKEL-COBALT-NATIVE SILVER DEPOSITS IN THE BLACK HAWK DISTRICT, GRANT COUNTY, NEW MEXICO*

By

Elliot Gillerman and Donald H. Whitebread

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Trace Elements Investigations Report 261

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By Elliot Gillerman and Donald H. Whitebread

ABSTRACT

The Black Hawk (Bullard Peak) district, Grant County, N. Mex., is 21 miles by road west of Silver City. From 1881 to 1893 more than $1,000,000.00 of high-grade silver ore is reported to have been shipped from the district. Since 1893 there has been no mining in the district except during a short period in 1917 when the Black Hawk mine was rehabilitated.

Pre-Cambrian quartz diorite gneiss, which contains inclusions of quartzite, schist, monzonite and quartz monzonite, is the most widespread rock in the district. The quartz diorite gneiss is intruded by many pre-Cambrian and younger rocks, including diorite, granite, diabase, monzonite porphyry and andesite and is overlain by the Upper Cretaceous Beartooth quartzite. The monzonite porphyry, probably of late Cretaceous or early Tertiary age, forms a small stock along the northwestern edge of the district and numerous dikes and irregular masses throughout the district.

The ore deposits are in fissure veins that contain silver, nickel, cobalt, and uranium. The ore minerals, which include native silver, argentite niccolite, millerite, skutterudite, nickel skutterudite, bismuthinite, pitchblende, and sphalerite, are in a carbonate gangue in narrow, persistent veins, most of which trend northeasterly. Pitchblende has been identified in the Black Hawk and the Alhambra deposits and unidentified radioactive minerals were found at five other localities. The deposits that contain the radioactive minerals constitute a belt 600 to 1,500 feet wide that trends about N. 45° E. and is approximately parallel to the southeastern boundary of the monzonite porphyry stock. All the major ore deposits are in the quartz diorite gneiss in close proximity to the monzonite porphyry.

The ore deposits are similar to the deposits at Great Bear Lake, Canada, and Joachimstahl, Czechoslovakia.

INTRODUCTION

Mining began in the Black Hawk (Bullard Peak) district in 1881 when high-grade silver ore was found at the Alhambra mine. Most of the silver produced was native silver, associated with nickel and cobalt arsenides and sulfides. In 1920 pitchblende was recognized on the dumps of some of the old mines, and since 1949 the district has been of interest as a possible source of ores that contain uranium, nickel, and cobalt.

Location, accessibility, and climate

The Black Hawk mining district is mostly in sections 20, 21, 22, 28, and 29, T. 18 S., R. 16 W., in Grant County, N. Mex. (fig. 1). The Black Hawk mine (fig. 3), near the center of the district, is 21 miles by road west of Silver City, the terminus of a branch line of the Atchison, Topeka and Santa Fe Railroad; and 2 miles northeast of Bullard Peak (Bullard Cone), a prominent landmark.

The district is in the northeastern foothills of the Big Burro Mountains at an altitude of 5,450 to 6,150 feet. Scattered junipers, scrub oak, small pines, and brush cover the hillsides, but no trees suitable for use in mining are present. Most of the district is drained by Black Hawk Canyon which bisects the area and flows northward to Mangas Creek, but the eastern part is drained by tributaries of Silver Dale Creek, which flows northeastward to Mangas Creek. Mangas Creek flows into the Gila River about nine miles northwest of the mouth of Black Hawk Canyon. All the streams, except the Gila River, are intermittent. Annual precipitation at Silver City is about 16 inches, most of which comes as heavy thundershowers in July, August, and September.

Scope and purpose of work

Field work in the Black Hawk district was done by the writers as part of the program for investigation of radioactive minerals by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. A preliminary reconnaissance (Granger, 1950) confirmed the presence of radioactive minerals in the district. Additional examinations for radioactivity of mine dumps, pits, and

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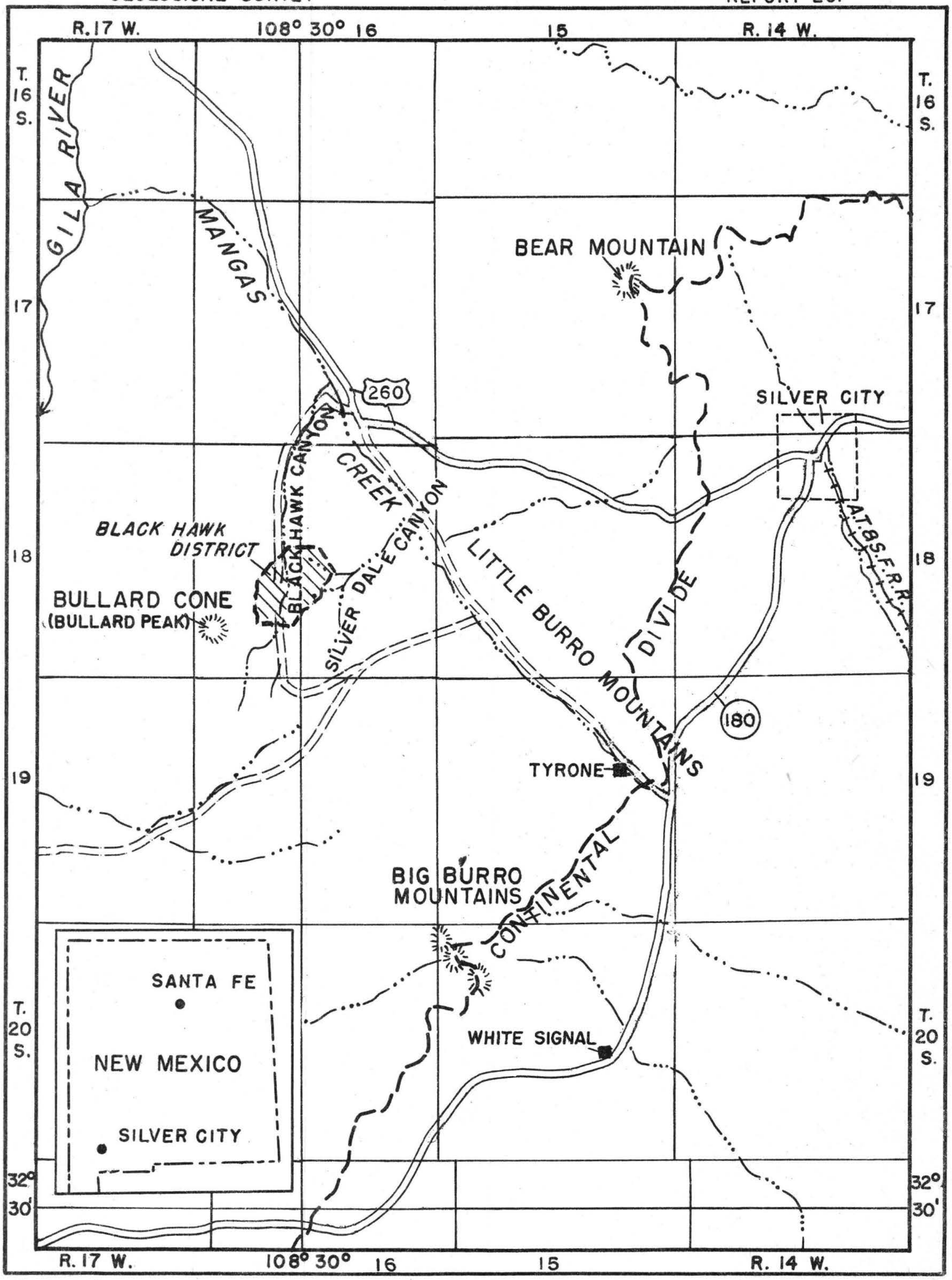

FIGURE 1.- INDEX MAP SHOWING THE LOCATION OF THE BLACK HAWK MINING DISTRICT, GRANT COUNTY, NEW MEXICO.

5 0 5 Miles

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shafts by A. J. Gude 3rd and Gillerman in the spring of 1951 resulted in the finding of small quantities of pitchblende on the dumps of the Black Hawk and Alhambra mines. The present study was begun in December 1951, and the writers spent about four months in the field. The investigations consisted principally of geologic mapping of an area of about 2 1/2 square miles (fig. 3) at a scale of 1:6,000. Detailed surface maps of the Black Hawk (fig. 5) and Alhambra mines (fig. 7) at a scale of 1:1,200 were made by plane table and alidade.

Acknowledgments

Mr. Ira L. Wright, General Manager of the Black Hawk Consolidated Mines Company, and Mr. and Mrs. A. A. Leach, owners of the Alhambra group of claims, were extremely helpful and cooperative. They made available to the writers old maps and reports of the mines in the district and also specimens of ore taken from the Black Hawk and Alhambra mines. Chemical analyses were made by the New Mexico Minerals Laboratory of Silver City, N. Mex.

