Uranium Deposits in the Eureka Gulch Area, Central City District, Gilpin County, Colorado

By P. K. Sims, F. W. Osterwald, and E. W. Tooker

Trace Elements Investigations Report 125

UNITED STATES DEPARTMENT OF THE INTERIOR
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Geology and Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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By

P. K. Sims, F. W. Osterwald, and E. W. Tooker

April 1954

Trace Elements Investigations Report 125

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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(Including master)	70

CONTENTS

ILLUSTRATIONS

TABLES

URANIUM DEPOSITS IN THE EUREKA GULCH AREA, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

By P. K. Sims, F. W. Osterwald, and E. W. Tooker

ABSTRACT

The Eureka Gulch area of the Central City district, Gilpin County, Colo., was mined for ores of gold, silver, copper, lead, and zinc; but there has been little mining activity in the area since World War I. Between 1951 and 1953 nine radioactive mine dumps were discovered in the area by the U. S. Geological Survey and by prospectors. The importance of the discoveries has not been determined as all but one of the mines are inaccessible, but the distribution, quantity, and grade of the radioactive materials found on the mine dumps indicate that the area is worthy of additional exploration as a possible source of uranium ore.

The uranium and other metals are in and near steeply dipping mesothermal veins of Laramide age that cut pre-Cambrian metasedimentary rocks, granite gneiss, pegmatite, and Laramide intrusive rocks. Pitchblende is present in at least four veins, and metatorbernite, associated at places with kasolite, is found along two veins for a linear distance of about 700 feet. The pitchblende and metatorbernite appear to be mutually exclusive and seem to occur in different veins. Colloform grains of pitchblende were deposited in the veins essentially contemporaneously with pyrite. The pitchblende is earlier in the sequence of deposition than galena and sphalerite. The metatorbernite replaces altered biotite-quartz-plagioclase gneiss and altered amphibolite, and to a lesser extent forms coatings on fractures in these rocks adjacent to the veins; the kasolite fills vugs in highly altered vein material and in

altered wall rocks. Much of the pitchblende found on the dumps has been partly leached subsequent to mining and is out of equilibrium. Selected samples of metatorbernite-bearing rock from one mine dump contain as much as 6.11 percent uranium.

The pitchblende is a primary vein mineral deposited from uranium-bearing hydrothermal solutions. The metatorbernite probably formed by oxidation, solution, and transportation of uranium from primary pitchblende, but it may be a primary mineral deposited directly from fluids of different composition from those that deposited pitchblende.

INTRODUCTION

Purpose and scope of this report

The Central City district, Gilpin County, Colo., prior to World War I, was an important domestic source of pitchblende, the black oxide of uranium, but since that time the district has produced no uranium. As early as 1871, pitchblende was noticed on the Wood mine dump in the Quartz Hill area by Pearce (1895); since 1872, when uranium production started, the Quartz Hill area has yielded 324 tons of high-grade ore containing 110,575 pounds of U_3O_8 (Armstrong, in preparation).

During and after World War II, because of the strategic importance of uranium, interest has been revived in the Central City and adjacent mining districts, and accordingly several new discoveries have been made by prospectors and government agencies. Many of the finds are outside of the previously known productive area on Quartz Hill, and some of these appear to be of possible commercial importance.

Uranium was first discovered in the Eureka Gulch area, in the northern part of the Central City district, in 1951 (fig. 1). A prospector found the dump of the adit on the Rara Avis mill site to be radioactive and submitted a sample of the ore to the Atomic Energy Commission. Subsequently, several additional uranium occurrences have been found in this area by the U. S. Geological Survey. Although pitchblende is the uranium mineral in most of the deposits, several from the north slope of Nigger Hill (fig. 3) contain green metatorbernite; this mineral was formerly believed to be sparse in the Central City district. Aside from the McKay shaft, on the R.H.D. claim, the discoveries of radioactive minerals have been made on the dumps of abandoned mines, and in December 1953 none of these mines had been reopened. The Eureka Gulch area formerly yielded gold, silver, lead, zinc, and copper, but mining has been sporadic since World War I, and only the Essex mine in Prosser Gulch was active in 1953.

This report, prepared because of the potential economic importance of the new discoveries in the Eureka Gulch area, presents a preliminary account of the geology and economic aspects of the uranium deposits in this part of the district. A more comprehensive report will be included in a later publication.

Previous geologic studies

Several reports describing the uranium deposits in the Central City district were published before World War I. The most important of these are Pearce (1895), Rickard (1913), Moore and Kithil (1913), Alsdorf (1916), Bastin (1916), and Bastin and Hill (1917). The report by Bastin and Hill gives a comprehensive summary of the information known to that time. Lovering

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REPORT 125

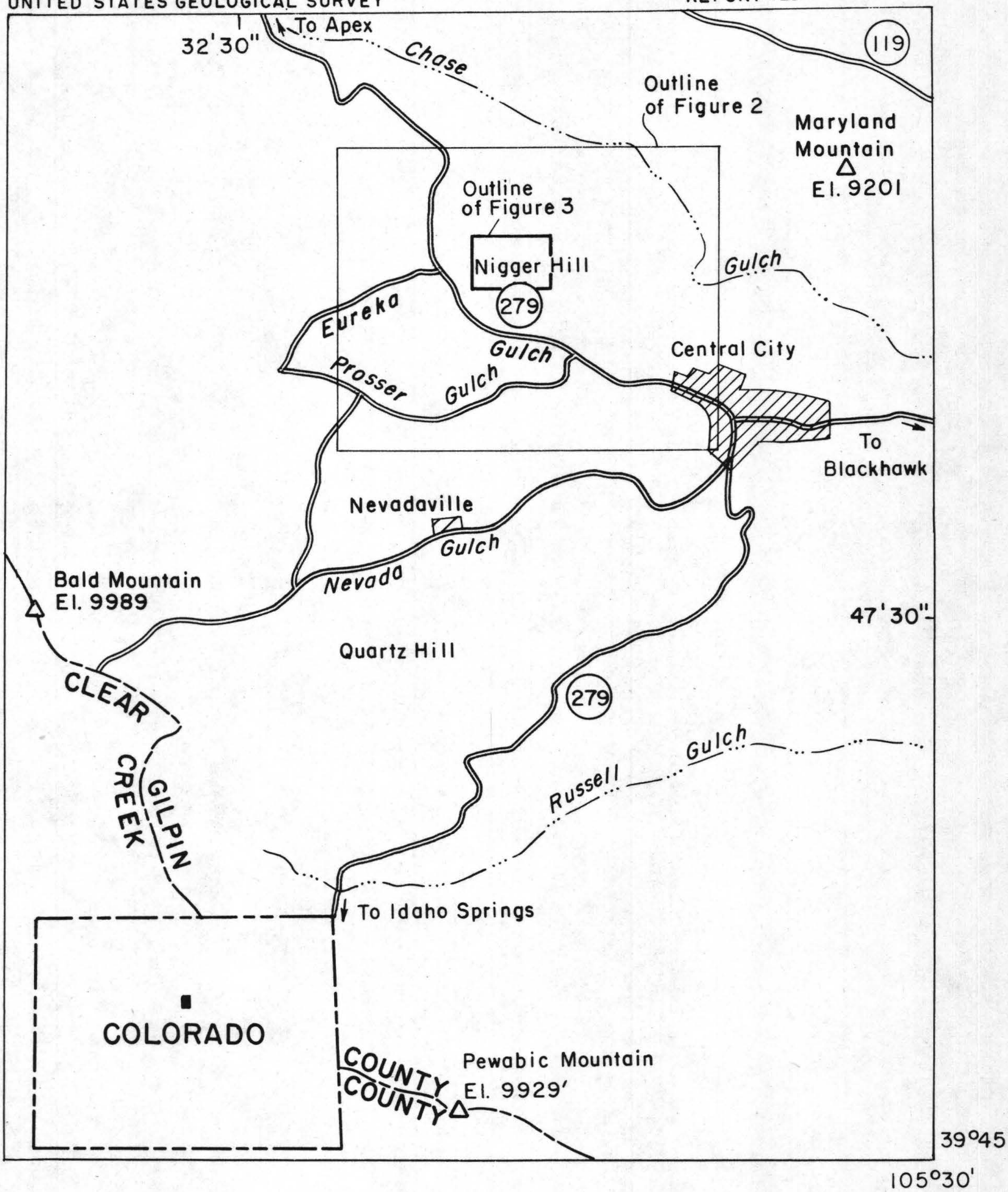

FIGURE I.- INDEX MAP SHOWING LOCATION OF EUREKA GULCH AREA, GILPIN COUNTY, COLORADO

0 1/2 1 Mile

Datum is mean sea level

GPO 833351

and Goddard (1950) described the geology of the entire Colorado Front Range and their report is the most authoritative source of information on the ore deposits of this vast region.

The results of the work of the various government agencies investigating the uranium resources of the Central City region have not, for the most part, been published. A report on the Wood and Calhoun mines (Moore and Butler, 1952) was released, and a report on the Quartz Hill area has been prepared for publication by Armstrong (in preparation).

Field work and acknowledgments

The U. S. Geological Survey's uranium investigations in the Colorado Front Range began in 1944. The work at first was on behalf of the Manhattan Engineer District, and later on behalf of the U. S. Atomic Energy Commission. In 1952 the Geological Survey began a comprehensive geologic study of a 60-square mile area in the Central City and Idaho Springs region, largely on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. As a part of this survey, a systematic reconnaissance for radioactivity, using both a ground scintillation counter and a rate meter with a six-inch probe, was made in the Eureka Gulch area by A. E. Dearth and A. L. Krueger during the 1953 field season. A geologic map of the area (scale 1:6,000) was prepared by P. K. Sims and E. W. Tooker (fig. 2).

