Geology of the Wood and East Calhoun Mines Central City District Gilpin County, Colorado

GEOLOGICAL SURVEY BULLETIN 1032-C

This report concerns work done on behalf of the U. S. Atomic Energy Commission and in part under the auspices of the Defense Minerals Exploration Administration and is published with the permission of the Commission

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By AVERY A. DRAKE, JR.

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By Avery A. Drake, Jr.

ABSTRACT

The Wood-East Calhoun area is underlain by complexly folded Precambrian gneiss and pegmatite. The major fold is an anticline that trends about N. 60° E. The Precambrian rocks are intruded by bostonite porphyry dikes of Tertiary age. All the rocks are cut by eastward- to northeastward-trending faults that have been filled by precious-metal-sulfide veins which have been worked chiefly for gold. The Wood vein, which has produced much of the uranium of the Central City district, fills an east-trending fault; the Calhoun vein is in a northeast-trending fault.

The veins consist chiefly of quartz; pyrite is the predominant metallic mineral and chalcopyrite ranks next in abundance. Sphalerite, galena, tetrahedrite-tennantite, and pitchblende occur locally. Alteration-stage quartz and pyrite were deposited first, followed in order of deposition by pitchblende, light-yellow pyrite, massive quartz, yellow pyrite, sphalerite, comb quartz, chalcopyrite, tetrahedrite-tennantite, galena, chalcopyrite, pyrite, and gray to light-brown fine-grained quartz. The veins of the district are zoned; quartz-pyrite veins are near the center, and galena-sphalerite veins are on the periphery. The pitchblende bodies occur between these veins, but, paragenetically, the pitchblende is earlier than all other metallic minerals.

A trace-element study of the ore shows an association of bismuth, antimony, and arsenic with copper, and of cadmium with zinc; high-grade uranium samples contain unusually large quantities of zirconium and molybdenum.

Pitchblende and other ore minerals are concentrated in ore shoots. These are in open spaces controlled by the competency of the wall rocks, the presence of a prevailing direction of weakness in the rocks, and changes in strike and dip of the vein. The pitchblende is believed to be a local constituent of the quartz-pyrite ores and was deposited by residual solutions from the quartz bostonite magma.

INTRODUCTION

The Wood and East Calhoun mines are on the south slope of Quartz Hill, near the head of Leavenworth Gulch, in unsurveyed sec. 14, T. 3 S., R. 73 E., about 1.5 miles southwest of Central City, Colo. (fig. 28). The mines are accessible from State Route 279 by about a quarter of a mile of unimproved road.

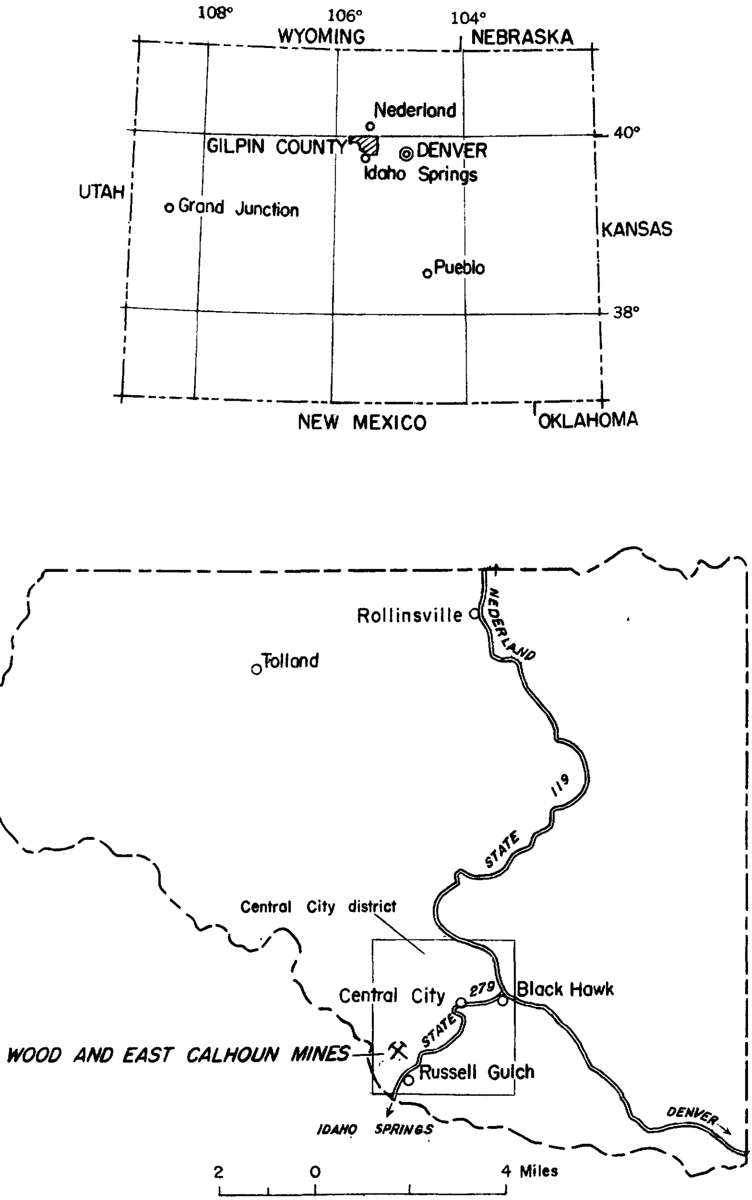

FIGURE 28.—Index maps showing location of the Wood and East Calhoun mines, Central City district, Gilpin County, Colo.

The Wood mine was an intermittent source of pitchblende from 1872 until about 1916 and the East Calhoun one of the largest gold mines in the Central City district, but both properties have been idle since World War I. Because of the strategic importance of uranium, the Defense Minerals Exploration Administration in 1951 negotiated a contract with the Denver Realty Co. to explore the Wood vein from the East Calhoun mine. As little was known about the distribution and paragenetic relations of pitchblende in the veins of the Central City district, the Geological Survey, on behalf of the U. S. Atomic Energy Commission and in part under the auspices of the Defense Minerals Exploration Administration, carried out a program of detailed geologic study and sampling in conjunction with the exploration work.

PREVIOUS INVESTIGATIONS

Pearce (1895, p. 156–158), Moore and Kithil (1913, p. 46), Alsdorf (1916, p. 270), and Bastin and Hill (1917, p. 245) have described the pitchblende and other ores obtained from the Wood mine. G. B. Guillotte (written communication, 1944) examined the Wood and East Calhoun dumps in 1943. Moore and Butler (1952) mapped the accessible workings of both mines in 1950 as part of the general reconnaissance investigation for radioactivity in the Colorado Front Range. F. C. Armstrong (written communication, 1956) studied the surface geology of Quartz Hill in 1951.

Phair (1952) noted a spatial relationship between uranium deposits and the quartz bostonite porphyry rocks of the Tertiary intrusive series of the Front Range. As a result of his work, he inferred a genetic relationship between the intrusion of these rocks and the uranium deposits.

Leonard (1952, p. 1274–1275) found that two main types of ore deposits give the Central City district a zonal arrangement in plan view: quartz-pyrite veins near the center and galena-sphalerite veins on the periphery. He noted that the pitchblende deposits of Quartz Hill lie between the zones.