Ownership

The principal deposits in the district are covered by patented claims, as shown in figure 2. The Black Hawk group, owned by the Black Hawk Consolidated Mines Company, Milwaukee, Wis., consists of the Black Hawk, Silver Glance, Cornucopia, Surprise, Kent County, Little Rhody, Chicago, and Extension patented claims. The Alhambra group, owned by Albert A., and Frances I. Leach of Lordsburg, N. Mex., consists of the Alhambra, Stonewall, Good Hope, Pumpkin, and Butternut patented claims and the Alhambra Extension, Easy Days, and Old Hobson unpatented claims. The Rose claim is owned by Mrs. Elizabeth J. McCabe, 741 S. Hudson Ave., Pasadena Calif., and Mrs. Elizabeth C. (Mrs. William Howard) Meade, 208 Fremont St., San Francisco, Calif. The ownership of the other claims in the district is not known.

History and production

In 1881 float of high-grade silver ore was found at the Alhambra mine, and subsequent prospecting soon resulted in the discovery of the Black Hawk, Rose, Hobson (Silver King), Good Hope, and other deposits (fig. 3). Mining began in the district in 1881 and continued until 1893, when a decline in the price of silver and the depletion of the rich silver ore caused the mines to be closed. Nearly all the ore produced was high in silver, and shipments of ore assaying as much as 15,000 ounces of silver per ton are reported (Jones, 1904, p. 55).

In 1917, when a new owner acquired the property, the Black Hawk mine was unwatered. The mine was opened to the lowermost levels where undeveloped high grade ore was reported (Storms, 1949). Some drifting was done on the upper levels to search for an ore body that had not been developed during the earlier operations. Walter H. Weed, (1917) consulting geologist, and Albert A. Leach, (1917) then geologist for Phelps Dodge Corporation at Tyrone, N. Mex., examined the mine and recommended further work. In 1917 there was also a shortlived interest in some of the smaller properties in the eastern part of the district. Since 1917 the district has been idle.

Because of the need for additional nickel, cobalt, and uranium, interest in the district was revived in 1949. In the spring of 1952 a Government exploration loan was granted to the Black Hawk Consolidated Mines Company to explore the Black Hawk mine, and 3 diamond core drill holes were completed by November 1952. The three holes were drilled to a depth of 1,000 feet; hole 3 intersected sparse ore minerals in carbonate gangue, but the other two holes were barren. (See fig. 8).

The silver production from the district prior to 1893 is estimated to be between $1,000,000 and $1,500,000 (Lindgren and others, 1910, p. 324, and Leach, A. A., 1916). The Black Hawk mine is reported to have yielded $600,000 to $650,000 (Jones, 1904, p. 55, and Leach, A. A., 1916); the Alhambra mine about $400,000 (Leach, 1950); the Rose mine about $140,000 (Anonymous, 1917) and the Hobson (Silver King) about $40,000 (Leach, 1950). The remainder of the production came from the Good Hope and other properties.

GEOLOGY

The Black Hawk district is within the pre-Cambrian Burro Mountains batholith, which is exposed over an area of about 400 square miles in southwestern Grant County. The batholith is a composite body made up chiefly of granite with inclusions of older gneiss, schist, quartzite, and intrusive rocks. Many stocks and dikes intrude the batholith.

The predominant rock in the Black Hawk district is pre-Cambrian quartz diorite gneiss--part of the batholith--that intrudes quartzite, schist, monzonite, and quartz monzonite. These rocks are cut by many igneous rocks of pre-Cambrian and younger age, the most prominent of which is monzonite porphyry of probable late Cretaceous or early Tertiary age. The Beartooth quartzite of Cretaceous age overlies the pre-Cambrian rocks. Numerous faults, most of which trend northeast, cut the rocks of the district.

The ore deposits are in fissure veins, and most commonly are in the quartz diorite gneiss. Native silver is the major ore mineral and is associated with nickel and cobalt arsenides and sulfides in a carbonate gangue. Pitchblende, associated with the silver, nickel, and cobalt minerals, has been identified from the Black Hawk and Alhambra mines. The metalliferous deposits possibly are spatially related to the monzonite porphyry and are considered Tertiary in age.

The rock units and their relationships to one another are shown on the geologic map (fig. 3).

Igneous and metamorphic rocks

Quartzite and schist

Pre-Cambrain quartzite, schist, and other metamorphic rocks have been shown on the geologic map (fig. 3) as quartzite and schist. These rocks form two broad irregular east-trending bands in the southwestern part and small isolated patches throughout the southern part of the mapped area. The beds strike N. 40° W. to West and dip 37° to 64° NE. at most places; but locally, near the western edge of the mapped area, they strike N. 50° to 65° E. and dip 62° NW. The quartzite is a thin-bedded, fine-grained gray to buff rock consisting mostly of angular quartz grains and a few flakes of mica and grains of magnetite. Thin mica schist layers that contain some magnetite and quartz, amphibolite, and knotted schist are associated with the quartzite. Epidote is present locally in the schist and amphibolite.

Monzonite and quartz monzonite

A rock of monzonitic and quartz monzonitic composition is exposed over a wide area in the southeastern part of the mapped area (fig. 3). This rock is predominantly homogeneous, fine-grained, and equigranular, but near its contact with the quartz diorite gneiss it commonly has a porphyritic texture, with phenocrysts of orthoclase as much as an inch in diameter. This porphyritic texture is especially well developed in areas where there has been lit-par-lit injection of gneissic material. Foliation is obscure, but a layering that possibly represents relict bedding is present locally. This layering suggests that the rocks designated in this report as "monzonite and quartz monzonite" may be migmatized sedimentary rocks.

The monzonite and quartz monzonite consist essentially of fresh-looking pink and white feldspars, biotite, and hornblende. Some quartz is present in places. Epidote occurs sparsely.

The age relationships of the monzonite and quartz monzonite to the quartzite and schist are unknown; these rocks are found in contact at only two localities and the relationships at these places are obscure. The monzonite and quartz monzonite are cut by the quartz diorite gneiss.

Quartz diorite gneiss

Quartz diorite gneiss of pre-Cambrian age constitutes the country rock in most of the district (fig. 3). The gneiss intrudes the quartzite, schist, monzonite and quartz monzonite; and it is a widespread phase of the Burro Mountains batholith. Approximately equal amounts of plagioclase and biotite comprise 85 to 90 percent of the rock mass. The plagioclase is white to pinkish gray and appears to be andesine. It occurs mostly as anhedral grains averaging 2 cm. in length, but subhedral to euhedral crystals as much as 2 inches in length are common as phenocrysts elongated parallel to the foliation. The feldspar is slightly altered to sericite in places. The biotite occurs as aggregates of small flakes between the feldspar grains. Some of the biotite is altered to chlorite. Anhedral quartz, which comprises 5 to 10 percent of the rock, occurs with the biotite. Orthoclase is present in minor amounts. Hornblende up to 2 cm. in length constitutes 2 to 3 percent of the rock and is found chiefly in the biotite aggregates. Zircon and magnetite are present, and some epidote is associated with the magnetite.

The gneissic structure, believed to be a primary flow structure, strikes northeast and dips steeply northwest except in the southeastern part of the mapped area and in areas contiguous to the older rocks, where there are local variations from the regional trend (fig. 3).

Biotite quartz diorite

Two small masses of biotite quartz diorite crop out along the southern edge of the district (fig. 3). The rock differs from the quartz diorite gneiss in the following respects: (1) it contains more biotite; (2) it does not contain large feldspar phenocrysts; and (3) it has a less pronounced gneissic structure. The contacts of the rock with both the quartz diorite gneiss and the diorite are obscured by surficial material, and the age relationships are unknown.

Diorite

Many small, irregular bodies of diorite have been mapped in the southern part of the district (fig. 3). The diorite is a coarse-grained, dark green to black rock with a characteristic greenish-brown and white mottled weathered surface. It consists predominantly of chloritized biotite and hornblende, anhedral grains of plagioclase feldspar, and minor amounts of quartz.

The diorite intrudes the quartzite and schist; it also probably intrudes the quartz diorite gneiss and the biotite quartz diorite, but conclusive evidence of an intrusive relation is lacking. At an excellent exposure of the diorite and the quartz diorite gneiss in Black Hawk Canyon, slightly more than half a mile southwest of the Black Hawk shaft, the diorite appears to intrude the quartz diorite gneiss. The age relationships, however, are partly obscured by pegmatite dikes that have been emplaced along the contact.

Syenite

Seven small bodies of syenite that range in size from short dikes from 20 to 75 feet wide to masses about 200 feet wide and 450 feet long are present about 2,000 feet southeast of the Black Hawk mine (fig. 3). The syenite is a medium-grained equigranular brown rock that consisted originally of pink orthoclase feldspar and biotite, but which now is highly altered. The biotite commonly is altered to a brown limonitic powder and the feldspar is kaolinized. The syenite is intruded by the granite; it intrudes the quartz diorite gneiss, but its age relationship to the other pre-Cambrian rocks is unknown.