During the radioactivity survey most mine dumps in the area were checked; ten were found to contain radioactive materials. These were the Buckley shaft, Bullion No. 2 shaft, Carroll shaft, Claire Marie shaft, J. P. Whitney shaft, adit on Rara Avis mill site, Two Sisters shaft, R.H.D. shaft, St. Anthony shaft and McKay shaft (fig. 3). Aside from the dump on the Rara Avis mill site, none of the localities had previously been reported as radioactive. Because of the possible economic interest in the uranium deposits on Nigger Hill, a detailed map of the north slope of the hill (scale 1:1,200) was made during August and September 1953 by plane table and alidade method by F. W. Osterwald (fig. 3). The accessible mine openings were mapped and sampled by Sims and A. A. Drake in September (fig. 6). E. W. Tooker collected samples of the altered rocks in the McKay shaft workings and on the Two Sisters shaft dump; these samples have been partially studied by X-ray diffraction and microscopic methods. A. E. Dearth and R. H. Campbell of the Geological Survey assisted in the preparation of the plane table map.

The writers are indebted to several local people, and particularly to Messrs. Henry DeLinde, Claude McKay, Van McKay, Joseph Pughes, W. C. Russell, Jr., and Noah Williams for information on inaccessible mines in the Eureka Gulch area. Many of the economic problems of the region were discussed with personnel in the Denver Exploration Branch of the U. S. Atomic Energy Commission.

GENERAL GEOLOGY

Most of the region described in this report is on the northwest flank of a northeast-trending, broad, upright anticline, which is the dominant structural feature in this part of the Central City district (fig. 2). Granite gneiss of pre-Cambrian age, described by Bastin and Hill (1917, p. 30-32), constitutes the core of the anticline. It contains abundant, small, discontinuous, folded layers and lenses of metasedimentary rocks and lenticular bodies of granite pegmatite. Pre-Cambrian metasedimentary rocks, principally sillimanitic biotite-quartz gneiss, which contains conformable layers and large, irregular-shaped bodies of granite pegmatite, flank the granitic core on the northwest. The metasediments and granite gneiss dip gently away from the crest of the anticline and locally are deformed into broad, gentle warps or tight drag folds.

Intrusive porphyritic monzonite and quartz bostonite dikes, Tertiary in age, cut the pre-Cambrian rocks. Most of the dikes occupy northwest-trending and northeast-trending fractures.

Many metalliferous veins cut all the rock types in the Central City district. Most of the veins contain quartz gangue, with lesser carbonate, and have been the source for the gold, silver, lead, zinc, copper, and uranium which have been produced in the district.

Pre-Cambrian rocks

The pre-Cambrian rocks in the Eureka Gulch area consist predominantly of biotite-quartz-plagioclase gneiss, sillimanitic, biotite-quartz gneiss, amphibolite, lime-silicate gneiss, cordierite-anthophyllite-garnet gneiss, granite gneiss, and granite pegmatite. All the rocks except some of the granite pegmatite have been deformed and recrystallized and have a metamorphic texture. Altered biotite-quartz-plagioclase gneiss and amphibolite constitute the host rocks for metatorbernite-bearing uranium deposits on Nigger Hill.

The biotite-quartz-plagioclase gneiss, sillimanitic biotite-quartz gneiss, amphibolite, and lime-silicate gneiss, believed to be of metasedimentary origin, are widespread in the Central City district and the adjacent region. Bastin and Hill (1917) and Lovering and Goddard (1950) included these rocks in the pre-Cambrian Idaho Springs formation. The cordierite-anthophyllite-garnet gneiss, probably also of metasedimentary origin, has not been described previously from this part of the Front Range; so far as known it occurs sparsely in the Central City district. The granite gneiss, as mapped by Bastin and Hill, is a metamorphic rock of uncertain origin. Studies of this rock indicate that it has an average composition of quartz monzonite; accordingly in a later report it will be defined as quartz monzonite gneiss. In this report, however, the writers follow the usage of Bastin and Hill and refer to it as granite gneiss. The granite pegmatite has a simple composition and is clearly younger than the granite gneiss. It is similar and probably correlative to the granite gneiss and pegmatite that is widely distributed south of the Central City district in north-central Clear Creek County (Harrison and Wells, in preparation).

Biotite-quartz-plagioclase gneiss

Biotite-quartz-plagioclase gneiss is not exposed at the surface in the Eureka Gulch area, but it is present in the McKay shaft workings (fig. 6) and on several mine dumps on the north slope of Nigger Hill (fig. 3). The gneiss occurs as generally thin, discontinuous layers and lenses that are widely dispersed through the granite gneiss; locally these layers may be several tens (or a few hundreds) of feet thick and several hundreds of feet long, but generally they are smaller. Nearly all of the rock contains conformable, but locally crosscutting, bodies of pegmatite, a few inches to several feet thick.

The gneiss is a variable, generally medium-grained rock that consists principally of quartz, oligoclase, and biotite. Within the McKay shaft workings the gneiss consists of two principal facies--a light gray, uniform gneiss containing a maximum of 15 to 20 percent biotite and a dark gray, well-layered gneiss containing as much as 30 percent biotite. Individual layers in the mine generally range from 6 inches to 3 feet in width. Soft biotite-quartz schist layers, commonly a foot or less thick, are present at places in the rock. Some parts of the gneiss contain scattered crystals of red garnet.

Altered facies of biotite-quartz-plagioclase gneiss on the dump at the Two Sisters shaft contain discrete crystals of metatorbernite, disseminated through the rock or on fracture surfaces.

Sillimanitic biotite-quartz gneiss

The northwest part of the Eureka Gulch area (fig. 2) is underlain by a variable gneiss that consists principally of biotite, quartz, and calcic oligoclase. It is distinguished from biotite-quartz-plagioclase gneiss, however, by the presence of visible white sillimanite, and by lesser quantities of plagioclase feldspar. Pegmatite bodies, generally conformable to the structure of the gneiss, occur throughout the rock.

Typically sillimanitic biotite-quartz gneiss is a light-gray to dark-gray, medium-grained, granoblastic rock that has a conspicuous gneissic structure because of an excellent preferred orientation of biotite and sillimanite. Weathered surfaces commonly are light gray or silvery gray to gray-brown. The sillimanite occurs as delicate fibers and bunches or in elliptical aggregates intergrown with quartz.

Lime-silicate gneiss

Lime-silicate gneiss consists of massive to layered rocks that principally contain variable quantities of quartz, garnet, and pyroxene, and lesser amounts of hornblende, plagioclase, epidote, apatite, magnetite, and sphene.

Two irregular zones of lime-silicate gneiss crop out on opposite sides of the major anticline, close to the trace of the axial plane (fig. 2). Individual layers within each zone are discontinuous and contorted, and are intimately associated with layers of amphibolite and epidote-rich hornblendic rocks, possibly altered amphibolites.

Cordierite-anthophyllite-garnet gneiss

Rocks composed principally of cordierite, anthophyllite, garnet, cummingtonite, and quartz are present at places within the Central City district, but so far as known, are absent elsewhere in the region. A few small bodies, generally less than 500 feet in length, have been mapped in the Quartz Hill area (Sims, Drake, and Moench, 1953); and one body, near the crest of Nigger Hill, is known in the Eureka Gulch area (figs. 2 and 3). The gneiss is a medium gray, generally medium-grained, but locally coarse-grained, layered rock of variable composition. Fresh surfaces commonly have a greasy, lustrous appearance. Weathered surfaces are grayish brown to reddish brown, and at places are ribbed. One layer is composed almost entirely of coarse, matted or felted anthophyllite and cummingtonite crystals. Cordierite layers, an inch or less thick, paralleling the gneissic structure of the rock, are common.

Amphibolite

Small, discrete, lenticular or pod-like bodies of dark gray to nearly black, medium-grained, equigranular amphibolite are scattered through the granite gneiss and biotite-quartz-plagioclase gneiss. The amphibolite is composed of nearly equal parts of oligoclase-andesine and hornblende, with as much as 10 percent clinopyroxene; accessory minerals include microcline, apatite, sphene, and epidote.

Several long, discontinuous layers of amphibolite are associated with lime-silicate gneiss and make up a conspicuous "stratigraphic marker bed" near the axis of the major anticline. In the McKay shaft workings (fig. 6), contorted pods of amphibolite, ranging from about one foot to seven feet in diameter, occur within biotite-quartz-plagioclase gneiss. For the most part the amphibolite in the mine is largely altered to clay minerals, and it is the principal host rock for metatorbernite.

Migmatite

Interlayered rocks, termed migmatite in this report, consisting of roughly 50 percent biotite-quartz-plagioclase gneiss and 50 percent granite pegmatite were mapped in the McKay shaft workings (fig. 6). The pegmatite forms closely spaced generally conformable layers and lenses, less than a foot to about 3 feet thick, in the gneiss. At places the pegmatite cuts across the foliation of the gneiss.

Granite gneiss

The granite gneiss consists essentially of quartz, plagioclase, microcline, and biotite. The composition varies from granodiorite to quartz monzonite, according to Johannsen's classification (Johannsen, 1939, p. 143-147). It is a distinctive rock type but is highly variable. The rock is generally medium-grained, and on freshly broken surfaces is light gray to dark gray, but generally changes to buff when weathered. Characteristically granite gneiss has a well-defined foliation marked by alternating biotite-rich and quartz-feldspar-rich layers which are a fraction of an inch thick, and by a sub-parallel arrangement of the tabular and platy minerals. Some outcrops of the gneiss, which appear to be massive, show a fair to good preferred orientation of biotite on close inspection; the biotite is more or less evenly distributed through this rock. Some of the granite gneiss contains abundant, closely spaced, relatively continuous mafic layers, but at many outcrops the mafic minerals consist only of discontinuous, parallel streaks. Discrete lenses, layers, and irregular-shaped bodies of metasedimentary rocks, usually only a few tens of feet wide and a few hundreds of feet long, are scattered through the gneiss at places. Younger granite pegmatite intrudes the gneiss.