FIELD WORK

The present investigation, part of the Geological Survey's current studies in the Front Range, began in July 1952 and continued through October 1953. The writer made geologic maps of the accessible East Calhoun workings and the exploration headings. The working faces were examined and sampled after each round of blasting until the last week of January 1953. Thereafter the workings were visited at least once a week, and samples were taken from the back of the drift at appropriate spacings. Office and laboratory work was completed at the Geological Survey offices in Denver. A total of 605 samples were cut. They were assayed for uranium, gold, silver, copper, lead, and zinc. A semiquantitative spectrographic analysis was run on a split of each sample.

All exploration at the mine, on or from the 600-foot level of the East Calhoun shaft, October 1951 to October 1953, was under a contract with the Defense Minerals Exploration Administration. The U. S. Atomic Energy Commission mapped the exploration workings and sampled the uranium-bearing parts of the Wood vein.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the work of A. E. Dearth, who assisted the writer in the geologic mapping and sampling. Every courtesy and consideration were shown the writer by the Denver Realty Co., present owners of the mines. The suggestions of P. K. Sims of the U.S. Geological Survey are deeply appreciated. All assays, chemical analyses, and spectrographic analyses were made by the Geological Survey. A. J. Martin of the U. S. Bureau of Mines kindly furnished the production data.

GENERAL GEOLOGY

The Wood-East Calhoun area is on a northeast-trending anticline, which is the major structural feature of this part of the Central City district (fig. 29). The area is underlain by interlayered Precambrian gneiss and granite pegmatite. The gneiss consists of layers of granite gneiss, described by Bastin and Hill (1917, p. 30–32), with lesser amounts of biotite-quartz-plagioclase gneiss, migmatite, and amphibolite. Conformable layers and small irregular-shaped pods of granite pegmatite occur within the gneiss. These units generally dip gently away from the crest of the anticline and are locally deformed into tight drag folds or broad, gentle warps.

The Precambrian rocks are intruded by several quartz bostonite porphyry dikes of Tertiary age. The dikes occupy northwest-trending fractures (fig. 29). Steeply dipping faults that trend from east to N. 40° E. cut all the rocks (fig. 29). The faults are occupied by veins that average about 1 foot in width. The veins contain quartz-pyrite-gold-silver in the east and quartz-pyrite-sphalerite-chalcopyrite-gray copper-galena-gold-silver in the west.

ROCKS OF PRECAMBRIAN AGE

The Precambrian rocks of the Wood and East Calhoun mines consist of granite gneiss, biotite-quartz-plagioclase gneiss, migmatite, amphibolite, and granite pegmatite. All these rocks except some of the granite pegmatite have been deformed and recrystallized and have a metamorphic texture.

The biotite-quartz-plagioclase gneiss and amphibolite are probably of metasedimentary origin. Bastin and Hill (1917, p. 26–30) and Lovering and Goddard (1950, p. 19–20) included these rocks in th

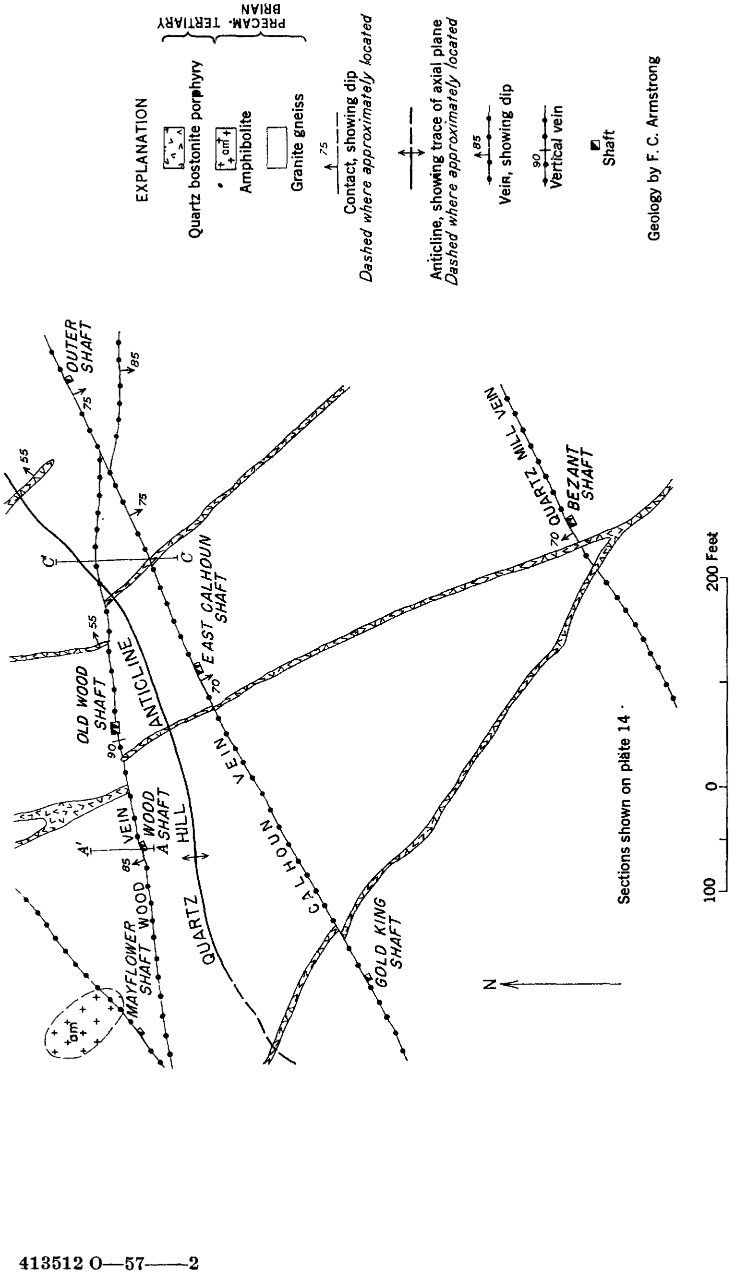

FIGURE 29.—Geologic map of the Wood-East Calhoun area, Central City district, Gilpin County, Colo.

Precambrian Idaho Springs formation. The granite gneiss, as described by Bastin and Hill, is a metamorphic rock of uncertain origin. Its average composition is quartz monzonite; in this report, however, the writer follows the usage of Bastin and Hill and refers to it as granite gneiss. The granite pegmatite has a simple composition and is younger than the other rocks.

BIOTITE-QUARTZ-PLAGIOCLASE GNEISS

Biotite-quartz-plagioclase gneiss does not crop out in the Wood-East Calhoun area, but it is found in the workings of both mines (pl. 12 and 13). The unit occurs principally in a layer between the fifth and sixth levels of the East Calhoun mine. Moore and Butler (1952) give schist, presumably equivalent to biotite-quartz-plagioclase gneiss, as the principal rock type in the upper workings of the Wood mine. Many layers of the rock that are too small to be mapped occur within the granite gneiss.