Granite

Many irregular bodies and dikes of granite intrude all the older rocks throughout the mapped area (fig. 3). The rock is similar to the granite that forms the main mass of the Big Burro Mountains to the south and constitutes most of the Burro Mountains batholith. The granite is a fine- to medium-grained, equigranular, pink rock that consists of quartz, orthoclase, and small amounts of plagioclase and biotite; apatite, sphene, and an unidentified mineral are minor constituents. Numerous pegmatite and aplite dikes cut the granite and the older rocks.

Diabase and basalt porphyry

Many diabase dikes have been mapped in the southern part of the district (fig. 3). These dikes, generally less than 25 feet wide, trend northwestward in most places. A basalt porphyry dike, exposed intermittently from near the center of the western edge of the mapped area to the southeast corner, has not been distinguished from the diabase dikes on the map (fig. 3). A few diabase dikes are present in the northern part of the district. The diabase is a fine-grained, dark gray rock that contains laths of plagioclase in a matrix of pyroxene and magnetite. The basalt porphyry consists of a dark gray, fine-grained, equigranular groundmass of pyroxene, plagioclase feldspar, biotite, and phenocrysts of light gray feldspar as much as .5 cm in diameter. The phenocrysts constitute from 10 to 15 percent of the rock.

Rhyolite

A white chalky-appearing, fine-grained rhyolite dike that ranges from 5 to 25 feet in width crops out intermittently from east to west across the mapped area, about midway between the northern and southern boundaries (fig. 3). The dike is texturally similar to aplite and has a chilled border facies. The rock consists mostly of feldspar with some quartz and a few flakes of mica.

Quartz monzonite

Small masses of quartz monzonite have been mapped along the northern edge of the district and near the southwestern corner (fig. 3). The quartz monzonite in the northern part is fine-grained, equigranular, and gray and consists predominantly of white and gray subhedral feldspar with subordinate amounts of quartz and altered euhedral books of biotite. Hornblende is sparse to absent. The rock in the southern part of the mapped area contains more hornblende. The two types of quartz monzonite have not been distinguished on the map. Dikes of monzonite porphyry cut both types of quartz monzonite.

Monzonite porphyry

Monzonite porphyry, the second most abundant rock in the Black Hawk district, is present as a stock-like mass in the northwestern part of the area and as dikes and irregular masses throughout the rest of the area (fig. 3). The rock consists of a grayish-white fine-grained groundmass with abundant white anhedral to subhedral feldspar crystals as much as .5 cm in diameter, and black hornblende needles ranging up to 1 cm in length. Small amounts of biotite are present in some places; quartz is rare. Locally the long axes of hornblende needles are alined to produce a linear structure. In the dikes the groundmass is mostly aphanitic, and the feldspar forms conspicuous phenocrysts.

In altered monzonite porphyry the groundmass is aphanitic, the feldspars are soft and earthy; and the hornblende is chloritized, epidotized, or converted to an iron-stained clay. Pyrite, in places altered to limonite, is common in the altered monzonite porphyry between Black Hawk Canyon and the Silver King mine. The altered rock is greenish gray, light gray to white, or reddish brown.

The monzonite porphyry is considered Early Tertiary or Late Cretaceous in age on the basis of correlation with lithologically similar stocks in the Silver City area. No intrusive relations with the Beartooth quartzite were observed in the vicinity of the Black Hawk district, but some of the other stocks intrude the Late Cretaceous Beartooth quartzite and Colorado shale. Eight or more similar stocks of monzonite, quartz monzonite, and granodiorite are known in the Silver City area. All are considered Early Tertiary or Late Cretaceous (Paige, 1916).

The monzonite porphyry stock is topographically higher than the surrounding country and constitutes the high peaks called Twin Peaks (fig. 3). The stock is known as the Twin Peaks stock.

Quartz diorite

Several easterly trending dikes of quartz diorite have been mapped in the northeastern part of the district (fig. 3). The rock is fine-grained, equigranular, brown to gray, and consists mostly of plagioclase feldspar, hornblende, and quartz. At places scattered grains of magnetite and some epidote are present. The quartz diorite dikes cut the monzonite porphyry, but they are cut by the ore-bearing veins.

Andesite

Two small stock-like masses of andesite crop out in the northeastern part of the district (fig. 3). Two dikes to the south of these andesite bodies and one dike about 1,500 feet to the west of them are believed to be of the same composition. The andesite is fine-grained and dark gray; it consists almost entirely of feldspar. A few phenocrysts of feldspar and hornblende, altered to a yellow-brown clay-like material, are present. The andesite intrudes the pre-Cambrian rocks, but its age relation to the Beartooth quartzite has not been determined. The megascopic appearance of the andesite is similar to the diabase, but for the most part it is less altered. The andesite contains abundant vertical joints at the edges of the stocks.

Sedimentary rocks

Beartooth quartzite

The Beartooth quartzite of Upper Cretaceous age crops out along the top of a long ridge in the northeastern part of the mapped area (fig. 3). The quartzite overlies the quartz diorite gneiss, granite, and quartz monzonite. The formation dips from 15° to 25° N. 30° E. and consists of alternating beds of conglomerate, sandstone, shale, calcareous sandstone, and quartzite. The quartzite extends both east and west of the area and lies between the older igneous rocks to the south and west, and volcanic rocks, probably of Tertiary age, to the north and east.

Alluvium

Recent stream deposits, consisting of silts, sands and gravels, are found in Black Hawk Canyon throughout much of its course.

Structure

Folds are of minor importance in the Black Hawk district, but faults are abundant and are found in all parts of the area. Many are filled with vein material or dikes. Foliation, planar structures and jointing are common in some of the igneous rocks.

Folds

The sedimentary and metasedimentary rocks of the Black Hawk district are inclined at angles of 15° to 65°. The Beartooth quartzite dips 15° to 25° northeast, and the inclined beds can be traced along the strike for at least one mile east and two miles west of the mapped area. The pre-Cambrian quartzites and schists also dip northeast, except for local variations. The larger exposed masses of the pre-Cambrian metasediments, included as xenoliths in the quartz diorite gneiss, trend east at an angle to the attitude of the beds. These easterly trending xenoliths extend for about a mile west of the area mapped.

Faults

Faults and shear zones are abundant in the Black Hawk district; most of the veins and some of the dikes are along faults. The dominant trend of the fractures is north-northeast to east, but a few, particularly in the southwestern part of the district, trend northwestward.

Two belts of faulting trend slightly east of north across the area. One belt passes a few hundred feet west of the Black Hawk shaft and extends from the southern boundary of the mapped area to near the northern edge, where it probably is interrupted by two parallel east-trending faults, now filled by veins. The belt, however, possibly extends north through the Beartooth quartzite. The other belt is about 1,600 feet east of the Black Hawk shaft and extends from the southern boundary to the northeastern edge of the district. Both of these belts cut the quartz diorite dikes and have been the loci of movement in Tertiary time. Each belt consists of a more or less persistent fault from which branch faults split off to the northeast. The northeast branches from the western belt tend to coalesce toward the north with the eastern belt. East of these two belts, the faults trend more easterly.

The shears and faults within the monzonite porphyry stock trend northeasterly and are parallel to the elongation of the stock. Part of the southeastern boundary of the stock is along a fault and shear zone.

Much of the faulting is later than the intrusion of the monzonite porphyry, which is probably Late Cretaceous or Early Tertiary in age. Some of this faulting may have followed breaks that originated in pre-Cambrian time.

Post-ore faults have cut some of the veins. In the Black Hawk mine, a flat-dipping fault, striking about N. 75°E. and dipping 25° -30° NW, is reported to cut the vein on the eighth level. The ore in the stopes below this level ends sharply against the fault (Leach 1917). At the Alhambra mine a northwest- and a northeast-trending fault cuts the vein and displaces it (fig. 7). Underground, on the first level, fragments of ore are reported to be found along these faults. The fragments are the result of movement and drag along these cross faults after the vein material was deposited in the Alhambra vein.

Igneous structures

The foliation of the quartz diorite gneiss, in general, trends northeasterly and dips from 60° NW to vertical. Locally the dips are less steep. Southeast and east of the Rose and Alhambra mines the foliation trends northwesterly and dips northeast (fig. 3). At places the foliation is parallel to the contacts of the quartz diorite gneiss with the older rocks, and this, combined with the absence of a regional foliation in the older rocks, is interpreted to indicate that the gneissic foliation is a primary flow structure.

The foliation in the quartz diorite gneiss probably was the main controlling structure for subsequent igneous intrusions in pre-Cambrian times. Most of the granite and associated aplite and pegmatite dikes were intruded parallel to the foliation. An excellent example of this is the area half a mile southeast of the Black Hawk shaft (fig. 3).

Prior to the intrusion of the diabase, northwesterly trending fractures developed throughout the Burro Mountains area that later were filled by diabasic and basaltic magma. The intrusion of the monzonite porphyry stock, however, was apparently along the trend of the older northeast-trending pre-Cambrian foliation. During intrusion of the monzonite porphyry, fractures developed in the surrounding area and some of the pre-Cambrian structures were reopened. Younger dikes and veins filled some of these fractures.