Granite gneiss is the predominate rock in the area and crops out in the core of the major anticline (fig. 2). Contacts of the gneiss are conformable to the layering of adjacent rock types.

Granite pegmatite

The granite pegmatite is generally white and coarse-grained; it consists predominantly of quartz and feldspar. Magnetite and biotite are conspicuous accessory minerals; magnetite is more abundant and widespread.

Small to large granite pegmatite bodies are generally conformable to the foliation of granite gneiss and sillimanitic biotite-quartz gneiss. The pegmatite bodies within granite gneiss are discrete, discontinuous layers along the limbs of folds and small, irregular shaped masses in the crests of minor folds (fig. 2). Pegmatites in sillimanitic biotite-quartz gneiss are in part discrete bodies, some of which are large enough to be mapped (fig. 2), and in part thin, conformable, discontinuous layers along the foliation.

Tertiary rocks

The intrusive dike rocks in the Eureka Gulch area--monzonite porphyry and quartz bostonite--belong to the Tertiary intrusive sequence in the Front Range, which is among the most radioactive igneous series in the world (Phair, 1952). The quartz bostonites of Eureka Gulch contain from 0.010 to 0.024 percent equivalent uranium (Phair, 1952, p. 31), and are 10 to 20 times more radioactive than the surrounding pre-Cambrian rocks.

Monzonite porphyry

Fresh monzonite porphyry is gray, medium- to fine-grained and contains abundant feldspar phenocrysts. The rock is altered and bleached to gray or white at most places; weathered surfaces characteristically are deeply pitted, where feldspar phenocrysts have weathered out.

A monzonite porphyry dike, generally less than 5 feet thick, crops out at places on the south slope of Nigger Hill (fig. 2). It can be traced from the vicinity of the Tom Martin mine (13) southwestward to the road in Eureka Gulch. A branching dike, which is exposed at places on the south side of Eureka Gulch, probably is correlative. Two analyses from the dike gave 0.001 and 0.002 percent chemical uranium (Phair, oral communication).

Quartz bostonite

Bostonite, a fine-grained rock resembling trachyte, is widespread and conspicuous in the Central City district (Bastin and Hill, 1917, p. 52). Fresh bostonite is lilac-colored to reddish brown, and contains abundant to sparse salmon pink feldspar phenocrysts. Light gray altered and bleached bostonite is common in the district; feldspar phenocrysts are changed to soft, green aggregates of sericite, or to a chalky, white clay mineral, and the groundmass is bleached to gray or white.

Three types of bostonite have been distinguished in the Central City district (Phair, 1952). These are quartz bostonite porphyry, nonporphyritic quartz bostonite, and syenitic bostonite porphyry; only nonporphyritic quartz bostonite is found in the Eureka Gulch area. The nonporphyritic quartz bostonite is shown on figures 2 and 3 as quartz bostonite.

Two long, narrow, branching nonporphyritic quartz bostonite dikes traverse the Eureka Gulch area (fig. 2). One dike trends northwest from the reservoir in Central City, about one mile south of the area shown on figure 2, to Mammoth Gulch, west of Apex, which is about 8 miles north of Central City (Bastin and Hill, 1917, pl. 1). This dike has been called the Nigger Hill dike (Phair, 1952, p. 11). Another dike trends northeast from Bald Mountain, across the center of the mapped area; this has been called the Prosser Gulch dike.

Most nonporphyritic quartz bostonites are uniformly fine-grained, but at a few outcrops they contain visible feldspar phenocrysts. A faint to good planar flow structure parallels the walls of the dikes at most places. Outcrops of the dikes are usually low, rounded ridges mantled with angular fragments of bostonite; even where exposures are poor the dikes can be traced by float.

The Nigger Hill dike is younger than the monzonite because it cuts and offsets the monzonite porphyry on the southeast side of Nigger Hill, about 250 feet northwest of the Iowa mine (no. 18, fig. 2.) The apparent horizontal displacement is 75 feet, the northeast side having moved northwest relative to the southwest side.

The unbleached parts of the Nigger Hill dike contain an average of about 0.022 percent equivalent uranium, generally less than 0.010 percent uranium, and about 0.020 percent thorium (Phair, 1952, table 3, p. 30-31); one analysis from the Prosser Gulch dike gave 0.018 percent equivalent uranium, 0.006 percent uranium, and 0.049 percent thorium. A sample of bleached bostonite from the Nigger Hill dike contained 0.010 percent equivalent uranium, 0.003 percent uranium, and 0.020 percent thorium.

Structure of pre-Cambrian rocks

Foliation and lineation

The pre-Cambrian rocks have a fair to excellent lithologic layering and sub-parallel alinement of tabular and platy feldspar, biotite, and hornblende. The foliation in the metasedimentary rocks everywhere parallels the layering produced by differences in mineral composition; hence, it is assumed that the foliation parallels the original bedding in the rocks. The contacts and megascopic gneissic structure of the granite gneiss conform to the gneissic structure of the metasedimentary rocks. The granite pegmatite cuts across the gneissic structure at a few places, but generally it is conformable.

Sub-parallel alinement of streaking, crinkling, warps, and minor fold axes is conspicuous in all rocks except pegmatite. The most prominent lineation trends about N. 40° E. and plunges northeast or southwest at angles less than 20°. The angle of plunge varies considerably even within individual outcrops, because of cross-warps described below. This lineation is marked chiefly by mineral parallelism, by streaking, and by minor fold axes; it essentially parallels the major fold in the region.

A second locally conspicuous lineation plunges northwest and is marked by warps in the foliation planes. Less commonly the warps plunge southeast. Most warps in the mapped area plunge 20° to 40° N. 50° to 70° W. The warps vary greatly in size, and the ratio of amplitude to wave length is usually greater than 1:3.

Folds

The attitude of the foliation and the outcrop patterns of the various rock units indicate that the pre-Cambrian rocks are folded along northeast-trending axes (fig. 2). The predominant fold in this part of the Central City district is a large, broad, symmetrical anticline that trends about N. 40° E. The fold axis locally plunges gently either northeast or southwest because of minor variations in the plunge angle. On the flanks of the anticline the rocks generally dip less than 45°, but at some places the dips are steeper. The flat-lying rocks in the crest of the anticline are contorted by abundant closely spaced, minor folds. Most minor folds are open and symmetrical and plunge gently to the northeast or southwest. Common locally abundant cross-warps plunge northwest or southeast.

The broad, gentle, asymmetric folds on the flanks of the major anticline, which are essentially parallel to the major fold axis, represent drag folds related to the major fold. Minor folds are abundant in the crests of these structures. The folds on the flanks of the major anticline are locally tight, and the limbs dip steeply; some are slightly overturned. Because of poor outcrops in critical areas, knowledge of these folds is incomplete.

Structure of Tertiary dike rocks

The Tertiary dikes are long and continuous and are rarely over 25 feet thick. They fill steeply dipping fractures in the older, pre-Cambrian rocks and are in different fracture systems than the metalliferous veins. Because the dikes are fractured (fig. 3) and offset along planes roughly parallel to some of the veins, it is inferred that the dikes fill older fractures systems than the metalliferous veins.

Although the general trend of each dike is consistent over long distances, local trends vary considerably from the average. The Nigger Hill dike trends about N. 45° to 50° W.; but it occupies two sets of fractures, one of which strikes between N. 40° to 60° W. and the other strikes about N. 10° W. Near the I. X. L. mine (25) (fig. 2) a branch of the Nigger Hill dike trends about N. 50° E. The apparent displacement along the fractures is small. On Nigger Hill, the Nigger Hill dike cuts and offsets a small lens of cordierite-anthophyllite-garnet gneiss; the apparent horizontal displacement is about 12 feet, with the northeast side relatively displaced to the southeast. The same dike cuts the Tertiary monzonite porphyry dike about 500 feet southeast of the cordierite-anthophyllite-garnet lens; the monzonite is displaced about 75 feet with relative northwestward motion of the northeast block. The difference in apparent horizontal displacement of the lens and monzonite dike probably is due to the varying dips of the two intersected rock bodies.

The average trend of the Prosser Gulch dike is about N. 50° E., but at places it occupies fractures that strike N. 80° to 90° E.; these are probably joints, as there has been little or no offset along the fractures.

The monzonite porphyry dike has numerous short branches, and is more irregular in trend than the bostonite dikes. Throughout most of its length the monzonite fills fractures trending northeast which are probably the same as the N. 50° E. set occupied by the Prosser Gulch dike, but near Eureka Gulch the monzonite fills eastward-trending fractures (fig. 2).

URANIUM DEPOSITS

General statement

The gold, silver, copper, lead, zinc, and uranium deposits of the Central City district are found in veins, or less commonly in stockworks, that are believed to have formed at intermediate temperatures. These deposits are early Tertiary in age (Phair, Shimamoto, and Sims, in preparation) and are genetically related to the intrusion of porphyritic rocks (Lovering and Goddard, 1950, p. 170-191; Phair, 1952). Gold and silver accounted for most of the dollar value of the ore produced.

Two main types of deposits give the district a zonal arrangement in plan view. A core, about 2 miles in diameter, of pyrite-quartz veins is surrounded by a rather wide outer zone of silver-lead-zinc veins (King and others, 1953, p. 6). In the zone of overlap between the two zones, transitional veins contain gold, silver, copper, zinc, and lead. All the known uranium deposits in the Central City district except those in the Eureka Gulch area are in the transition zones as outlined by Leonard (1952).

The uranium deposits in the Eureka Gulch area are of two types, one carrying pitchblende and the other metatorbernite. So far as known the two types are mutually exclusive. Pitchblende occurs at places along metalliferous veins; it is earlier than sphalerite, galena, chalcopyrite, and most of the pyrite. The metatorbernite primarily replaces altered biotite-quartz-plagioclase gneiss and amphibolite wall rocks adjacent to veins in the oxidized zone.