The biotite-quartz-plagioclase gneiss is light to dark gray, depending on the biotite content. The rock ranges from fine to medium grained; the medium-grained variety predominates. The principal minerals in order of abundance are plagioclase (near oligoclase), quartz, biotite, and microcline. Accessory minerals include magnetite, zircon, and apatite. In the East Calhoun mine, Wood drift east, a somewhat different phase of the unit is found within the granite gneiss in layers ranging from an inch to about 1 foot in thickness. It is a fine-grained salt-and-pepper rock that contains as much as 5 percent pink garnet.

The rock is moderately to strongly foliated by mineral orientation and compositional banding. Nearly all the rock contains conformable layers of pegmatite from a few inches to several feet thick.

AMPHIBOLITE

Amphibolite occurs as layers and lenses from 1 to 24 inches thick within the granite gneiss. It is a dark- to medium-gray, medium- to coarse-grained equigranular rock composed of nearly equal parts of dark-green hornblende and oligoclase-andesine. Accessory minerals include biotite, microcline, and some quartz. Many lenses of the rock have been altered to a "punky" biotite schist. Subparallel layering produces a fair to good foliation. Amphibolite lenses, now chiefly biotite schist, occur on the crests and troughs of northwest-trending warps in the more alaskitic granite gneiss.

MIGMATITE

A unit of closely interlayered rocks, termed migmatite in this report, was mapped west of the shaft on the fourth level of the East Calhoun mine (pl. 12). The unit is composed of biotite-quartz-plagioclase gneiss in layers 1–2 inches thick separated by granitic layers averaging about 1 inch in thickness. The unit is somewhat similar in appearance to the so-called "injection gneisses."

GRANITE GNEISS

The most abundant rock in the area is granite gneiss. It is dominant in the East Calhoun mine above the first and below the fifth levels. Several 1–10-foot layers are also present in the metasedimentary body between the first and fifth levels. Contacts of the granite gneiss are conformable to the layering of the metasedimentary rocks. The granite gneiss is a dark- and light-gray layered, medium-grained rock composed chiefly of feldspar, quartz, and biotite. Individual layers range from about an inch to several feet in thickness and contain different proportions of biotite. The perfection of rock foliation varies, depending upon the primary layering and parallel orientation of biotite flakes; foliation in the more alaskitic phases of the rock is poor.

Bastin and Hill (1917, p. 30–32) classified the rock as granite gneiss, but the composition of the specimens and thin sections examined by the writer more nearly approximates that of quartz monzonite. The average composition is about 44 percent plagioclase (An_{25}), 30 percent quartz, 20 percent microcline, and 5 percent biotite. Other minerals, not everywhere present, include magnetite (as much as 1 percent in some specimens), muscovite, hornblende, apatite, sphene, rutile, and epidote. The texture is granoblastic. Discrete layers and lenses of metasedimentary rock, commonly only a few feet wide, are scattered through the granite gneiss at places. Younger granite pegmatite intrudes the gneiss.

GRANITE PEGMATITE

The granite pegmatite is a medium- to coarse-grained light-gray alaskitic rock composed primarily of microcline and quartz. Biotite and magnetite are accessory minerals; magnetite is more widespread and abundant. Granite pegmatite bodies are generally conformable to the foliation of the other Precambrian rocks. Bodies of pegmatite within the granite gneiss are discrete layers along the foliation and small irregular-shaped pods in the crests and troughs of small folds. The pegmatite in the biotite-quartz-plagioclase gneiss occurs as distinct bodies in part large enough to map (pl. 12) and as discontinuous thin conformable layers.

ROCKS OF TERTIARY AGE

The bostonite dike rocks in the area mapped belong to the Tertiary intrusive sequence of the Front Range and are among the most radioactive igneous series in the world. Phair (1952) has divided the bostonite rocks into three subtypes—quartz bostonite porphyry, nonporphyritic quartz bostonite, and syenitic bostonite—depending on the presence or absence of quartz in excess of 5 percent by volume and by the presence or absence of megascopic phenocrysts of pink potash feldspar. The quartz bostonite subtype of this area contains from 0.010 to 0.025 percent equivalent uranium and is from 10 to 20 times more radioactive than the intruded Precambrian rocks.

QUARTZ BOSTONITE PORPHYRY

Four quartz bostonite dikes were mapped on the surface and underground in the area. The dikes trend northwestward, dip moderately to steeply to the northeast, and range in thickness from 1 to perhaps 10 feet. Quartz bostonite is a lilac-colored fine-grained porphyritic rock. Its characteristic texture is trachitoid, resulting from the subparallel arrangement of feldspar phenocrysts in a groundmass of quartz and feldspar. The margins of the dikes are finer grained than the interiors; glass is found at some contacts.

SYENITIC BOSTONITE PORPHYRY

In the Wood drift east, about 22 feet west of the face (pl. 13), a relict 2- to 3-inch bostonite dike was found in what is now a northwest-striking vein. The dike is badly broken and on the north wall of the drift it is completely obliterated. A thin-section study shows that this dike contains very little quartz, is high in mafic minerals, and that the phenocrysts are plagioclase. Based on the classification by Phair (1952) this rock is syenitic bostonite porphyry.

STRUCTURE

The principal Precambrian structure in the area is a broad, east-northeast-trending anticline with gentle to moderate dipping limbs. Associated minor fold structures, such as warps and drag folds, essentially parallel the anticlinal axis or transect it at an angle of 60° Mineral lineations generally parallel the fold axes.

Steeply dipping faults of Tertiary age trend east, east-northeast, and northwest. The northwest faults were loci for dike emplacement and the east and east-northeast faults are metallized. The northwest faults are cut and displaced by both the east and east-northeast trending faults; the east-trending faults are displaced by the east-northeast faults. Some of the joints were formed by the same forces that produced the faults. There is no apparent genetic relationship between the Precambrian structures and the faults of Tertiary age.

FOLDS

The major structural feature in the area is the Central City anticline. The trace of its axial plane trends about N. 60° E. (fig. 29), but it averages about N. 30° E.[1] Associated with this major structure are many small drag folds which plunge gently to the north-northeast or east-northeast. Superposed on the major anticline and its associated structures are a series of warps that trend N. 10°–50° W., averaging about N. 30° W., and plunge gently to the northwest or southeast (not shown on figures).

LINEATION

Lineations measured in the East Calhoun and Wood mines include mineral alinement, small drag-fold axes, warps, rodding, and corrugations. A lower-hemisphere Schmidt-net plot of 110 lineations (fig. 30) shows four maximums: 10° N. 30° E., 5° S. 60° W., 5° N. 60° E., and