The planar structures within the northeastern part of the monzonite porphyry stock strike parallel to the elongation of the stock and dip northwest at steep angles. The stock in this area appears to dip northwest also and was emplaced, at least in its upper part, as a tabular body.

Vertical joints parallel the boundaries of the two andesite stocks in the northeastern part of the area. The joints are best developed in the northernmost stock (fig. 3).

ORE DEPOSITS

Deposits of uranium-bearing nickel-cobalt-silver ore in the Black Hawk district occur in fissure veins, most commonly in the quartz diorite gneiss. The veins are numerous over an area about one mile wide and two to three miles long contiguous to the southeast side of the Twin Peaks monzonite porphyry stock. Two intersecting systems of veins appear to be present, one striking north to north-northeast and the other striking northeast to east. Ore minerals found in the veins are pitchblende, native silver, argentite, nickel and cobalt sulfides and arsenides, and small amounts of other sulfides; the gangue minerals are pyrite, carbonates, and some quartz and barite. All the major silver producers, with one exception, are known to contain nickel and cobalt minerals and pitchblende.

The ore deposits belong to the nickel-cobalt-native silver ore type described by Bastin (1939) and are similar to the major pitchblende-producing deposits at Joachimsthal, Czechoslovakia, and Great Bear Lake, Canada.

Mineralogy

The vein minerals that have been reported from the Black Hawk district are listed in table 1. This list has been compiled in part from previous reports; the minerals that have been observed by the present writers are indicated in the table.

All the mines were inaccessible in 1951 and 1952. Only a few of the ore minerals were found on the dumps. Thus little information could be gathered in the field relative to the kind and quantities of the vein minerals and their paragenetic relationships. Most of this information also is taken from previous published and unpublished reports.

Pitchblende is present on the dumps of the Black Hawk and Alhambra mines. Radioactivity was noted on the dumps of the Rose and Good Hope mines and at 5 other localities (fig. 4), but no uranium minerals have been identified. The pitchblende at the Black Hawk mine, in the specimens observed, occurs as black shiny grains less than 2 mm in diameter, intimately associated with sphalerite, a nickel arsenide (probably nickel skutterudite), and other ore minerals. The minerals were sent to a Geological Survey laboratory for identification by X-ray and polished section methods.

Native silver is the most abundant ore mineral in the veins. Masses as much as 60 to 70 feet long, 6 to 18 inches wide, and 1 to 2 feet thick are reported (Hess, 1917, p. 753). The silver is massive and arborescent. According to Bastin (1939, p. 27), silver in deposits of this type is generally primary.

Argentite, which was a commercially important ore mineral at the Black Hawk and Rose mines (Weed, 1917, and Anonymous, 1917), is present as fillings in fractures at the Alhambra mine (Leach, A. A., 1916). According to Leach (1916) crystals of argentite occurred on the niccolite and carbonate gangue at the Alhambra mine.

Table 1.--Minerals reported from the Black Hawk district.

Name	Chemical formula
Ore minerals	
Pitchblende*	UO_2
Native silver*	Ag
Argentite	Ag_2S
Cerargyrite	AgCl
Proustite	$3Ag_2S.As_2S_3$
Pyrargyrite	$3Ag_2S.Sb_2S_3$
Pyrostilpnite	$3Ag_2S.Sb_2S_3$
Niccolite*	NiAs
Millerite	NiS
Skutterudite**	$CoAs_3$
Nickel skutterudite**	$(Ni, Co, Fe)As_3$
Smaltite (?)	$CoAs_2$
Chloanthite (?)	$NiAs_2$
Erythrite	$Co_3As_2O_8.8H_2O$
Annabergite	$Ni_3As_2O_8.8H_2O$
Rammelsbergite*, ***	$NiAs_2$
Sphalerite*	ZnS
Chalcopyrite	$CuFeS_2$
Galena*	PbS
Stannite	$Cu_2S.FeS.SnS_2$
Bismuthinite	Bi_2S_3
Gangue minerals	
Pyrite*	FeS_2
Calcite*	$CaCo_3$
Dolomite*	$CaMg(CO_3)_2$
Siderite	$FeCO_3$
Rhodochrosite	$MnCO_3$
Manganocalcite	$MnCO_3$
Ankerite*	$CaCO_3.(Mg, Fe, Mn)CO_3$
Barite*	$BaSO_4$
Quartz*	SiO_2

* Minerals observed by the writers

** Minerals possibly observed by the writers

*** Tentatively identified as rammelsbergite by the U. S. Geological Survey

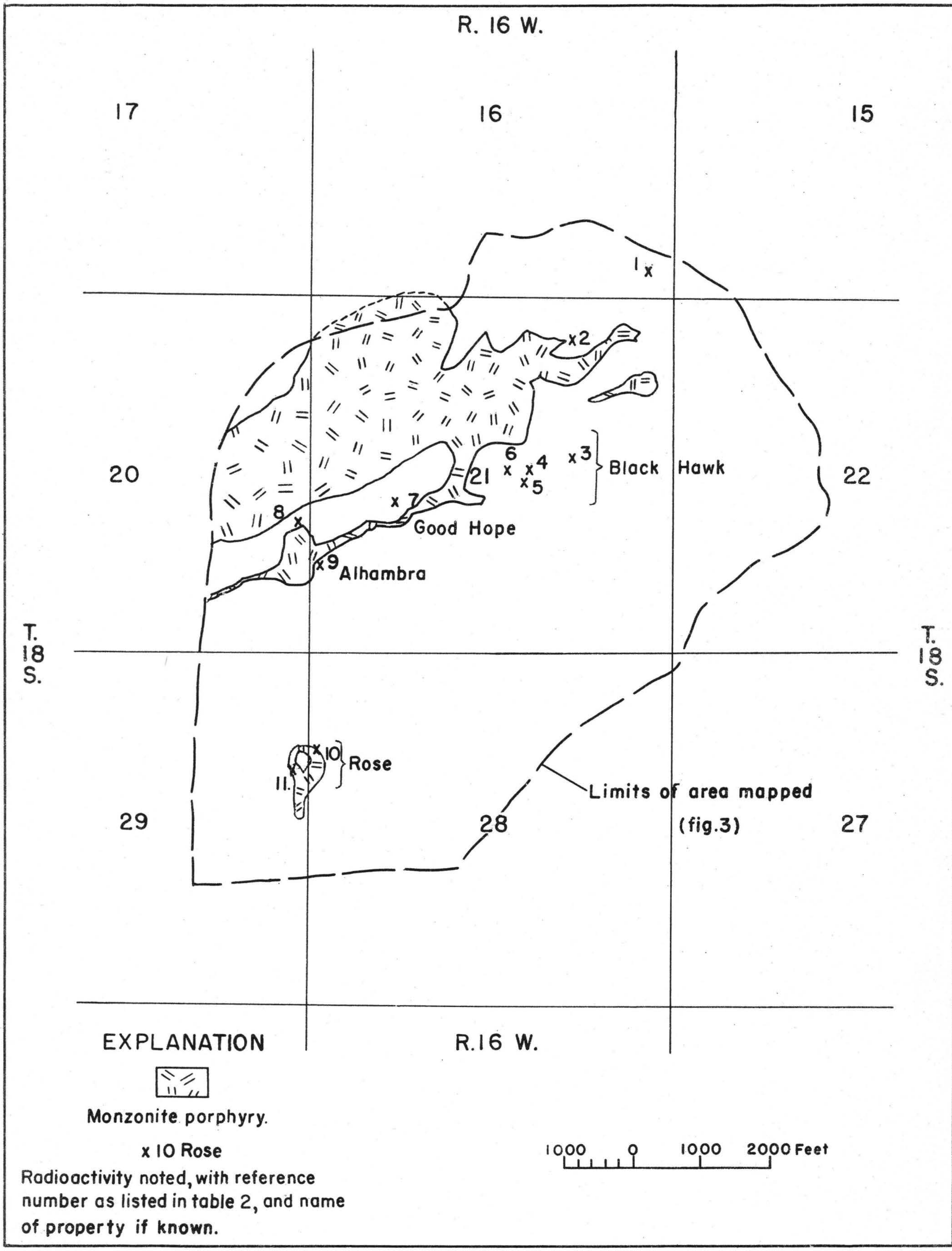

FIGURE 4.– RADIOACTIVE LOCALITIES IN THE BLACK HAWK DISTRICT, NEW MEXICO, AND THEIR RELATIONSHIP TO THE MAIN MASSES OF THE MONZONITE PORPHYRY.

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Cerargyrite, proustite, pyrargyrite, and pyrostilpnite are reported only from the Rose mine (Anon. 1917). The cerargyrite was reported in the upper levels and the antimonial sulfides of silver on the 200-foot level. Appreciable amounts of antimony are present in a specimen from the Black Hawk dump (table 3).