Mineralogy and grade

Pitchblende, metatorbernite ($Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$), and kasolite ($Pb(UO_2)SiO_4 \cdot H_2O$) have been identified in the Eureka Gulch area. Some of the metatorbernite may contain torbernite ($Cu(UO_2)_2P_2O_8 \cdot 8\text{-}12H_2O$). The pitchblende and metatorbernite are sufficiently concentrated locally to be of possible commercial value; kasolite has been found only on the Two Sisters mine dump in small quantities.

Black, heavy pitchblende with a dull metallic luster was found on the dumps of the J. P. Whitney shaft (33), Bullion No. 2 shaft (32), Carroll shaft (6), and the adit on the Rara Avis mill site (34). Under a reflecting microscope, the pitchblende from the J. P. Whitney shaft shows a colloform structure with radiating syneresis cracks. The pitchblende is brecciated at places, and is veined by later sphalerite, galena, pyrite, and chalcopyrite.

Metatorbernite _/ was found on the dumps of the Two Sisters, R.H.D., McKay, and Claire Marie shafts (fig. 3), and also in the underground workings of the McKay shaft (fig. 6). It is disseminated as tiny, apple-green crystals or it occurs as fracture coatings in altered biotite-quartz-plagioclase gneiss and amphibolite.

Yellowish-brown kasolite occurs in thin mats of closely spaced fibers, rosettes, and tabular crystals that coat fractures and partly fill vuggy openings in highly altered, porous, hydrous-iron vein material and in altered wall rocks.

_/ Identification by W. F. Outerbridge, Denver X-ray laboratory, U. S. Geological Survey.

The grade of selected material from radioactive dumps in the Eureka Gulch area is given in table 1; the grade of material from the mine workings of the McKay shaft (fig. 6) is given in table 3.

Dump samples of material containing pitchblende vary widely in grade (table 1), and the equivalent-uranium content of many, determined by radioactivity analysis, far exceeds the chemical uranium. Sample N16 from the Carroll dump contains 6.4 percent equivalent uranium, but only 0.62 percent chemical uranium; and sample N16-C from the same dump contains 10.5 percent equivalent uranium but only 0.095 percent chemical uranium. Radium and other daughter products of uranium, principally radon and radiogenic lead, account for the disequilibrium. Phair and Levine (1953) demonstrated that pitchblende from pyritic dumps in the Central City district oxidizes rapidly. The uranium is leached by sulfuric acid derived from pyrite, and both radium and lead remain in the original material in approximately proportional amounts. Accordingly, many of the highly radioactive "hot spots" on pyritic dumps in the Central City district are caused by residual concentrations of radium and other decay products of uranium. For this reason the equivalent-uranium analyses indicate the approximate uranium content of the original material when removed from the vein.

Sample analyses of selected metatorbernite-bearing material from the Two Sisters mine dump show as much as 6.11 percent uranium (table 1). A grab sample of metatorbernite-bearing rock from the 40-foot level of the McKay shaft workings assayed 0.24 percent uranium, and two other samples assayed more than 0.1 percent uranium (table 3). Two analyses of radioactive material from the Claire Marie dump (table 1) indicate a low uranium content.

Table 1.--Uranium analyses of selected dump material, 1/
Eureka Gulch area, Gilpin County, Colorado

Field Number	Locality	Equivalent uranium (percent)	Chemical uranium (percent)	Rn (curies x 10-9)	Pb^{210} (curies x 10-9)	Remarks
B-1	Boodle mine	0.013	0.003			Probably middlings from radioactive ore milled from Wood mine
N109	Buckley mine	.31	.33			Black uranium oxide, probably pitchblende
N20	Bullion mine	.021	.007			Pitchblende (N20, N20)
N20	Do.	6.7	6.87			
N16	Carroll mine	6.4	.62	45	45	Pitchblende has been leached (N16 to N16-C)
N16-A	Do.	1.7	.025			
N16-B	Do.	.93	.68			
N16-C	Do.	10.5	.095	64	68	
N-23	Claire Marie mine	.027	.017			Green secondary mineral (N-23, N-23-A)
N-23-A	Do.	.054	.034			
N-45	J. P. Whitney	8.9	5.92			Pitchblende (N-45 to E-2)
N-18	Adit, Rara Avis millsite	.80	.59			
S-1-53	Do.	.17	.15			
E-1	Do.	.22	.03			
E-2	Do.	1.7	.94			
N-44	Two Sisters shaft	.92	1.42			Uranium principally contained in metatorbernite
N-44-C	Do.	5.6	6.11			Do.
N-44-A	Do.	4.4	4.70			Do.
N-44-B	Do.	2.6	3.05			Uranium principally contained in kasolite

1/ Analyses by Denver Trace Elements Laboratory, U. S. Geological Survey.

All are grab samples.

Localization

Pitchblende, associated with gangue quartz, is a primary vein mineral. Metatorbernite is principally confined to altered rocks adjacent to oxidized veins or is sporadically distributed within some veins. So far as known, the metatorbernite is associated with gold-silver veins of the galena-sphalerite type (Bastin and Hill, 1917, p. 110). Vein material containing pitchblende is not known to bear metatorbernite, and no pitchblende has been observed in the metatorbernite-bearing rock. Pitchblende and metatorbernite, therefore, seem to be mutually exclusive in the Eureka Gulch area and appear to occur in different veins (fig. 2).

Pitchblende has not been observed in place in underground mine workings within the Eureka Gulch area because the mines known to contain it are inaccessible. However, small lenses probably are distributed along the main veins, in a manner similar to the better known deposits in the Quartz Hill area. Some pitchblende may be in subsidiary, branching veins, adjacent to the main veins. The distribution and quantity of pitchblende on the dumps at the J. P. Whitney shaft (33), Carroll shaft (6), and the Rara Avis adit (34, fig. 2) indicate that uranium-bearing material probably was mined from at least two places in each mine, because radioactive material was concentrated in two or more distinct places on the dumps. At the Bullion mine dump (32), radioactive rock was localized in one spot; hence, the pitchblende probably came from a single body.

Metatorbernite-bearing rock on the dumps at the McKay, R.H.D., and St. Anthony shafts (fig. 3) probably came entirely from the R.H.D. vein, though the writers do not know definitely which veins are radioactive because most mines are inaccessible. The uranium-bearing material on the Two Sisters dump (fig. 3) could have been mined from either the Two Sisters or the Claire Marie veins, or both, because both veins are reported to have been worked underground in the Two Sisters mine.

Wall rock alteration

The wall rock alteration associated with the metatorbernite-bearing deposits is neither clearly defined nor exactly known, but tentative conclusions based upon incomplete data can be given. The alteration, as indicated by samples from the McKay shaft workings (fig. 6) and dump samples from the Two Sisters mine (fig. 3), is complex. At least two types of altering conditions existed: (1) hydrothermal, probably related to lead-zinc ore deposition, and (2) supergene, related to later circulating ground waters. The supergene alteration has been superimposed upon the hydrothermal stage. As it is difficult to interpret the environment-sensitive clay mineral alteration products that are present, the writers cannot at present distinguish with certainty the products of each phase of alteration. Another complicating factor--the variability of composition of the original wall rocks--produces observable differences in alteration products.

Clay mineral alteration is predominant, but distinct clay mineral sub-zones are not well defined. Zones of silicification and/or sericitization are not present in the rocks studied. Two sub-zones of argillic alteration_/ are recognized in the biotite-quartz-plagioclase gneiss: (1) brown biotite and (2) bleached mica-clay. The brown biotite sub-zone contains biotite,

_/ Megascopic descriptive terms are used in the absence of distinctive clay mineral constituents.

quartz, and an almost completely altered plagioclase feldspar, the latter component now a montmorillonite. More intense alteration bleached and subsequently altered the biotite to clay mineral aggregates. Accordingly in the bleached mica-clay sub-zone of most intense alteration, quartz is the only original constituent that remains. Kaolinite apparently is not an important constituent, but it appears to increase quantitatively with more intense alteration. Illite and/or sericite increase in abundance near the outer margin of the bleached mica-clay sub-zone, decreasing again in the brown biotite sub-zone. The sequence of alteration of the biotite-quartz-plagioclase gneiss apparently is as follows:

1. <u>Brown biotite sub-zone</u>

   Feldspar (plagioclase, An_{20-25}) altered to montmorillonite.

2. <u>Bleached mica-clay sub-zone</u>

   Biotite altered to illite (trioctahedral variety (?)) and/or sericite mica (used as a size term) and perhaps finally to kaolinite and/or montmorillonite.

The alteration of the amphibolite in the McKay shaft workings is less well known. Megascopic examination suggests that the amphibolite alters to biotite and subsequently to the soft, green clay in the bleached mica-clay sub-zone. The relative amounts of kaolinite and montmorillonite, or the type of montmorillonite, have not as yet been determined.

The intensity of the alteration depended upon the conpetency of the rocks and upon their availability to altering solutions. In the McKay shaft workings the amphibolite pods in the biotite-quartz-plagioclase gneiss were more susceptible to alteration than the gneiss and were nearly completely changed to green clay. The plagioclase feldspar in the gneiss was largely converted to clay minerals, except locally, but the biotite apparently remained fresh. The distinction between the brown biotite and bleached clay-mica sub-zones is not so well defined in the McKay shaft workings as in samples from the Two Sisters dump; rather, it is a gradual, irregular transformation.

Relation of metatorbernite to altered host rocks

The metatorbernite at the Two Sisters mine and the McKay shaft workings is disseminated through altered biotite-quartz-plagioclase gneiss and amphibolite pods in the gneiss; it replaces constituent minerals of the host rocks. At places it forms coatings on fractures in the rocks.