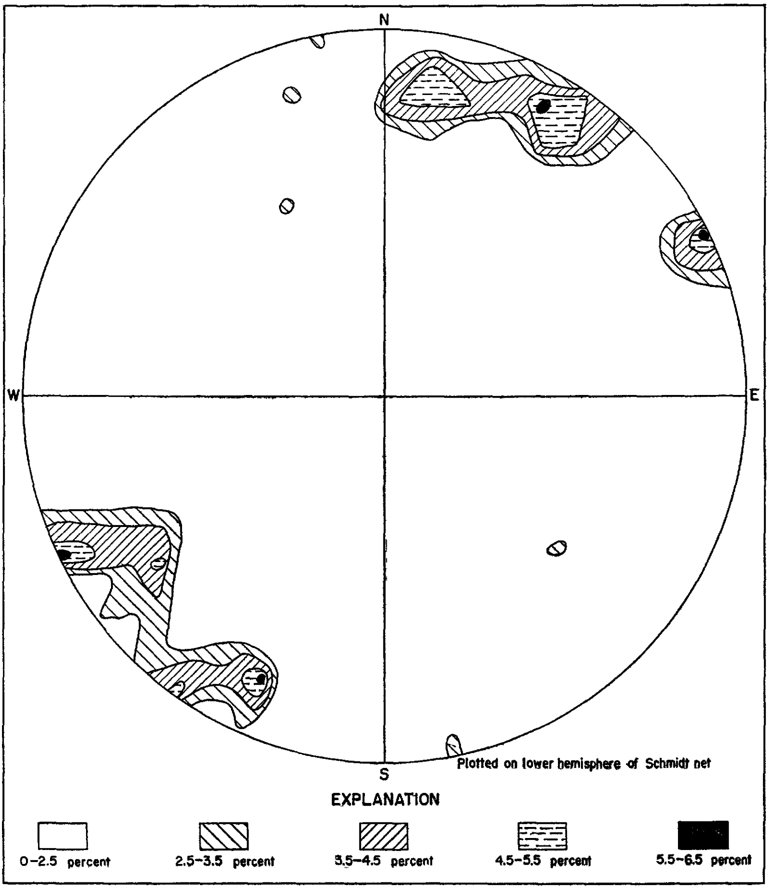

FIGURE 30.—Contour diagram of 110 lineations in rocks of the East Calhoun and Wood mines plotted on the lower hemisphere of the Schmidt net.

[1] Sims, P. K., Drake, A. A., Jr., and Moench, R. H., 1953, Preliminary geologic and vein maps of part of the Central City district, Gilpin and Clear Creek Counties, Colo.: U. S. Geol. Survey open-file rept.

15° S. 25° W. These lineations generally parallel the major and minor folding in the area studied.

JOINTS

To avoid overcrowding, joints have not been plotted on plates 12 and 13. Instead, the poles to joint planes were plotted and contoured on the upper hemisphere of a Schmidt net (fig. 31). Three strong maximums representing joint sets are present: N. 80° E., nearly vertical; N. 40° W., nearly vertical; and N. 45° W., 70° NE. The steep N. 80° E. set closely approximates the attitude of the Wood vein and possibly was formed by the same forces that produced the east-west fractures. The two northwest-trending maximums probably represent statistical peak readings on the same joint set.

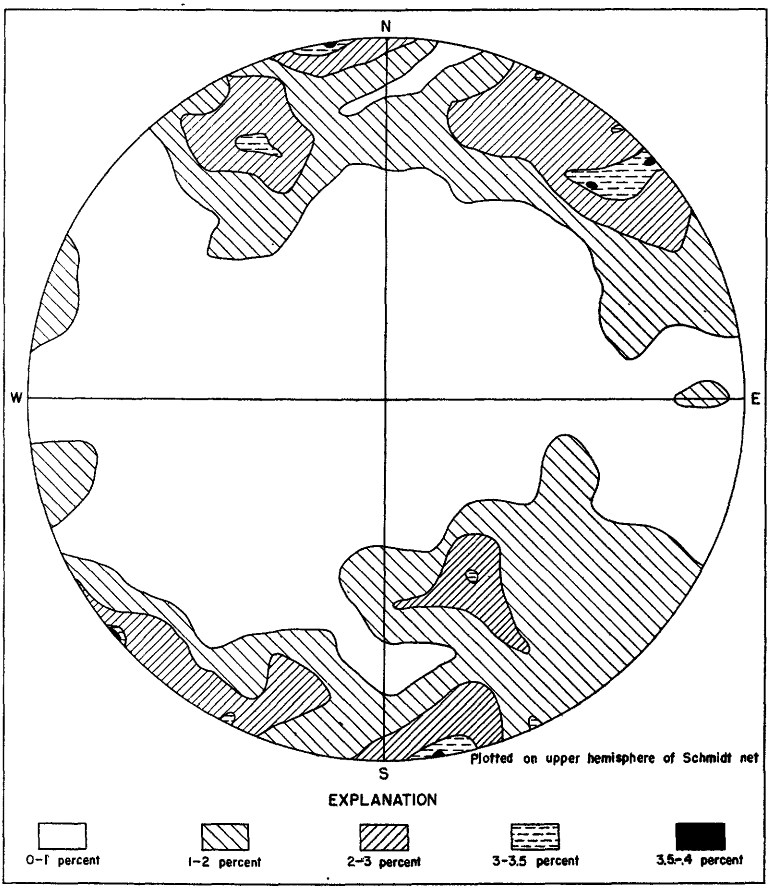

FIGURE 31.—Contour diagram of 386 joints in the Wood-East Calhoun area plotted on the upper hemisphere of the Schmidt net.

FAULTS

The three principal faults in the area are the east-trending Wood fault and the east-northeast-trending Calhoun and Quartz Mill faults. These faults are metallized and are major veins. Minor east-northeast to northeast-trending faults are also metallized. Several barren northwest-trending faults were mapped underground (pl. 13). The faults in order of age from oldest to youngest are northwest-, east-, and east-northeast-trending.

CALHOUN FAULT

The Calhoun fault strikes about N. 65° E. and dips an average of 70° SE. It is the most persistent fault on the south slope of Quartz Hill and has been traced on the surface for 4,000 feet.[2] Minor ore brecciation and the formation of gouge indicate that some postmineral movement took place along the break. Neither the true direction nor the amount of movement on the fault is known, but on the fourth level of the East Calhoun mine a bostonite dike contains an apparent horizontal separation of 10 feet, the south wall having moved west with respect to the north wall. On the first level of the East Calhoun mine the Wood vein is displaced by the Calhoun vein, the south wall having moved west horizontally about 4 feet. On the same level, the south segment of a bostonite dike has moved west a few inches. It therefore seems that movement on the Calhoun fault was strike-slip with a normal type of displacement.

QUARTZ MILL FAULT

The Quartz Mill fault crops out south of the Calhoun fault and intersects it just above the sixth level of the East Calhoun mine (pl. 12). The fault strikes about N. 65° E. and dips 70°–75° N. It is similar in character to the Calhoun fault. In the Bezant mine, which exploits the Quartz Mill vein, the Quartz Mill fault displaces the south segment of a bostonite dike about 7 feet horizontally to the west. Therefore, it appears that the movement along the fault was similar to that along the Calhoun fault. The Quartz Mill-Calhoun fault crossing can no longer be seen, but Sanderson[3] observed no displacement at the intersection. The attitude of the two veins is such that their intersection is essentially horizontal except for local flat plunges to the east or west.

[2] Sims, P. K., Drake, A. A., Jr., and Moench, R. H., op. cit.

[3] Sanderson, H. S., 1909, Report on the properties of the Bezant Mining Co.: Unpublished private mining report.