Nickel and cobalt minerals are reported from all mines for which records are available, namely the Black Hawk, Alhambra, and Rose mines. Leach (1916) describes millerite at the Alhambra mine as tiny capillary crystals containing some silver. Niccolite associated with native silver and argentite is reported from the Black Hawk and Alhambra mines. Hess (1917, p. 753) reports that "in one place in the Alhambra vein a shoot, --from 2 to 3 feet wide is said to have carried from 15% to 20% nickel, in the form of niccolite, and the ore was rich in silver." In general skutterudite and nickel-skutterudite appear to be the major primary nickel and cobalt minerals in the district. The only other occurrence of skutterudite in the United States listed by Ford (1932, p. 437) is at Franklin, N. J., and nickel-skutterudite is known in the United States only from the Black Hawk district, its type locality. According to Waller and Moses (1892), who first described this mineral, nickel-skutterudite from the Black Hawk mine is a silver-gray granular mineral with a tubercle structure, the interior of the tubercle being commonly filled with carbonate. Waller and Moses (1892), and Krieger (1935) state that native silver also fills the tubercle. Smaltite and chloanthite have been reported from the Rose and Alhambra mines (Leach, 1916), but probably were confused with skutterudite and nickel-skutterudite (Northrop, 1942, p. 283). Erythrite and annabergite, the hydrous cobalt and nickel arsenates, form crustiform masses at the Alhambra mine (Leach, 1916) and have been found on some of the dumps.[1]

[1] Storms, W. R., and Wright, I. L., personal communication.

Sphalerite may be present in appreciable quantities in the lower levels of the Black Hawk mine (Weed, 1917). The other ore minerals are of minor importance, and little is known of their occurrence and characteristics.

The principal gangue minerals reported in the veins are calcite, dolomite, siderite, and ankerite; less abundant gangue minerals include barite, quartz, rhodochrosite, and mangano-calcite. Black manganiferrous oxide, containing some iron, is present on some of the dumps (Storms, 1949).

Distribution of the veins

Veins are abundant within the Black Hawk district. In general they are limited on the northwest edge of the mapped area by the stock of monzonite porphyry in the vicinity of Twin Peaks, and on the northeast by the Beartooth quartzite. The veins are younger than both these rocks units, and a few veins cut them.

Most of the veins in the district are confined to any area approximately one mile wide that lies contiguous to the southeast side of the Twin Peaks monzonite porphyry stock (fig. 4). At the Black Hawk, Alhambra, Rose, and Silver King (Hobson) mines, and at a deposit 1,100 feet south of the Black Hawk Shaft, the ore deposits are along faults in the quartz diorite gneiss. The Alhambra deposit and the deposit northwest of the Alhambra mine are adjacent to a small stock-like body which is probably a cupola on the Twin Peaks stock.

The distribution of the uranium-bearing veins in a zone contiguous to the southeastern side of the Twin Peaks stock suggests there may be a similar zone on other sides of the stock, and prospecting in these areas might be productive. Prospecting to the southwest along the continuation of the mineralized zone might result in the finding of additional deposits containing nickel, cobalt, and uranium minerals.

The veins are most common in the quartz diorite gneiss and in the granite. They are generally absent in the quartzite and schist, and in the monzonite and quartz monzonite. Ore shoots are reported to be almost entirely confined to the gneiss.

The veins occupy faults and fractures and thereby reflect the structural pattern of the district. An examination of the vein pattern reveals two intersecting sets of veins, one trending north to north-northeast, and the other trending northeast to east. The north-northeast set of veins is best developed along the two north-northeast belts of faulting, but the Alhambra vein and the sub-parallel veins south and southwest of the Alhambra mine probably also belong to this set. The northeast-trending veins are arranged in three belts: one along the southeast side of the Twin Peaks stock, that widens northeastward to include the Black Hawk vein; another that extends from the Rose mine to just south of the southernmost andesite stock in the northeastern part of the area; and a third in the southern part of the area. These are not continuous belts but are indicated by numerous discontinuous parallel and sub-parallel veins. Toward the northeast they trend more easterly, particularly in the southern belt.

The ore minerals are mostly confined to the northeast set of veins, but the Alhambra vein, one of the most productive, is a north-northeast vein. There appears to be no correlation between the intersection of the two sets of veins and the presence of ore minerals. The northeast-trending veins, which in general parallel the schistosity of the gneiss, appear to be cut by the north-northeast veins, but the relationships are obscure in many places.

Character of the veins

The veins in the Black Hawk district are fissure fillings along faults and fractures with only minor replacement of the wall rock. They are similar throughout the district and differ only in the presence or absence of some of the ore minerals. On the geologic map (fig. 3) the veins are divided into three groups: 1) veins known to contain uranium, silver, nickel, and cobalt minerals, 2) veins known to contain silver, nickel, cobalt, or silver minerals_/ and 3) veins not known to contain any ore minerals.

_/ Information pertaining to deposits that contain silver, nickel, and cobalt obtained from A. A. Leach by oral communication, 1953.

This division is based only on the known presence of the specific metals. Many of the veins containing nickel, cobalt, or silver minerals may also contain uranium minerals, and many of the veins mapped as barren veins may contain ore minerals in unobserved portions. A single vein may in part belong to one group and in part belong to another group. The information on the character of the veins and the mineralogy, except that deduced from surface observation, is taken from old reports by Weed (1917), Lidstone (1917), and Leach (1917).

Many of the veins are only a foot or less in width, but they may open up suddenly into ore shoots three to ten feet in width. The veins are wider in the quartz diorite gneiss and granite and pinch noticeably upon entering the monzonite porphyry. Many of the veins can be followed for more than 1,000 feet, but others are only a few hundred feet long. The greatest vertical extent known is in the Black Hawk vein which has been mined to a depth of 600 feet vertically below the collar of the shaft and which crops out to the northeast on ground 175 feet higher than the collar of the shaft.

The veins are inconspicuous in the outcrop and are marked generally by soft brown-stained carbonate fillings. In places a crude banding is developed, but most commonly the vein filling lacks any definite structure. Oxidation is not deep, and primary minerals are found within a few feet of the surface. The boundary between barren gangue minerals and ore shoots rich in silver is sharp. The ore-shoots within the veins are reported to be "poddy" and lense-like in character and do not conform to any known pattern.

Carbonates comprise most of the vein filling and are associated with some quartz, fragments of the country rock, and locally ore minerals. The carbonates, which are chiefly calcite, dolomite, siderite, and ankerite, weather brown in the outcrop. The quartz is generally a dull wax-like chert or chalcedony; the rock fragments are mostly altered gneiss. The ore minerals are chiefly native silver, argentite, and nickel and cobalt minerals, with a small amount of base metal sulphides present. On the surface small specks of galena, and small amounts of native silver comprise the metallic minerals. In the major mines the pryite was common only in the waste, and galena was reported to be scarce.

Native silver was abundant in the veins in the upper portions of the mines and comprised the major portion of the ore. Argentite increased in the lower levels, and nickel and cobalt minerals appeared below 100 feet. Pitchblende in the veins is probably associated with the nickel and cobalt minerals.

Radioactivity

Almost all pits, shafts, adits, and dumps that were accessible in the Black Hawk district in 1952 were examined with a Geiger counter, equipped with a 2 by 20-inch copper probe. Many of the deeper shafts were tested by lowering the probe, attached to a 100-foot cable, into the shaft. The localities that show anomalous radioactivity are listed in table 2 and are shown in figure 4.

A black shiny mineral in a specimen from the dump of the Black Hawk mine (locality 6) was identified in the field as pitchblende. This identification was later confirmed by X-ray powder analyses. An orange incrustation that coats the surface of one of the specimens from the dump of the Alhambra mine (locality 9) was identified in the field as a secondary uranium mineral. Pitchblende was later identified by the laboratory in this and another specimen from this locality. No uranium minerals were identified in the specimens from localities 4 and 7. The chemical analyses of specimens from localities showing anomalous radioactivity are shown in table 3.

Comparison with foreign deposits

Nickel-cobalt-native silver deposits have been described from the Erzegebirge region of Saxony and Czechoslovakia, from elsewhere in Germany, from Hungary, Switzerland, Sardina, France, Portugal, England, South Africa, Canada, and Mexico, and from Wickenburg, Ariz. and the Black Hawk district, N. Mex. in the United States, (Bastin, 1939, p. 3-19). At some of the deposits in the Erzegebirge region, at Great Bear Lake, Canada, at Cornwall, England, and at Black Hawk, pitchblende occurs with the nickel, cobalt, and silver minerals. The deposits at Joachimsthal, Czechoslovakia, and Great Bear Lake, Canada comprise two of the major pitchblende districts in the world. A brief description of these deposits and comparison of them with the Black Hawk deposits may be of value.

At Joachimsthal, two intersecting vein systems, the north-south "Midnight" veins dipping west, and the east-west "Morning" veins dipping north cut pre-Cambrian schists. The "Midnight" veins cut the east-trending schistosity of the schists and are offset by minor faults. They are older than the

Table 2.--Localities showing anomalous radioactivity. (See fig. 4.)