In the McKay shaft workings (fig. 6) the metatorbernite is concentrated in the margins of the altered amphibolite pods, but it is also abundantly disseminated through the green clay. Samples of altered biotite-quartz-plagioclase gneiss from the Two Sisters dump contain disseminated metatorbernite granules or aggregates of granules in the brown biotite sub-zone. The granules are closely associated with the biotite, either completely or partly penetrating the biotite flakes as seen in two dimensions in thin sections. Evidence for replacement of the biotite by metatorbernite is inconclusive; however, many granules occur where the biotite has been bent or flexed. The grain boundaries are generally smooth and regular. A marked concentration of metatorbernite occurs in the bleached mica-clay sub-zone at its boundary with the brown biotite zone. In this environment the metatorbernite appears to replace the biotite along cleavage planes and crystal edges, and it assumes tabular or flake-shaped aggregations, rather than a granular form. Under the microscope it is seen to be intimately mixed with sericite and/or illite. Granules persist into the bleached mica-clay zone, and, away from the zone of concentration of flake-type metatorbernite in the boundary zone, granules are present in approximately equal proportions with the flake type. Along fractures, and at places along foliae in the rock, the flake type predominates over the granular type of metatorbernite in the bleached mica-clay zone.

The two different morphological types of metatorbernite--granules and flakes--from the Two Sisters mine dump samples are difficult to explain from the present, inadequate data. Two alternative explanations may be suggested for their development. Either they were formed at different times, perhaps under slightly different environmental conditions directly related to the degree of completion of the wall rock alteration, i.e. flakes relate to very late supergene action; or they were more nearly contemporaneous, where the physical and structural conditions were such that the flake type was favored in the more accessible parts of the system. The granular phase may be slightly older than the flake phase, but there is no other relation of the granules to a particular texture or structure; the formation and concentration of the flake type metatorbernite, however, appears to have a direct relation with the early stages of breakdown of biotite.

Origin of pitchblende and metatorbernite

Pitchblende deposits and quartz bostonite dikes have a close spatial relationship within the Central City district (Alsdorf, 1916; Bastin, 1916; Phair, 1952). Phair (1952) concluded that the uranium was derived from a cooling quartz bostonite mass at depth; additional uranium could have been obtained by leaching of uranium from quartz bostonite during the rise of the uranium-rich solutions. The dikes also contain a relatively high proportion of thorium; the veins contain almost none. This suggests that either the uranium in the dikes was more readily available than thorium, or that the uranium in veins (and dikes) was derived from some other common source. The pitchblende was deposited in fractures which were open at the time of its formation.

The pitchblende in the Central City district was deposited early in the sequence of Tertiary vein formation; in some veins it is essentially contemporaneous with pyrite; in others it is definitely older than the pyrite. So far as known, it is always older than sphalerite, galena, and chalcopyrite and commonly was brecciated before the deposition of these metals.

Uranium minerals other than pitchblende are sparse in the Central City district. The occurrences of metatorbernite for a distance of about 700 feet along the Two Sisters and R.H.D. veins (fig. 3) are unique in the district. The metatorbernite probably formed by oxidation, solution and transportation of uranium from primary pitchblende, but it may be a primary mineral deposited directly from mineralizing fluids of different composition from those which deposited pitchblende. The PO_4 ion, required for crystallization of metatorbernite, possibly was derived from apatite in the host rock, or from adjacent rocks. The SiO_4 ion, required for the precipitation of kasolite, could have been derived from the silica within the quartz vein or from alteration of feldspar in wall rocks. The necessary copper and lead were primary vein constituents, because the veins are known to contain copper and lead sulfides.

Economic evaluation

If the metatorbernite and kasolite are secondary minerals deposited by circulating waters which dissolved uranium from pitchblende, then primary pitchblende deposits may be encountered at depth. The quantity and location of the pitchblende cannot be determined with the existing information, but it should be below the zone of oxidation. However, if the metatorbernite is a primary mineral deposited directly from a deep-seated source, it is unlikely that any pitchblende deposits will be found at depth. The grade, tonnage, and depth extension of the metatorbernite deposits cannot be estimated on the basis of existing information. The abundant disseminated metatorbernite in altered wall rocks in the Nigger Hill area so far as is known is a unique deposit in the United States.

It is recommended that the R.H.D., Two Sisters, and Carroll shafts be made accessible for examination. This rehabilitation should yield valuable data concerning the relationship between pitchblende and metatorbernite deposits, as well as a better basis for evaluation of the metatorbernite deposits themselves. Recommendations for further exploration of the deposits will be deferred until after the mines have been examined in greater detail.

The pitchblende deposits in the area are too little known to evaluate them as potential sources of uranium. The better-known pitchblende deposits in the Quartz Hill area of the Central City district consist of small, high-grade bodies sporadically distributed along the veins; the ones at Eureka Gulch are probably similar. These deposits can best be mined together with other metals contained in the veins. Some of the veins, however, might contain bodies of sufficient size and grade to be mined profitably for uranium alone.

DESCRIPTION OF INDIVIDUAL MINES

Within the Eureka Gulch area (fig. 2) there are 67 principal shafts and adits, locally referred to as tunnels. The list of mines that correspond to the numbers on figure 2 is given in table 2. Because most of the mines were worked several decades ago and subsequently have partly caved, few mine openings were accessible in 1953.

Table 2.--List of principal shafts and adits, Eureka Gulch area, Central City district, Colorado. (Table to accompany figure 2)

1.	Monitor shaft	24.	Troublesome shaft
2.	Spur Daisy shaft	25.	IXL shaft
3.	Boodle shaft	26.	Casto shaft
4.	Bon Ton shaft	27.	Review shaft
5.	Maggie M shaft	28.	Winnebago shaft
6.	Carroll shaft	29.	Shaft, Thurman claim (?)
7.	Claire Marie shaft	30.	Shaft
8.	Two Sisters shaft	31.	Huddleston shaft (?)
9.	R.H.D. shaft	32.	Shaft, Bullion No. 2 claim
10.	McKay shaft, R.H.D. claim	33.	J. P. Whitney shaft
11.	Harkaway shaft	34.	Adit, Rara Avis mill site
12.	Shaft, Harkaway claim	35.	Prospect, Louis claim
13.	Tom Martin shaft	36.	Adit, Kohinoor No. 2 claim
14.	Shaft, Garden No. 2 claim	37.	Columbia Avenue shaft
15.	Adit, Garden claim	38.	Arlington shaft
16.	Adit, Prospector claim	39.	Independence shaft
17.	Lake Superior shaft	40.	Ready Cash shaft
18.	Iowa shaft	41.	Roosewelt shaft
19.	Freiburg shaft	42.	Essex shaft
20.	Minnesota shaft	43.	Sierra Madre shaft
21.	Shaft, Oro claim	44.	Gilpin-Eureka shaft
22.	Adit, Oro claim	45.	Discovery shaft, Eureka claim
23.	Prospect, Humboldt claim	46.	Shaft, Spur vein

Table 2.--List of principal shafts and adits, Eureka Gulch area, Central City district, Colorado--Continued
(Table to accompany figure 2)

47. Shaft, Damon claim

48. Prospect, Carrie G claim

49. Gold Collar shaft (Hydrant vein)

50. Marine shaft

51. Concrete shaft

52. Fagan shaft

53. Grand Army shaft

54. Gunnell shaft

55. Wood shaft

56. Buckley shaft

57. Peru shaft

58. James Henry shaft

59. Adit, Mechanics claim

60. Shaft, Mount Lincoln claim

61. Shaft, Gunnell claim

62. Whiting shaft

63. St. Louis shaft

64. Prospect, Francis claim

65. Adit, Gulnare claim (?)

66. Shaft, Burlington claim (?)

67. Shaft

In the following pages only those mines that are known to contain radioactive materials are described, and of these only one, the McKay shaft (10), R.H.D. claim, was accessible for underground examination in 1953.

Buckley mine (56)

The Buckley mine (fig. 2), now inaccessible, was opened by a two-compartment shaft inclined 80° S. 15° W. The shaft is open at the collar but appears to be jammed at a depth of about 40 feet. To judge from the size of the dump, the mine contains several hundred feet of underground workings. Between 1902 and 1922, 57.42 ounces of gold and 93 ounces of silver were reported to have been produced._/ Considerable ore probably was extracted prior to that time.

The shaft was sunk on a vein trending N. 65° to 70° W. The Wood shaft (55), 650 feet to the northwest across Prosser Gulch, probably was sunk on the same vein. According to Bastin and Hill (1917, plate IV) the vein belongs to the pyritic gold type. Pyrite and sparse galena and sphalerite can be recognized on the dump.

A small radioactive area on the surface of the dump, about 2 feet in diameter, was sampled, and it assayed 0.31 percent equivalent uranium and 0.33 percent uranium (table 1). The radioactive material is black and presumably contains pitchblende.

Bullion mine (32)

The Bullion mine, on the Bullion No. 2 claim, is about 1,000 feet west of the portal of the Rara Avis tunnel, on the south side of Eureka Gulch (fig. 2). The mine is inaccessible and little is known of the extent of the mine workings.

_/ Production from A. J. Martin, Metal Economics Branch, U. S. Bureau of of Mines.

According to W. C. Russell, Jr. (oral communication), the mine consists of two levels about 100 feet vertically apart, and a vertical shaft, now caved at the collar. Some drifting was done on both levels west of the shaft; probably little ore was extracted. The mine was last worked during World War II.

At the surface the Bullion vein trends N. 80° to 85° E. and dips essentially vertical; the vein appears to be equivalent to the vein worked on the Prospector claim, on the northeast side of Eureka Gulch.

The dump contains abundant quartz, pyrite, sphalerite, and galena. The vein belongs to the galena-sphalerite type. Pitchblende can be found at places within an area about 5 feet square at the top of the dump near the north end. A selected sample assayed 6.7 percent equivalent uranium and 6.87 percent uranium (table 1). To judge from the distribution of radioactive material on the dump, the pitchblende was mined from a single location underground.