WOOD FAULT

The Wood fault has been traced on the surface for about 1,000 feet.[4] It trends eastward and dips steeply either side of vertical. Abundant gouge, intravein slip planes, and numerous slickensides indicate that, in contrast to the Calhoun fault, there was much recurrent movement along the break. The attitudes of 70 slickensides were plotted and contoured on the lower hemisphere of a Schmidt net (fig. 32). This diagram shows nearly horizontal maximums in an east-west direction, indicating that the movement along the fault was essentially horizontal. Several steep slickensides, too few to show a statistical maximum, plunge vertically down the dip of the fault. Where measured, these dip-slip slickensides are later than the

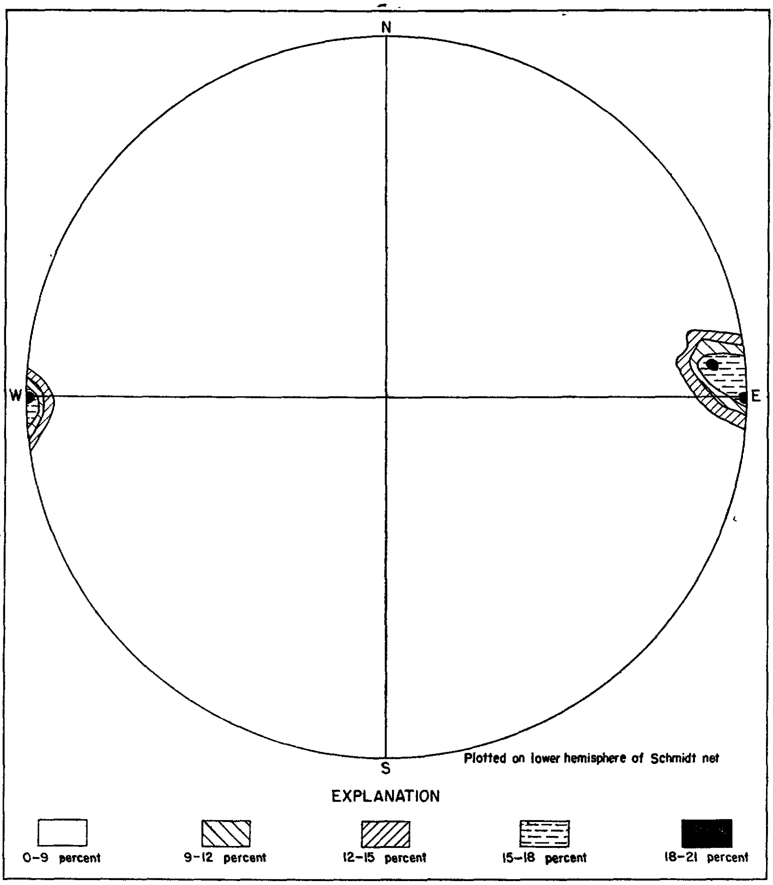

FIGURE 32.—Contour diagram of 70 slickensides on the Wood vein plotted on the lower hemisphere of the Schmidt net.

[4] Sims, P. K., Drake, A. A., Jr., and Moench, R. H., op. cit.

strike-slip slickensides. The direction and amount of displacement on the Wood fault are not known definitely, but it appears probable that the movement was principally horizontal, the south wall having moved east with respect to the north wall. Detailed geologic mapping of the surface shows that the south segments of two bostonite dikes have shifted 30–40 feet east along the Wood fault. The horizontal displacement may appear exaggerated, however, because of the poor exposures on Quartz Hill. On the first level of the East Calhoun mine, the south segment of a bostonite dike is displaced perhaps 3 inches to the east. As the Wood fault is distinguished by lateral movement, is nearly vertical, and varies little in strike and much in dip, it is probably a wrench fault (Anderson, 1951, p. 59–60).

MINOR FAULTS

The Wood exploration drift east (pl. 14) does not follow the Wood vein but is instead on a northeasterly split that dips steeply either side of vertical. This fault alines well with the Willowdale patented claim, and accordingly the writer has named this split the Willowdale vein. Moore and Butler (1952) show a split off the Wood vein near the shaft on the 135, 197, and 275 levels of the Wood mine that bears S. 75°–80° W. and dips nearly vertical. On the 275 level west, about 200 feet from the Wood shaft, they show another southwestward-trending split from the Wood fault. The writer's mapping shows many minor splits from the Wood fault that trend either northeastward or southwestward. Many branches connecting parallel to subparallel veins have a general northeasterly strike. Although these minor faults have the appearance of splays from the Wood fault, the presence of gouge and abundant slickensides characteristic of shearing complicates the theory of fault movement. This is mechanically resolved in the following interpretation of the order of faulting: (1) formation of the Wood fault and associated tension fractures, the movement being south wall east with respect to the north wall; (2) formation of the Calhoun fault, the movement being south wall west with respect to the north wall; (3) stress relieved by movement along the Wood fault and shearing along the previously formed tension fractures, such movement tending to realine displaced units along the Wood fault and accounting for the apparent lack of displacement. If this type of fracturing took place, one would expect strong fracturing in the vicinity of the Wood fault-tension fracture junctions. Such loci are in fact strongly fractured.

The Mayflower fault, mapped on the surface in the Wood-East Calhoun area, strikes about N. 50° E. and dips nearly vertical. Its relation to the Wood fault is obscure. Armstrong (written com-

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munication, 1956) believes that this fault extends north and south of the Wood fault, but the writer mapped no structure underground that correlates with the Mayflower fault.

STRUCTURE OF TERTIARY DIKES

The Tertiary dikes in the Wood-East Calhoun area fill steeply dipping fractures in the Precambrian rocks. The attitude of the dikes is essentially the same as the northwest-trending joint set and barren northwest-trending faults. This evidence indicates, at least for the small area studied, that the dikes were emplaced in northwest-trending fractures. Because the dikes are cut and displaced by the veins, it is inferred that they fill a fracture system older than the veins.

ECONOMIC GEOLOGY

The gold, silver, uranium, copper, lead, and zinc deposits of the area are found in veins probably formed at moderate temperatures. These deposits are early Tertiary in age and have been related genetically to the intrusion of porphyritic dike rocks (Lovering and Goddard, 1950, p. 170–191; Phair, 1952). Gold, silver, and uranium provided most of the dollar value of the ore produced.

Two main types of ore deposits give the Central City district a zonal arrangement in plan view (Leonard, 1952). A core, about 2 miles in diameter, of quartz-pyrite veins is surrounded by a wide outer zone of lead-zinc-silver veins. The area of overlap of these two zones includes the Wood and East Calhoun mines where transition veins contain pitchblende in addition to gold, silver, copper, lead, and zinc ores.

The uranium deposits of the area contain pitchblende and occur at places along the metalliferous veins as pods and lenses. These pods and lenses occur in the same westerly raking ore shoots as the other metals. Pitchblende was deposited earlier than sphalerite, galena, chalcopyrite, gray copper, and most of the pyrite and contains high trace amounts of zirconium and molybdenum.

HISTORY AND EXPLORATION

EAST CALHOUN MINE

The East Calhoun mine (pl. 12) was probably opened in the 1860's. The mine was operated intermittently until World War I. It was reopened in 1949, and a Defense Minerals Exploration Administration project was approved in 1951.

The East Calhoun shaft is inclined about 70° south from the surface to just above the sixth level, where the Calhoun vein intersects the Quartz Mill vein. The original shaft was continued on the Calhoun vein for perhaps another 30 feet,[5] but as the vein was valueless another shaft was sunk on the Quartz Mill vein which dips to the north. This vein was exploited to a depth of about 980 feet. In 1954 the mine was inaccessible below the sixth level. The positions of drifts and stopes are shown on figure 33.