Number on fig. 4	Locality	Scale reading: radioactive material 0.2 scale	Scale reading: normal background 0.2 scale
1.	Pit, 450 feet N. 45° W. of SE cor. sec. 16	3	1 1/2
2.	Pit, 1,600 feet S. 68° W. of NE cor. sec. 21	2 1/2	1-1 1/2
3.	Dump, Hunecke shaft, Black Hawk vein	3 1/2-4	1 1/2
4.	Dump, Copper vein, Black Hawk mine	3 1/2	1 1/2
5.	Vein outcrop at shaft, Black Hawk mine	4-5	1 1/2
6.	Dump, Black Hawk mine	5-6	1 1/2
7.	Dump, Good Hope mine	8	1 1/2
8.	Shaft and pit, 750 feet No. 22° W. of Alhambra new shaft, sec. 20	3	1 1/2
9.	Dump, Alhambra mine	5-6	1 1/2
10.	Dump, Red vein adit, Rose mine	3	1-1 1/2
11.	Dump, Main shaft, Rose mine	3	1-1 1/2

Table 3.--Chemical analyses of specimens from localities showing anomalous radioactivity

(See figures 3 and 4 and table 2 for location of localities listed.)

Locality	U_3O_8 (percent)	Ni (percent)	Co (percent)	Ag (ounces per ton)	As (percent) (approximate)	Sb (percent) (approximate)	Cu (percent) (approximate)
No. 4 1/	0.09	trace 3/	trace 3/	2.15	-	0.1 - 1.0	0.1 - 1.0
No. 6 1/	.24	4.23	0.22	8.20	1.0 - 10.0	1.0 - 10.0	-
No. 7 1/	.07	1.58	.48	8.40	1.0 - 5.0	trace 3/	-
No. 9 1/	.15	0.35	.27	3.45	-	-	-
Rose mine dump 2/	-	.07	.08	10.55	-	-	-
Alhambra mine dump 2/	-	.18	.10	34.70	-	-	-

1/ Samples collected by U. S. Geological Survey and analyzed by the New Mexico Minerals Laboratory, Silver City, New Mexico

2/ Samples collected and analyzed by the U. S. Bureau of Mines

3/ Indicates less than 0.001 percent

"Morning" veins. Most of the pitchblende is found in the "Midnight" veins - the lines of intersection of the "Morning" veins being particularly favorable for pitchblende bodies. The open vertical portions of the veins are mineralized and the flat places are barren and contain breccia. Veins are mostly 15-60 cm wide and rarely range up to 2 meters in width. Minerals present include pitchblende, native silver, native bismuth, silver sulfides, nickel and cobalt sulfides, arsenides, sulfarsenides, and sulfantimonides, copper sulfides, galena, sphalerite, pyrite, specularite, quartz, fluorite, calcite, dolomite, siderite, ankerite, and barite. Within the ore bodies pitchblende increases with depth. Silver minerals are more abundant in the upper levels, and nickel and cobalt minerals at intermediate levels. The increase of pitchblende with depth may be due in part to wall-rock control. Near the veins the biotite almost disappears from the host rock and is replaced by muscovite. The dolomite and calcite in the veins is colored reddish-brown near pitchblende. The pitchblende is older than the quartz and younger than the dolomite; associated sulfides are partly older and partly younger than the pitchblende. Only veins which contain dolomite contain pitchblende. The mineralization is considered to be Carboniferous in age and is generally believed to be associated with the pitchblende-bearing Eibenstock granite. (Bastin, 1939, p. 3-10, Everhart and Wright, 1953, p. 79-80, Bain, 1950, p. 303-304).

At Great Bear Lake several parallel veins cut pre-Cambrian metasediments and metavolcanics. The ore shoots are influenced by the wall rock and by changes in strike of the shear zone, or by both. Ore minerals include pitchblende, native silver, native bismuth, nickel and cobalt arsenides, sulfides, and sulfarsenides, molybdenite, sphalerite, galena, pyrite, copper-bearing sulfides, silver sulfides, and manganese and iron oxides. Gangue minerals include dolomite, rhodochrosite, witherite, barite, and quartz. Pitchblende occurs in bodies up to 20 inches wide and 40 feet long. Alteration is prominent near the veins. The wall rock within 4 to 5 feet of the vein is colored red by hematite, and the texture is practically obliterated. The greatest alteration effects are in the quartzose sediments. Magnetite is localized around the vein deposits, and the uranium deposits are related to a quartz-hematite period of mineralization. The pitchblende is earlier than most of the other minerals, and the native silver is late. The mineralization is considered to be pre-Cambrian in age and may be related to a nearby intrusive granite. (Bastin, 1939, p. 3-6, 15, Everhart and Wright, 1953, 81, 85, Bain, 1950, p. 300-301).

The assemblage of minerals in the Black Hawk district is almost identical to that at Joachimsthal. The predominance of native silver in the ores, appreciable quantities of argentite and the cobalt and nickel sulfides and arsenides, and minor amounts of other silver sulfides, chalcopyrite, galena, sphalerite, pyrite, bismuth, and pitchblende are common to the deposits in both areas. The gangue minerals too are identical except that fluorite has not been observed at Black Hawk. The mineral assemblage at Great Bear Lake is also remarkably similar to that at Black Hawk and differs chiefly in the presence of minor amounts of molybdenite and some witherite, and in the apparent absence of calcite, siderite, and ankerite. The iron and manganese oxides found on some of the dumps in the Black Hawk district have their analogies in the iron and manganese oxides at Great Bear Lake and in the iron-manganese veins at Joachimsthal, some of which seem to grade into the nickel-cobalt-silver veins.

Many other features of the veins are similar in the three districts. The veins at Great Bear Lake and at Joachimsthal are mostly short and narrow, and open suddenly into wide high-grade ore shoots. This feature is characteristic of the Black Hawk deposits. The ore in all three districts has filled open spaces with little or no replacement of the wall-rock. It is confined mostly to foliated rocks, although in the Black Hawk district the rocks are gneiss rather than schist. The association of pitchblende with hematitic alteration is striking at Great Bear Lake and Joachimsthal, and the reddish-brown staining of the dolomite has been used as a guide to pitchblende by the miners in the Erzegebirge region. In the Black Hawk district narrow reddish-stained bands within the Alhambra mine have been reported, but their relationship to pitchblende is unknown. No other information is available due to the inaccessibilty of the underground workings.

DESCRIPTION OF MINES AND PROSPECTS

Black Hawk Mine

Principal features

The Black Hawk mine, the largest mine in the district, is along the Black Hawk vein, which is the largest vein on the Black Hawk property (fig. 5).

The workings in the Black Hawk mine are inaccessible. The Black Hawk No. 1 shaft is in the bottom of a dry gulch and is filled with sand and debris. Only a few pipes sticking up above the sand show its location. Information on the underground workings and the nature of the vein has been obtained from old reports (Weed, 1917, Leach, 1917, Lidstone, 1917).

The Black Hawk No. 1 shaft, the principal opening on the Black Hawk vein, was sunk on the Black Hawk vein to the eighth level -- to a depth of 497 feet. The shaft is vertical above the second level, but it is inclined 60° N. 20° W. below that level. An aggregate of about 3,000 feet of drifts were cut on 8 levels; most of these workings are east of the shaft. At the east end of the eight level a winze, inclined about 85° S., was sunk for a distance of 150 feet (fig. 6). The ninth and tenth levels, 50 feet vertically apart, were driven from the winze. A crosscut on the second level extends about 120 feet north to the Copper vein.

The Black Hawk No. 2 shaft, also filled, is about 300 feet southwest of the Black Hawk No. 1 shaft. It is 100 feet deep, with short workings on the 100-foot level. It probably is not on the Black Hawk vein. The Hunecke shaft, 800 feet northeast of the Black Hawk No. 1 shaft, is on the Black Hawk vein but is not connected with the other workings. The shaft is caved and no information on the underground workings is available.

The Black Hawk vein strikes N. 70° E. and dips 60° to 70 NW. According to the mine maps the dip flattens with depth. The vein can be followed for more than 1,000 feet on the surface and has been followed underground for as much as 700 feet (figs. 5 and 6). Ore has been mined in the vicinity of the No. 1 shaft, for about 500 feet along the strike and at least 600 feet down dip. Ore has been mined also at other localities along the vein.