Carroll mine (6)

The Carroll mine, on the west slope of Nigger Hill near the southeast corner of the cemetery (fig. 3), was inaccessible in September 1953. So far as known the mine was closed about 1903. The Carroll shaft is a two-compartment opening, inclined 64° NE, at the surface, which is reported to be 245 feet deep (fig. 4). Short levels are present at depths of 40, 50, 135, 185, and 245 feet. Except for a small stope on the 50-foot level, the only stoped ground is on the 185-foot and 135-foot levels, as shown in figure 4.

The Carroll shaft appears to be located at the approximate junction of three veins, as shown on figure 3. The principal (Carroll) vein, to judge from surface pits, trends about N. 65° W. and dips 68° NE. At the shaft

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TRACE ELEMENTS INVESTIGATIONS
REPORT 125

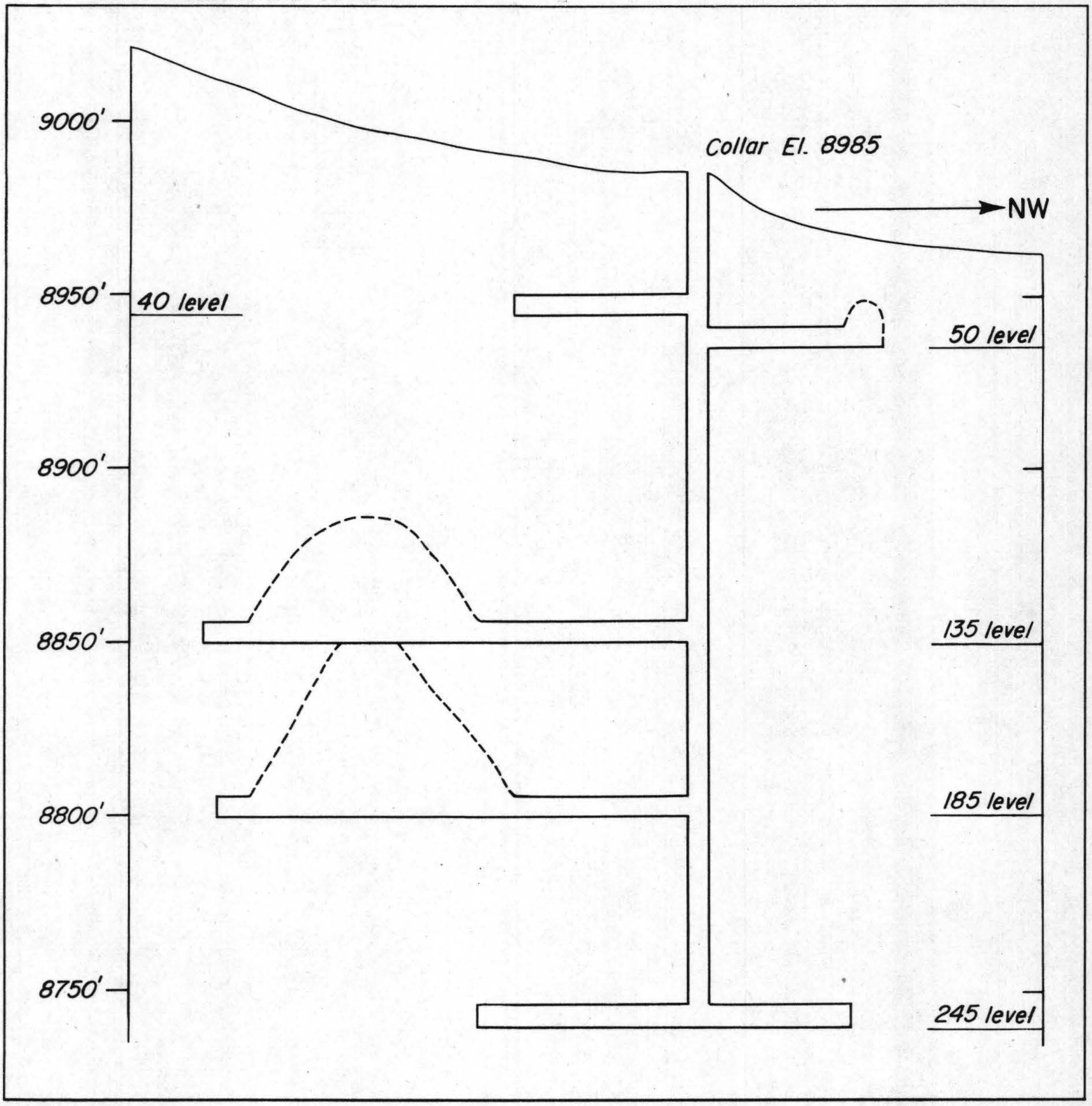


FIGURE 4.-VERTICAL LONGITUDINAL PROJECTION OF CARROLL MINE, EUREKA GULCH AREA, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

0 50 100 Feet

Datum is approximate mean sea level

collar, however, the vein trends about N. 55° W. and dips 64° NE. Because of the presence of three shallow pits between the Carroll and Claire Marie shafts, the writers infer that the Claire Marie vein probably joins the Carroll vein near the Carroll shaft collar.

An area several feet in diameter on the northwest edge of the mine dump, near the shaft collar, is highly radioactive. The radioactivity is largely due to residual concentrations of radium and other daughter products of uranium, but pitchblende has been identified. Four analyses of selected radioactive material are given in table 1. Two samples, N16 and N16-B, respectively, contain 0.62 and 0.68 percent uranium. In addition to pitchblende, the ore minerals include galena, sphalerite, and pyrite. The gangue is largely white quartz.

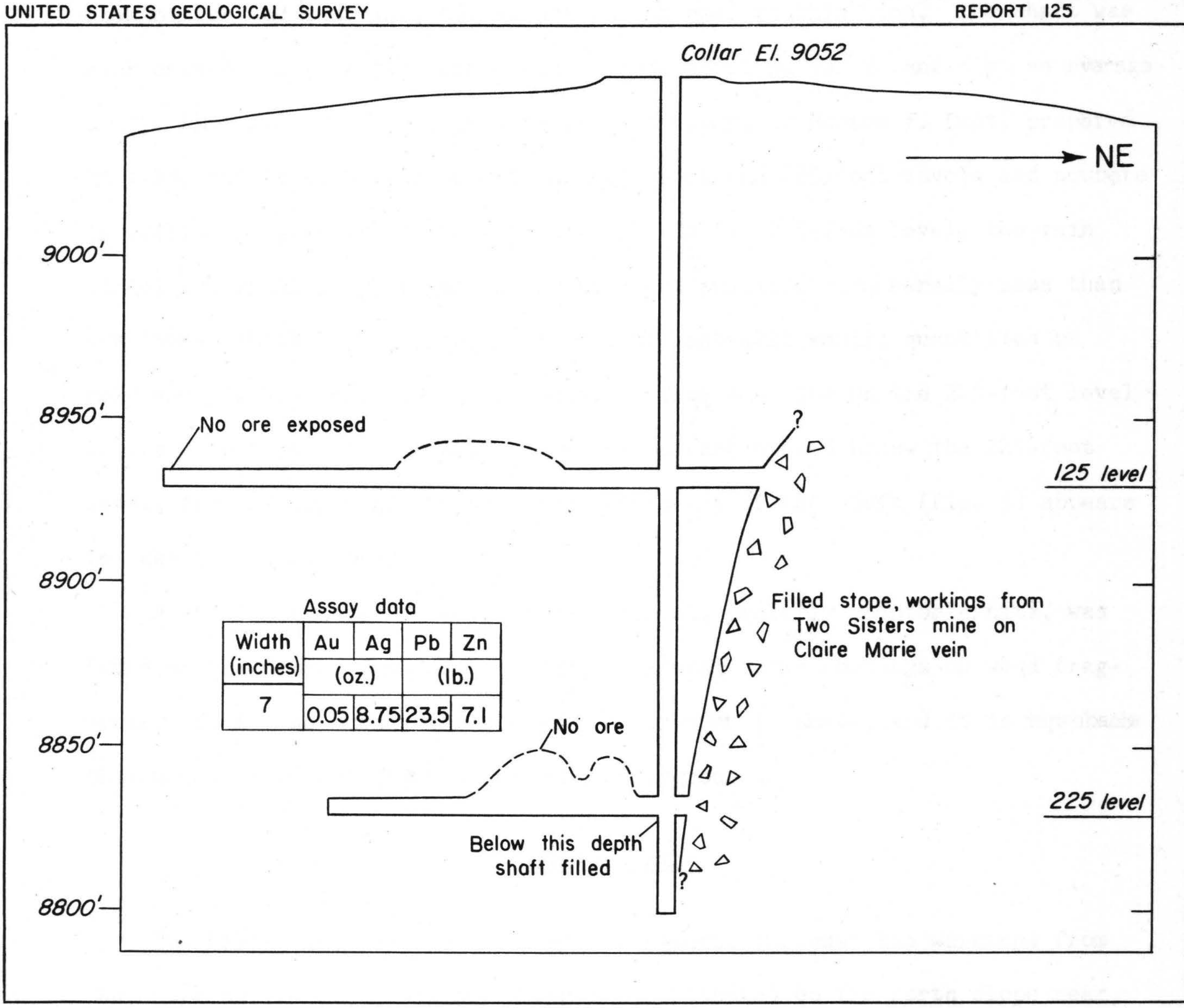
The source of the radioactive material found on the dump is not known, but probably it was extracted from a small body of pitchblende encountered in one of the stopes.