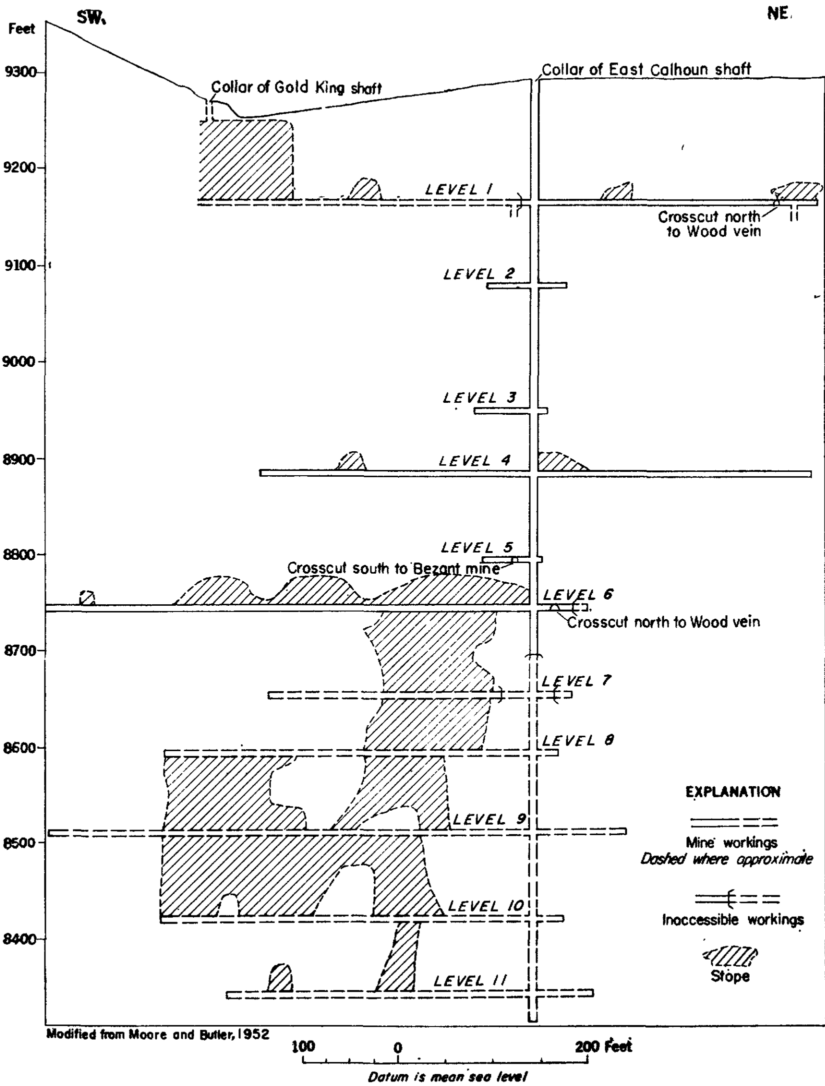

FIGURE 33.—Longitudinal projection of the East Calhoun mine, Central City district, Gilpin County, Colo.

[5] Sanderson, H. S., op. cit.

WOOD MINE

The Wood mine is one of the oldest patented locations on Quartz Hill, No. 232. It has been worked intermittently from the late 1860's to the present. Pitchblende was first noted on the dump of the Old Wood shaft in 1871 (Pearce, 1895, p. 157–158).

The Wood vein is exploited by the Wood and Old Wood shafts on the west (fig. 29) and by the Ross shaft that is 320 feet east of the junction of the Wood and Calhoun veins. Moore and Butler (1952) mapped the 135, 197, and 275 levels of the Wood mine (fig. 34); other levels that are inaccessible supposedly are present at vertical depths of 400, 500, and 600 feet. Neither the depth nor the amount of working from the Old Wood shaft is known. The Ross shaft is about 120 feet deep and is inclined about 85° south. The vein has been stoped from the surface to a point about 70 feet below the collar of the shaft. These workings were inaccessible in 1954. The Wood vein is accessible from the first level of the East Calhoun mine by a crosscut north and a short drift (pl. 12) and by the exploration workings on the sixth level of the East Calhoun mine (pl. 13).

PRODUCTION

EAST CALHOUN MINE

The total production of ore from the East Calhoun mine is not known. Table 1 shows the production from the Jefferson-Calhoun vein from 1902 to 1915, including production from the East Calhoun, West Calhoun, Kemp Calhoun, and Jefferson mines. Residents of the district generally assign a value of about $1,500,000 to the ore produced from the Calhoun vein. Little ore was produced from the Calhoun vein in the East Calhoun mine as most of the stopes are on the Quartz Mill vein. So far as known, no pitchblende has been produced from the East Calhoun mine.

WOOD MINE

There are no records of the total production of ore from the Wood mine. Table 2 shows the substantiated pitchblende production. The writer found record of only one shipment of gold and silver, but residents of the district assign a value of about $600,000 to the ore mined from the Wood vein. Bastin and Hill (1917, p. 245) state that the ore extracted in driving the 200 level to the east averaged $10 per ton (gold value in 1917: $20.67 per ounce) and that the gold content was exceptionally high, one assay showing 35 ounces.