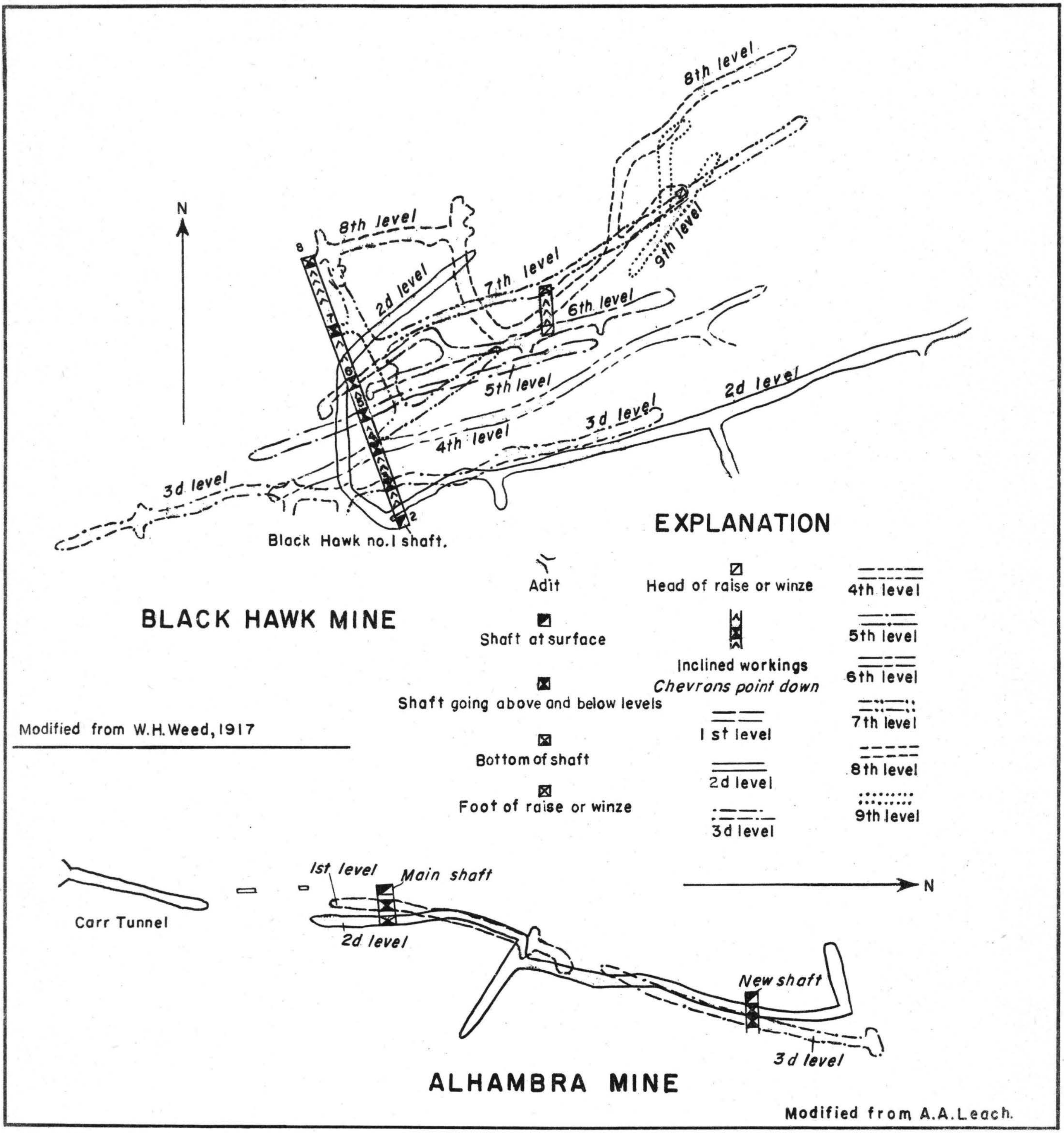

FIGURE 6.- UNDERGROUND WORKINGS OF THE BLACK HAWK AND ALHAMBRA MINES

100 0 100 Feet

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The vein normally ranges from an inch to about a foot in width but the ore shoots are from 3 to 10 feet wide. The vein consists of a series of imbricate and subparallel fractures. The high-grade ore within the ore shoots is in streaks and bunches separated by low-grade ore.

On the eighth level a fault that strikes N. 78° E. and dips about 30° NW appears to displace the vein 30 feet to the south and to the left. The vein segment below the fault dips about 85° S. The winze, sunk from the eighth level, is along this segment of the vein. The correlation of the veins above and below the flat-dipping fault is uncertain because the two segments dip in opposite directions.

The mine workings indicate that although the ore shoots in the upper levels do not persist downwards, other ore shoots of as great or greater length and width were found on the lower levels (Weed, 1917)

According to Weed (1917) and Leach (1917), the ore occurs as fissure fillings, and there is only minor replacement of the wall rock. Included fragments of country rock are common, but crusts of ore around the fragments are rare. The vein contains a central core of carbonate and quartz, bordered by a few inches of altered wall rock, and opens abruptly into the wide ore shoots without any apparent change in the general character of the vein. The ore within the shoots was mainly altered gneiss netted with tiny veinlets of ore minerals. The high-grade ore was in streaks and bunches, principally along the footwall.

Native silver constituted 80 per cent of the value of the ore that was mined. Appreciable quantities of argentite were present, and galena, pyrite, chalcopyrite, and sphalerite were minor constituents. Niccolite and smaltite are recorded, but most of the nickel and cobalt are probably present as nickel skutterudite (Northrop, 1942, p. 283). Old reports state that the nickel minerals were found below the 100-foot level (Waller and Moses, 1892, p. 49). An analysis of a 100-pound sample taken in 1917 by E. D. Lidstone (1917) from the bottom of the winze and analyzed by Smith, Emery and Company, San Francisco, California is as follows:

Bismuth	Present, small amounts
Arsenic	Present, large amounts
Antimony	Traces
Copper	Trace
Nickel	8.92 percent
Cobalt	0.90 percent
Zinc	8.81 percent
Silver	2,542.00 ounces per ton

No analysis for uranium was made on this sample, but two specimens of high-grade massive silver from the mine tested by the writers are radioactive. These samples were from the mineral collection of Messrs. Ira E. Wright and William Rowlee of Silver City and their source in the mine is unknown. Pitchblende from the dump is associated with a nickel arsenide and sphalerite. One of the specimens of high-grade silver and the specimen of ore containing pitchblende from the dump were checked with a Geiger counter equipped with a 6-inch probe. A count of 10 on the 0.2 scale was recorded for the high-grade silver specimen and a count of 5 on the 2.0 scale was recorded for the specimen of ore from the dump. The background count was 1 on the 0.2 scale. The specimen from the dump contained 0.24 percent U_3O_8 (table 3, specimen no. 6). Radioactive material also was found on the dump of the Hunecke shaft (fig. 4 and table 3).

The Copper vein on the Black Hawk property strikes N. 50°E. and dips about 80° to 85° NW. It may intersect the Black Hawk vein to the west of the Black Hawk No. 1 shaft (fig. 5). It is explored by surface trenching, shallow shafts, and by a 100-foot drift from the second level of the Black Hawk No. 1 shaft. The Copper vein did not contain silver in the underground workings, according to Weed (1917); however, radioactive material was found on the dump of the westernmost of the surface workings (table 3 and fig. 4).

Results of drilling

In May 1952, the Black Hawk Consolidated Mines Company began a program of diamond drilling at the Black Hawk Mine. Three 1,000-foot holes were drilled to intersect the Black Hawk vein below the mine workings. Holes No. 1 and 2 were directed N. 20° W. and inclined 70°; hole No. 3 also was directed N. 20° W. but was inclined 63° (figs. 5 and 8). The three holes were alined parallel to the strike of the vein. The position of underground workings was determined from mine maps made from a Brunton and tape survey by Leach in 1917.

Diamond drill holes Nos. 1 and 2 were drilled simultaneously. Although calculated to intersect the vein at depths of about 750 feet and 800 feet respectively, the holes were drilled to 1,000 feet without intersecting any vein material recognizable as the Black Hawk vein. Hole No. 3 passed through a vein containing carbonate gangue minerals and a few specks of galena, pyrite, and native silver between 641 and 651 feet. Assays showed a trace of silver but no cobalt or nickel. The sample was not assayed for uranium, but the vein material showed no anomalous radioactivity. At about 750 feet the hole passed through 6 inches of carbonate gangue containing galena, pyrite, and niccolite. This material was not assayed. It showed no anomalous radioactivity.

All three holes penetrated quartz diorite gneiss cut by dikes of monzonite porphyry, pegmatitic granite, and diabase. Pyrite was abundant in seams and disseminated in the gneiss, and narrow calcite veinlets were present throughout the core. The core showed no anomalous radioactivity.

In February 1953, the three holes were checked by gamma-ray logging. Results were negative.

The failure of holes Nos. 1 and 2 to intersect the vein may have been due to deflection of the hole or to the inaccuracy of the underground maps upon which the location, inclination, and direction of the drill holes were based. Although hole No. 3 intersected two carbonate veins, the thicker of which resembles the Black Hawk vein, attempts to correlate the intersection with position of the Black Hawk vein as shown on the underground maps were unsuccessful.

Alhambra mine

The Alhambra mine (fig. 7) has been worked by at least four shafts and an adit driven along the vein (Storms, 1949, Leach, 1950). The New shaft is reported to be 420 feet deep, with short levels at 25, 50, 100, and 150 feet (fig. 6). A total of about 750 feet of drifts on these levels, are shown on old maps. Deeper levels that do not appear on available maps are reported. The shaft is caved around the collar and water stands about 40 feet below the surface.