Claire Marie mine (7)

The Claire Marie mine is on the north slope of Nigger Hill about 280 feet southwesterly from the Two Sisters shaft (fig. 3). The mine workings consist of a shaft, 255 feet deep, which is inclined on the average 75° SE., and levels at depths of 125 feet and 225 feet (fig. 5). The workings connect to those from the Two Sisters mine through a filled stope on the Claire Marie vein. So far as known, little mining was done from the Claire Marie shaft, and the value of the shipments probably was small. A shipment of concentrates (about 3 tons) contained 5.125 ounces gold, 10.9 ounces silver, 25.55 percent lead, and 10.7 percent zinc. The gross value of this shipment was $114.40

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATIONS
REPORT 125



Width (inches)	Au	Ag	Pb	Zn
	(oz.)		(lb.)	
7	0.05	8.75	23.5	7.1

Assay data and underground workings by Horace F. Lunt, E. M.

FIGURE 5.-VERTICAL LONGITUDINAL PROJECTION OF CLAIRE MARIE MINE, NIGGER HILL, CENTRAL CITY DISTRICT GILPIN COUNTY, COLORADO

50 25 0 50 Feet

Datum is approximate mean sea level

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per ton, based on a $19—gold price. The mine was worked principally during the 1890's. It was reopened in 1928 by the Claire Marie Mining Company for examination and sampling, but no ore was shipped at this time. The shaft was sunk on the Claire Marie vein, which trends about N. 70° E. and dips an average of 75° SE. According to a private company report by Horace F. Lunt, prepared in 1928, the vein is weak on both the 125-foot and 225-foot levels and nowhere is sufficiently thick to mine profitably. On the 225-foot level, the vein contains a small body of galena, pyrite, and sphalerite, generally less than six inches thick that carries varying, but generally small, quantities of gold and silver. The best assay obtained from the mine on the 225-foot level is given on figure 5. Minable ore might be encountered below the 225-foot level, for the ore mined in the stope northeast of the shaft (fig. 5) appears to rake to the southwest.

A small quantity of radioactive material, probably metatorbernite, was found on the dump. Some of the uranium mineral forms coatings on wood fragments. So far as known, the quantity of uranium is small, and it is improbable that material of ore grade is present underground.

Rara Avis mine

The Rara Avis mine, as used in this report, includes the workings from the shaft on the J. P. Whitney claim (33), situated on the north slope near the top of the hill between Eureka and Prosser Gulches, and the adit on the Rara Avis mill site (34), on the south side of Eureka Gulch (fig. 2). Both the dump at the shaft and the dump at the portal of the adit contain appreciable quantities of pitchblende-bearing rock.

The J. P. Whitney shaft, now inaccessible, is nearly vertical and is reported to be 589 feet deep. Six levels approximately 100 feet vertically apart, that consist of a total of 1,190 feet of drifts, connect with the shaft. The shaft collar is at an altitude of approximately 9,102 feet. The adit, at an altitude of about 8,800 feet, bears S. 25° W. and connects with the workings from the shaft on the 300 level. The portal is caved and accordingly the adit is partly filled with water. There are no known records of production.

At the surface the vein intersected by the J. P. Whitney shaft, where observed, trends N. 75° to 85° E., and dips 84° SE. At the shaft collar the vein is about a foot wide. Presumably this was the principal vein worked underground. The ore consists predominantly of galena and sphalerite. The pitchblende has a colloform structure and is earlier than sphalerite, galena, chalcopyrite, and at least part of the pyrite.

Pitchblende-bearing material is present at three places on the shaft dump and at two places on the adit portal dump. According to Henry DeLinde (oral communication) pitchblende was reported from the third level below the adit, presumably the 600 level. It is possible, however, that more than one pitchblende body was encountered in the underground workings. Selected grab samples from the dumps assayed as much as 8.9 percent equivalent uranium and as much as 5.92 percent uranium (table 1). The analyses indicate that there has been some leaching of uranium since the material was placed on the dumps; the equivalent-uranium content is thought to be indicative of the grade of ore mined underground.

R.H.D. claim

The R.H.D. claim adjoins the Two Sisters claim on the east; the west end line is just west of the R.H.D. shaft (9), and east of the St. Anthony shaft (fig. 3). The principal mine openings on the claim are the R.H.D. shaft and

McKay shaft (10), 70 feet to the east. The R.H.D. shaft, inaccessible in September 1953, is a nearly vertical shaft that extends downward into an open stope (Van McKay, oral communication). At a vertical depth of about 100 feet a drift extends eastward beneath the workings from the McKay shaft.

The McKay shaft, vertical to a depth of 23 feet, then inclined 80° N., is 42 feet deep; a drift, 117 feet long, extends eastward from the bottom of the shaft a distance of 105 feet and connects to the west with a stope from the R.H.D. shaft workings (fig. 6). In September 1953 the connection was closed by caved material in the drift. The bottom of an old shaft was encountered 100 feet east of the McKay shaft; this opening has been timbered and its exact location could not be determined.

The R.H.D. vein trends northwestward west of the McKay shaft and slighty north of east, east of the shaft (fig. 3); the vein dips 60° to 80° N. In the McKay shaft workings the vein is curved and has many, irregular branches and splits, as shown on figure 6. Whereas the main vein trends roughly easterly, the subsidiary veins branch to the northeast or to the southwest; many branches roll into the foliation of the wall rocks and die out within a few feet from the main vein. "Horses" between splits in the vein typically are sheared and altered and at places are brecciated.

The main vein consists predominantly of white clay gouge, at places associated with some breccia, and sparse white quartz; near the shaft the vein contains as much as two inches of gray, fine-grained quartz. The vein ranges in thickness from less than an inch to a maximum of about 12 inches. The subsidiary veins generally are less than 6 inches thick, and many are less than an inch thick. The vein is reported to contain local pockets of galena surrounded by cerussite, but sulfides were not observed by the writers. McKay (Van McKay, oral communication) reports that a small shoot containing free gold is present east of the McKay shaft.

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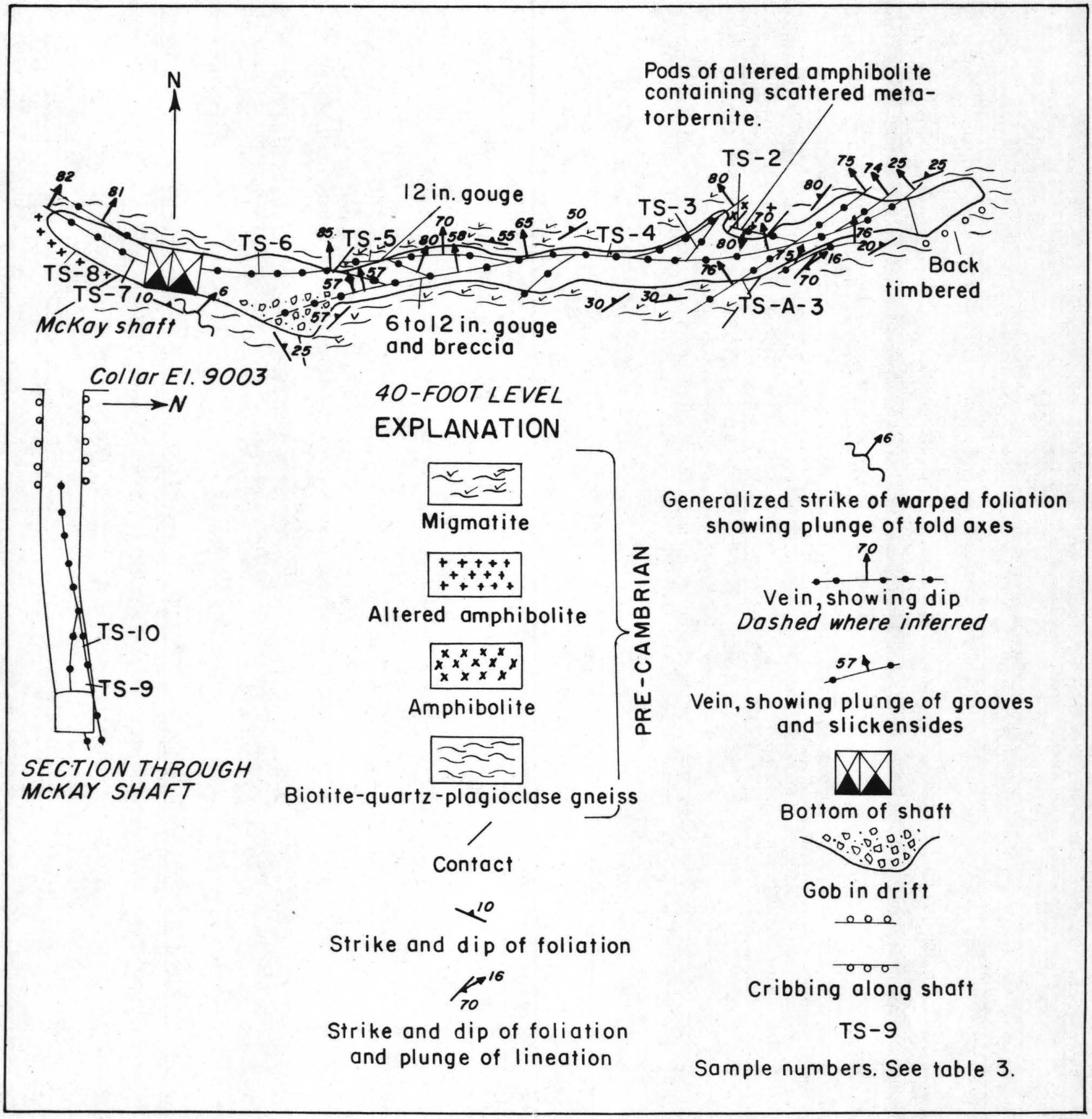
TRACE ELEMENTS INVESTIGATIONS
REPORT 125



Geology by P.K. Sims and A.A. Drake, September 1953

URE 6. – GEOLOGIC MAP AND SECTION OF McKAY SHAFT WORKINGS, R.H.D. CLAIM, GILPIN COUNTY, COLORADO

20 0 20 40 Feet

Datum is approximate mean sea level

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The wall rocks consist predominantly of biotite-quartz-plagioclase gneiss, locally garnetiferous, which at places contains inter-layers of granite pegmatite and pods of amphibolite. Most of the biotite-quartz-plagioclase gneiss and nearly all of the amphibolite have been intensely altered. The amphibolite has been altered to biotite and subsequently to a soft, green clay that when wet resembles olive green soap. (See p. 37.) The biotite-quartz-plagioclase gneiss and associated pegmatite layers trend northeastward and dip, on the average, moderately northwest. The amphibolite occurs within the gneiss in pod-like bodies as much as 7 feet in diameter, that plunge gently northeast. Most amphibolite bodies are too small to be shown on figure 6.