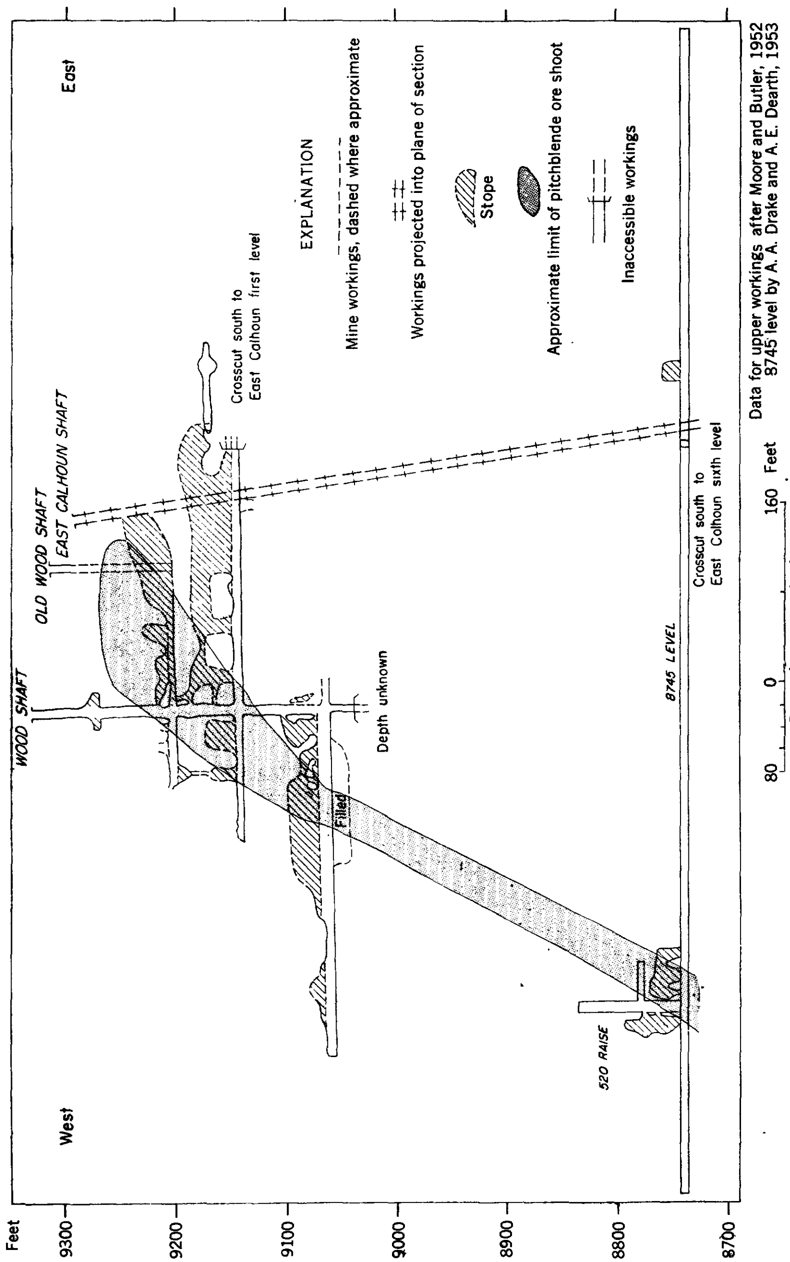

FIGURE 34.—Vertical longitudinal projection of the Wood mine, Central City district, Gilpin County, Colo.

TABLE 1.—*Production from the Jefferson-Calhoun vein, 1902–15* [1]

Year	Crude ore shipped (tons)	Concentrates shipped (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)
1902	219		179.00	1,020	5,829	
1903	313		225.37	1,051	3,533	
1904	60		90.00	900	3,429	
1905	1,510		755.00	750	10,786	
1906	30		96.75	746	2,043	
1907	2,280		901.16	1,944	9,676	
1907		382	265.55	3,021	4,630	
1908	5,843		1,724.34	4,079		
1908		695	472.29	3,828	19,373	5,476
1909	38		28.00	304		1,125
1910	198		74.89	550	3,333	
1910		11	3.98	49		
1912	171		49.06	70	660	
1912		27	20.40	48		
1913	1,406		592.53	1,577	7,014	
1913		130	39.44	517	2,027	330
1914	561		342.98	1,012	6,338	
1914		62	36.97	225	569	
1915	5		3.86	29	181	
Total	12,634	1,307	5,901.57	22,720	79,421	6,931

[1] A. J. Martin, Metals Economics Branch, U. S. Bureau of Mines, Denver, Colo. Published with permission of the Bureau of Mines.

TABLE 2.—*Substantiated pitchblende production from the Wood vein*

[From Armstrong, F. C., written communication, 1956]

Year	Crude ore shipped (tons)	Concentrates shipped (tons)	Gold (ounces)	Silver (ounces)	U_3O_8 (pounds)	Remarks
1871	0.10				120	Hand sorted.
1872	3.10				3,720	Do.
1873	2.70				2,254	
1884	3.00				4,200	
1894	(?)				(?)	Pearce purchased a quantity of ore.
1897	17.00				27,000	Not fully substantiated.
1898	33.00				7,920	
1913	.20				200	
1916	10.00				1,200	
1940	.50	[1] 35	[1] 53.60	[1] 77	135	
Total	69.60	35	53.60	77	46,749	

[1] A. J. Martin, Metals Economics Branch, U. S. Bureau of Mines, Denver, Colo. Published with permission of the Bureau of Mines.

GENERAL CHARACTER OF THE VEINS

The veins in the area are for the most part single well-defined fault fissures ranging from ½ inch to 24 inches in width containing from a few to many subparallel veinlets and slips which form complex lodes. Outward from these fissures the wall rocks are replaced for a few inches to a few feet. The wall rock is exceptionally silicified and pyritized to widths as much as 5 feet; on the average, the width of the altered zone is about 18 inches. The east-trending veins, such as the Wood, show a marked tendency to form looping and "horsetail type" branches. These branches generally are more common in areas of metasedimentary rocks. "Horses" of rock between splits and parallel veinlets are strongly shattered, silicified, pyritized, and in some places nearly completely replaced by ore minerals. The lode zones are generally uniform in strike, but highly variable in dip. Ore shoots commonly occur on the steeper parts of the veins. All the veins show repeated fracturing, open filling, and replacement to a greater or lesser degree. Breccia fragments of both altered wall rock and vein filling, granulation of minerals, particularly pyrite, and many sets of crosscutting veinlets and slip planes indicate repeated movement. Deposition in open cavities is shown by the pronounced formation of comb structure in the vein quartz and abundant crystals and encrustations of ore minerals on the walls of openings. The veins are stronger in the granite gneiss and in places pinch to a barren slip in the biotite-quartz-plagioclase gneiss and amphibolite.

CALHOUN VEIN

The Calhoun vein strikes about N. 60° E. and for the most part is a single well-defined fault fissure that ranges in width from ½ to 18 inches. It consists of pyritized silicified wall-rock fragments, gouge, pyrite, and quartz, with spotty chalcopyrite and sphalerite and, rarely, a little sooty pitchblende. Individual streaks of quartz and ore minerals seldom exceed 3 inches in width. The silicified and pyritized halo may be as much as 5 feet in width but averages about 18 inches. The vein is tight—much more so than the Wood—and shows little evidence of much postmineral movement; however, 1–3 inches of gouge is present along the walls and along a few oblique postmineral slips, and ore minerals, particularly pyrite, are granulated. Deposition in open spaces is indicated by the presence of comb quartz, pyrite, chalcopyrite, and sphalerite crystals in a few vugs. Silicified and pyritized wall rock, relict islands of pyrite surrounded by chalcopyrite and sphalerite, and the corrosion of quartz crystal faces by sulfides indicate that the vein-forming minerals formed, in part at least, by replacement.

The Calhoun vein generally is narrow and sparsely filled where it cuts metasedimentary rocks, except where these rocks were strongly migmatized. The vein seldom splits or loops except on the fourth and sixth levels west, where the vein is in biotite-quartz-plagioclase gneiss. For the most part the vein is stronger on the "steeps." The vein steepens in dip to the west and is nearly vertical at the West Calhoun shaft (Moore and Butler, 1952); all the major stopes are to the west of the area mapped.

QUARTZ MILL VEIN

The Quartz Mill vein strikes about N. 65° E. and dips 70°–75° N. and ranges in width from about 3 inches to 3 feet. Where present in the East Calhoun and Bezant mines the vein has been stoped and little is known about its character. It consists of silicified and pyritized wall-rock fragments, quartz, and pyrite. Presumably, where stoped, the vein also contained chalcopyrite and possibly some gray copper, for samples cut by Sanderson [6] show moderate amounts of copper. In the area studied, most of the stoping was done on the steeper parts of the vein.