The Alhambra vein strikes N. 15° E., dips 80° to 85° SE, and is from 1 to 5 feet wide at the surface. The vein cuts quartz diorite gneiss near a large easterly trending monzonite porphyry dike. The vein can be traced south from the New shaft for about 500 feet. A weakly mineralized vein, possibly an extension of the Alhambra vein, is found about 400 feet north of the shaft and can be followed northeasterly for about 300 feet.

Massive native silver, similar to that mined at the Black Hawk mine, was the chief ore mineral in the Alhambra vein. Mr. Alex Woodburn, the mine superintendent at the time of abandonment, reported there was good ore on the 350-foot and 400-foot levels of the mine when it was shut down (Leach, 1950). Niccolite is reported to be associated with the silver. Pitchblende was found on the dumps (fig. 4, tables 2 and 3) by the writers and had previously been reported by Leach (1950).

Rose mine

The Rose mine is in the northeastern part of section 29, in the southwestern part of the mapped area (fig. 3). The mine has not been operated since 1889 and the shaft is now filled. High-grade silver ore and ore containing nickel and cobalt minerals were reported to remain in the lower workings when the mine was abandoned (Anonymous, 1917). The mine was worked from a shaft sunk near the intersection of two veins, the Red vein and the Spar vein, and by an adit driven on each vein. The shaft is reported to be 200 feet deep with levels at 50 feet and 100 feet on the Spar vein, and levels at 150 feet and 200 feet on both veins. The most extensive workings were on the 150-foot level.

Both veins at the Rose mine cut granite, quartz diorite gneiss, and monzonite porphyry (fig. 3). The Spar vein strikes about N. 75° E. and dips 75° to 80° NW. At the surface it can be traced for about 700 feet east and 400 feet west of the old Rose shaft. The Red vein strikes N. 30° E. at the shaft but at a point 200 feet northeast it turns N. 70° E. and is mappable in this direction for about 250 feet. It dips 60° to 75° SE. The veins range from 2 1/2 feet to 4 feet in thickness; they have well defined hanging walls and irregular footwalls.

The ore consists of native silver, argentite, and cerargyrite in a quartz and carbonate gangue. High-grade silver ore that contains a large percentage of nickel and cobalt was mined on the 150-foot level. On the 200-foot level the argentite is associated with pyrargyrite, proustite, and pyrostilpnite.

Radioactive material was found on the dumps of the main Rose shaft and at the portal of the adit on the Red vein (fig. 4 and table 2).

Silver King (Hobson) mine

The Silver King mine, formerly known as the Hobson mine, is about 1,300 feet north of the Black Hawk mine (fig. 3). According to Holmquist and Sheridan (1945), the vein was worked from an adit 300 feet long and an inclined shaft. A raise and a winze about 200 feet from the portal of the adit explore the vertical extent of the vein. Part of the adit is accessible.

The vein in a fault that strikes N. 50° to 65° E. and dips 65° NW cuts quartz diorite gneiss. The fault intersects the main body of the monzonite porphyry stock 200 feet northeast and 150 feet southwest of the shaft. Northeast of the shaft a quartz diorite dike is along the contact of the monzonite porphyry and the quartz diorite gneiss.

In the adit the vein has a well-defined hanging wall and is along a strong shear zone for 200 feet northeast of the portal, and along an irregular series of branching fractures for an additional 100 feet. It is from 2 to 4 feet wide and is reported to have been followed for 300 feet down the dip. Argentite, associated with some native silver, was the principal ore mineral. No nickel, cobalt, or uranium minerals are recorded, and none were found on the dumps.

Good Hope mine

The Good Hope shaft, now filled, is about 1,900 feet S. 82° W. of the Black Hawk No. 1 shaft (fig. 3). Lindgren and others (1910, p. 325) state that the workings attained a maximum depth of about 120 feet. The vein, which strikes N. 65° to 75° E. and dips 65° SE., is in quartz diorite gneiss, about 400 feet south of the monzonite porphyry stock. Radioactive material, which could not be identified mineralogically, was found on the dump by the writers. Chemical analysis of the radioactive material show uranium, nickel, silver, and cobalt (fig. 4, and tables 2 and 3).

Other prospects

Many other veins in the district have been explored by surface cuts and shafts (fig. 3). Waste rock on some of the dumps shows some ore minerals, but production of ore has probably been small. Cobalt bloom has been reported (Storms and Wright, 1951, oral communication) on the dump of a shaft 1,100 feet south of the Black Hawk shaft. Radioactive material was found at two small pits, 3,550 feet N. 30° E. and 2,200 feet N. 18° E. of the Black Hawk No. 1 shaft. Radioactive material was found also in a shallow shaft and pit, 750 feet N. 22° W. of the Alhambra New shaft.

SUMMARY DISCUSSION AND SUGGESTIONS FOR PROSPECTING

Pitchblende has been found on the dumps of the Black Hawk and Alhambra mines; five other localities contain unidentified radioactive minerals. The pitchblende and the unidentified radioactive minerals occur in veins that contain silver, nickel, and cobalt minerals. All the mines of the district are inaccessible and information on these minerals can be obtained only from old reports and records and from old mine dumps which have been picked over for many years by mineral collectors. The old reports indicate that nickel and cobalt minerals were present with the silver at all the larger deposits, but no mention is made of uranium. Nickel and cobalt minerals were found on the dumps of only a few of the deposits where they are reported to be present. Pitchblende, where found, is associated with the nickel and cobalt minerals. This association of pitchblende with the nickel and cobalt minerals possibly indicates that the pitchblende may be as widely distributed as the nickel and cobalt minerals.

The possibilities for finding commercial ore bodies are difficult to evaluate. Mining in the district was stopped in the 1890's because of the high costs of mining and a drop in silver prices; there is no indication that the ore had been completely mined out. According to old reports (Weed, 1917; Leach, 1916; Lidstone, 1917; Anonymous, 1917) much high grade silver ore remains in the mines; nickel and cobalt minerals are present in the lower parts of the mines. Some reports (Weed, 1917; Anon., 1917) indicate that the silver content of the ore decreases as the nickel and cobalt content increases, and that considerable low silver, high nickel-cobalt ore remains in the mines.

The ore deposits in the Black Hawk district are similar to the nickel-cobalt-native silver deposits at Joachimsthal, Czechoslovakia, Great Bear Lake, Canada, Cobalt, Ontario, and Cornwall, England, (Leach, 1916; Lindgren, 1933, p. 600-610; Bastin, 1939). Native silver, with sulfides and arsenides of nickel and cobalt, and small amounts of chalcopyrite, galena, sphalerite and bismuthinite, in a carbonate gangue, characterize these deposits. The deposits are in narrow veins. Pitchblende is found at all the deposits except Cobalt, Ontario. The geologic and mineralogic similarities of the Black Hawk district to the deposits at the other localities suggest that commercial deposits of uranium, nickel, and cobalt might be found in the Black Hawk district.

Geologic mapping in the district indicates an area of several square miles in which there are many narrow veins from a few hundred to several thousand feet in length. Field observations and available production records and reports indicate ore minerals in many of these veins. Some of the veins contained moderately-sized ore bodies, rich in silver and containing nickel, cobalt, and uranium minerals. The uranium content of the ore bodies is unknown.

The U. S. Geological Survey has no immediate plans for further exploration in this district. However should investigations be made in the future, the following suggestions are presented. It should be remembered that the ore deposits in the Black Hawk district are in fissure veins that pinch and swell both along the strike and with depth. At the Black Hawk and Alhambra mines, the veins generally are from a few inches to a foot in width but are reported to swell abruptly into ore shoots that are from 3 to 10 feet wide. Because of the discontinuous nature of the ore in the veins and the absence of geologic data to determine where ore shoots are localized, results of diamond drilling would be inconclusive. Therefore, it is suggested that any further work should commence with shaft unwatering and rehabilitation followed by mapping and sampling of the veins.

If any mines are considered for exploration and testing, certainly the Black Hawk and Alhambra mines should be included because they are the largest and best known deposits in the district. The Black Hawk mine is accessible by road whereas the Alhambra is more than one-quarter mile from the road over rough terrain. More accurate mine maps and more data on mineralogy and nature of the ore shoots are available for the Black Hawk than for the Alhambra mine. On the other hand the Black Hawk is the deeper mine and has more extensive workings and unwatering of the mine would be more costly. The main Alhambra shaft is caved around the collar and the water level is within 40 to 50 feet of the collar. The main Black Hawk shaft is filled with debris, and the water level in the mine is probably within about 75 feet of the surface. The Alhambra mine has been inactive since 1893; the Black Hawk mine was closed in 1888, but was reopened in 1917. In 1917 the mine was completely unwatered and rehabilitated; it has been shut down since. The workings should be in better condition than those at the Alhambra.

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