Abnormal radioactivity is widespread on the 40-foot level and in the lower part of the McKay shaft; uranium analyses are given in table 3. The radioactivity is caused by metatorbernite, except for sample TS-7, which possibly contains kasolite.

Metatorbernite occurs sporadically along the R.H.D. vein and subsidiary branching veins but generally is not abundant; an exception is the hanging-wall vein in the lower part of the McKay shaft (fig. 6), where a vein, one inch wide, contains 0.19 percent uranium. Substantial quantities of metatorbernite occur in altered amphibolite adjacent to the main vein or subsidiary veins. The metatorbernite primarily is concentrated in the margins of the altered biotitic amphibolite pods, but it is also disseminated through the green clay. A selected sample (TS-2, table 3) of metatorbernite-bearing clay from a pod 65 feet east of the McKay shaft contains 0.24 percent uranium. Other adjacent pods contain comparable, but generally somewhat lesser quantities of uranium. Small bodies of altered amphibolite near the shaft (samples TS-8 and TS-9) from a "horse" between two veins contain respectively 0.004 and 0.018 percent equivalent uranium (table 3).

Table 3.--Uranium analyses from McKay shaft workings, R.H.D. claim, Central City district, Colorado.

Field Number	Type of sample	Width (inches)	Material	Location	Equivalent uranium (percent)	Chemical uranium (percent)
TS-2	Grab	-	Altered amphibolite (clay-mica subzone)	68 ft. east of shaft	0.18	0.24
TS-3	Chip	6	Shear zone	62 ft. east of shaft	.12	.14
TS-4	Grab	-	Vein	52 ft. east of shaft	.025	.025
TS-5	Chip	8	do.	20 ft. east of shaft	.006	.003
TS-6	Chip	12	do.	7 ft. east of shaft	.036	.033
TS-7	Grab	-	Hydrous iron oxides	2 ft. west of shaft	.031	.034
TS-8	Grab	-	Altered amphibolite (clay-mica subzone)	10 ft. west of shaft	.004	-
TS-9	Grab	-	do.	2 ft. west of shaft	.018	.011
TS-10	Chip	1	Hanging wall vein	Shaft	.15	.19
TS-A-3	Chip	4	Altered amphibolite (clay-mica subzone)	69 ft. east of shaft	.053	.062

Abnormal radioactivity extends to within 25 feet of the surface in the McKay shaft; above that altitude the vein is barren and presumably the uranium, if ever present, has been leached. The radioactive material can be expected to extend to lower depths but possibly will not be found below the lower limit of the zone of oxidation.

Two Sisters mine (8)

The Two Sisters shaft, on the north slope of Nigger Hill (fig. 3), is the largest mine in the Nigger Hill area but like most others in the region has been closed for many years. In 1953 the Two Sisters shaft was caved at the collar, and the mine was inaccessible. The mine workings, according to a private company report by Daniel Munday, consist principally of a 700-foot shaft, which is inclined about 75° SE., and three levels at depths of 100, 150, and 300 feet. Extensive stoping was done northeast of the shaft on the Two Sisters vein (?) from the 100-foot level to the surface, and gold ore valued at nearly $100,000 was extracted. West of the shaft, some stoping was done on the Claire Marie vein between the 100- and 150-levels, and Munday reports that ore valued at about $35,000 was removed. Apparently little, if any, stoping was done on the 300-level. West of the shaft, on the 100-level, the workings on the east-trending Two Sisters vein connect to the workings on the northeast-trending Claire Marie vein through a crosscut about 60 feet long. According to the company report the drift to the west on the 100 level is 750 feet long, but it is probable that this drift is much shorter. On the 150-foot level the drift extends 70 feet to the east and 95 feet to the west; and on the 350-foot level the drift extends 190 feet to the east and 75 feet to the west. Munday reported good showings of lead ore in the east drift, 300 level.

Another shaft on the Two Sisters claim--the St. Anthony--is near the east end line (fig. 3); apparently it was sunk on the R.H.D. vein. According to the report by Munday, the St. Anthony shaft is 230 feet deep and drifts were driven from it at depths of 50 and 100 feet. At the 50-foot level the drift extends 60 feet southeast and 35 feet northwest; from the east drift the vein was stoped nearly to the surface. At the 100-foot level the drift extends 125 feet to the east and 40 feet to the west. According to Munday the west drift on the 100-foot level encountered the Claire Marie vein 40 feet northwest of the shaft. If this is true, the Claire Marie vein must intersect the Two Sisters vein near the collar of the Two Sisters shaft; possibly the shallow pits that are alined northeasterly between the Two Sisters and St. Anthony dumps were dug on the Claire Marie vein (fig. 3) north of its intersection with the Two Sisters vein.

The Two Sisters shaft was sunk at the approximate junction of the northeast-trending Claire Marie vein and the east-trending Two Sisters vein. The Two Sisters vein was prospected to shallow depths in the pits west of the Two Sisters shaft, south of the road (fig. 2). East of the Two Sisters shaft the Two Sisters vein (?) was mined in "grass root" stopes. In these workings the vein makes a very flat S-shaped bend, changing in strike from N. 86° E. to N. 70° E., and back to N. 86° E. The dip ranges from 68° to 75°. Probably the vein joins with the R.H.D. vein in the vicinity of the McKay shaft, but this cannot be proved (fig. 3). In the open stope 160 feet east of the Two Sisters shaft the vein trends N. 70° E. and dips 75° S. where the stope is 3 to 4 feet wide, but it is 5 to 6 feet wide where the trend is N. 86° E. and the dip is 68° S.

Bastin and Hill (1917, plate IV) classified the Two Sisters vein as a gold-silver vein of the galena-sphalerite type. So far as known galena and sphalerite are the predominant metallic minerals, with lesser quantities of pyrite. Free gold is present, at least in the near surface part of the vein.

Substantial quantities of metatorbernite and kasolite are present on the Two Sisters mine dump; no pitchblende was found. Most of the uranium-bearing material is near the toe of the dump, near the shaft on the west side, and on the east side of the lobe that extends east from the shaft (fig. 3). The dump contains a minimum of 3.5 tons of material of ore grade.

The metatorbernite occurs primarily in a distinctive, green altered biotite-quartz-plagioclase gneiss, but also is present in lesser quantities in other rock types. Although most of the metatorbernite is disseminated through the altered gneiss, it also is present along fractures in the rock. A description of the relation of the uranium mineral to the host rock has been given on pages 29-30 and will not be repeated here. Analyses of selected pieces of metatorbernite-bearing altered biotite-quartz-plagioclase gneiss (N44, N44-A, N44-C, table 1) indicate a range from 1.42 to 6.11 percent uranium. The equivalent-uranium content of the samples is 8 to 25 percent less than the chemical uranium.

Kasolite is much less abundant than metatorbernite; most of it is in the west side of the dump near the shaft. The kasolite occurs in vugs within hydrous iron-rich vein material that resembles gossan, and to a lesser extent as coatings on fractures in altered vein material. An analysis of a selected kasolite bearing specimen (N44-B, table 1) of the most radioactive material indicated 2.6 percent equivalent uranium and 3.05 percent uranium.

Because the mine is inaccessible, an evaluation of the uranium deposit must be based entirely upon the known geology of the region. It is probable that the biotite-quartz-plagioclase gneiss that is the principal host rock for the metatorbernite constitutes less than 5 percent of the wall rocks in the mine. It also is likely that the uranium is mainly confined to the upper part of the mine, within the zone of oxidation; the depth of this zone is unknown. To judge from the high proportion of altered rocks on the dump, it is quite possible, however, that the oxidized zone extends to the 150 level, and perhaps deeper.

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RESERVES

It is estimated that a minimum of 3.5 tons of metatorbernite-bearing material of ore grade is present on the Two Sisters' mine dump (fig. 3). This material largely consists of disseminated metatorbernite in altered biotite-quartz-plagioclase gneiss, a unique type of ore in the Central City district. Analyses of selected pieces from the dump range from 1.42 to more than 6 percent uranium. Sampling of the mine workings at the McKay shaft indicates more than 10 tons of metatorbernite-bearing rock of a grade in excess of 0.1 percent uranium. Several times this quantity of uraniferous material should be present along the vein and at depth. The metatorbernite replaces altered amphibolite and forms coatings on fractures; other rock types in the mine are nearly barren.

The data, collected in the McKay shaft workings together with those obtained from mine dumps along a distance of about 700 feet on the R.H.D., Two Sisters, and Claire Marie veins (fig. 3), suggest that the deposits of metatorbernite are possibly of economic importance. The tonnage and depth extension of the metatorbernite deposits cannot be estimated from existing information.

RECOMMENDATIONS AND PLANS

The uranium shows on dumps in the Eureka Gulch area are sufficiently promising to warrant further investigations by government agencies. Particularly the investigation of the occurrence of metatorbernite for 700 feet along the Two Sisters and R.H.D. veins should be continued, to determine the economic value of the material and to determine the relations between pitchblende and metatorbernite.

The Geological Survey plans to continue its work in the Eureka Gulch area during the next fiscal year (1955) as part of its investigations of the uranium resources of the Central City and Idaho Springs region. As mines are rehabilitated they will be mapped and sampled. The Carroll mine now is being reopened by a private mining company.