WOOD VEIN

The Wood vein trends nearly east-west and is highly variable in dip (pl. 14). It consists of one principal vein-filled fissure with many parallel to subparallel fractures and veinlets; therefore, it more properly should be termed a lode (Lindgren, 1933, p. 157–158). The principal vein-filled fissure ranges from 2 to about 24 inches in width. Discontinuous streaks of sulfides and quartz seldom exceed 6 inches in width. The vein shows abundant evidence of repeated fracturing, open filling, and replacement. Breccia fragments of altered wall rock, granulation of pyrite and pitchblende, many crosscutting veinlets and slip planes, abundant slickensides, and strong gouge indicate repeated movement (pl. 14). Deposition in open cavities is shown by the colloform structure in the pitchblende, a well-defined comb structure in vein quartz, and the abundant deposition of quartz, pyrite, and sphalerite crystals as encrustations in vugs. Replacement is indicated by silicified and pyritized wall rock and by the texture of the ore minerals. The vein is thickened near acute fissure intersections because of the shattering of the intervening wedge of rock. Parts of the vein are similarly thickened between parallel fissures. The vein is stronger on strike changes to the northeast, indicating that wider fissures were produced by movement of the south wall east. No dip control was noted; however, the vein appears to be stronger on steep dips to the north.

[6] Sanderson, H. S., op. cit.

WILLOWDALE VEIN

The Willowdale vein, a hanging-wall branch of the Wood vein (pl. 13), strikes about N. 45° E. and is highly variable in dip north and south. The vein is similar to the Wood in that it shows abundant evidence of recurrent movement. However, it is a much weaker structure and carries sparse amounts of ore minerals.

MINERALOGY

The veins in the Wood and East Calhoun mines contain in order of decreasing abundance: quartz, pyrite, chalcopyrite, sphalerite, tetrahedrite-tennantite, galena, pitchblende, bornite, sooty chalcocite, and covellite. The suite is generally typical of those deposits that probably formed at moderate temperature and pressure.

QUARTZ

The gangue mineral in all the veins is quartz. At least four types of quartz are recognized. The first type is a light-gray very fine grained cherty material that replaces the wall rock. In polished surface observed under the microscope, a similar-appearing fine-grained quartz cements fragments of pitchblende. White massive medium-grained quartz replaces the wall rock and fills fractures. White to clear, terminated quartz crystals, as much as half an inch long, grow outward from the massive quartz, line vugs, and form comb structure in the veins. The fourth type of quartz, the last to form, is a brown to gray fine-grained, sometimes banded, variety (the horn quartz of the miners) which fills open spaces in the veins and forms thin coatings on crystals in vugs.

PYRITE

Pyrite is the most abundant mineral in the veins and four types are recognized. The first type is yellow finely crystalline cubic pyrite that impregnates the wall rock. Another type—pale-yellow pyrite—is associated paragenetically and spatially with pitchblende in the Wood vein. This pyrite occurs in veinlets and aggregates and is brecciated or fractured. Where unbroken, it is chiefly cubic in habit. Nearly everywhere observed, this pyrite veins pitchblende or pitchblende-quartz breccia; but in a few polished surfaces it appears also to be intergrown with pitchblende. The third type of pyrite, a yellow generally crystalline (mostly cubic) variety, is the principal vein-filling mineral. A fourth type of pyrite forms cubic crystals and encrustations on quartz and other crystals in vugs, and is in turn coated by gray to brown fine-grained quartz. Gold and silver occur in the third type of pyrite (table 3). The other types of pyrite also may carry gold and silver, but no data are available.

TABLE 3.—*Gold and silver content of pyrite, Calhoun and Wood veins, Central City district, Gilpin County, Colo.*

Locality	Ounces per ton	
	Au	Ag
East Calhoun mine, 6th level:		
Calhoun vein, 800 feet west of shaft [1]	1.24	2.46
Wood exploration drift, Wood vein, 500 feet west of crosscut [2]	.04	3.02

[1] Armstrong (written communication, 1956).
[2] Sized, superpanned, and hand-picked. Analysis by U. S. Geological Survey.

CHALCOPYRITE

Chalcopyrite is the second most abundant ore mineral in the Wood and Calhoun veins. Veinlets of chalcopyrite cut sphalerite, pyrite, quartz, and galena. Under the reflecting microscope, a replacement texture composed of relict islands of sphalerite and pyrite was noted in chalcopyrite. Relict islands of chalcopyrite were noted in galena. Two analyses of chalcopyrite (table 4) show a high silver and a moderate gold content.

TABLE 4.—*Gold and silver content of chalcopyrite, Calhoun and Wood veins, Central City district, Gilpin County, Colo.*

Locality	Ounces per ton	
	Au	Ag
East Calhoun mine, 6th level:		
Calhoun vein, 800 feet west of shaft [1]	0.90	33.80
Wood exploration drift, Wood vein, 500 feet west of crosscut [2]	.34	17.60

[1] Armstrong (written communication, 1956).
[2] Analysis by U. S. Geological Survey.

SPHALERITE

Sphalerite veins, which commonly consist of the dark iron-rich variety, marmatite (table 5), cut quartz and pyrite; sphalerite crystals fill fractures and vugs and corrode pyrite crystals along mutual boundaries. "Resin jack" is also found in vugs as small tetrahedrons that have been deposited on dark sphalerite. Chalcopyrite veinlets traverse sphalerite, and tiny blebs and needles are distributed through the dark sphalerite. Most of this chalcopyrite probably is of replacement origin, but some may have been exsolved. The sphalerite contains small amounts of gold and silver (table 5).

TABLE 5.—*Analyses of sphalerite, Calhoun and Wood veins, Central City district, Gilpin County, Colo.*

Locality	Ounces per ton		Percent		
	Au	Ag	Fe	Cu	Pb
East Calhoun mine, 6th level:					
Calhoun vein, 800 feet west of shaft [1]	0. 16	0. 76	------	------	------
Wood exploration drift, Wood vein, 500 feet west of crosscut [2]	------	------	17. 03	4. 26	0. 30

[1] Armstrong (written communication, 1956).
[2] Analysis by U. S. Geological Survey.

TETRAHEDRITE-TENNANTITE

Gray copper is moderately abundant in both the Calhoun and Wood veins. It is steel gray, has a red streak, and may be mistaken for hematite. In polished section the mineral has a greenish cast indicating that it may be near the tennantite end of the solid solution. Bastin and Hill (1917, p. 99) found that most of the gray copper of the Central City district was tennantite. In polished section, tetrahedrite-tennantite veins chalcopyrite and sphalerite. Good "sea and island" textures of gray copper in both sphalerite and chalcopyrite indicate replacement.

GALENA

Galena is sparse in both the Wood and Calhoun veins. Generally it is strongly crystalline and fills open spaces in the veins. Under the reflecting microscope galena veins sphalerite, tetrahedrite-tennantite, and chalcopyrite, and it is in turn cut by chalcopyrite veinlets. Relict islands of pyrite, sphalerite, and chalcopyrite occur in the galena. Galena streaks were also noted along the cleavage of pyrite, sphalerite, and chalcopyrite. Relict islands of galena also were seen in chalcopyrite.

GOLD AND SILVER

Gold and silver are carried by pyrite, chalcopyrite and sphalerite, and probably also by tetrahedrite-tennantite and galena. It is not known, however, whether they are carried mechanically or in solid solution. Free gold is also present. Miners at the East Calhoun mine have panned gold from ore from stopes above the 520 level (fig. 34 and pl. 13). The gold is a "flour" type which is lost by normal milling practice. No gold was observed in polished section. The gold-silver ratio in samples from the Wood exploration drift is 1:5 (fig. 35).

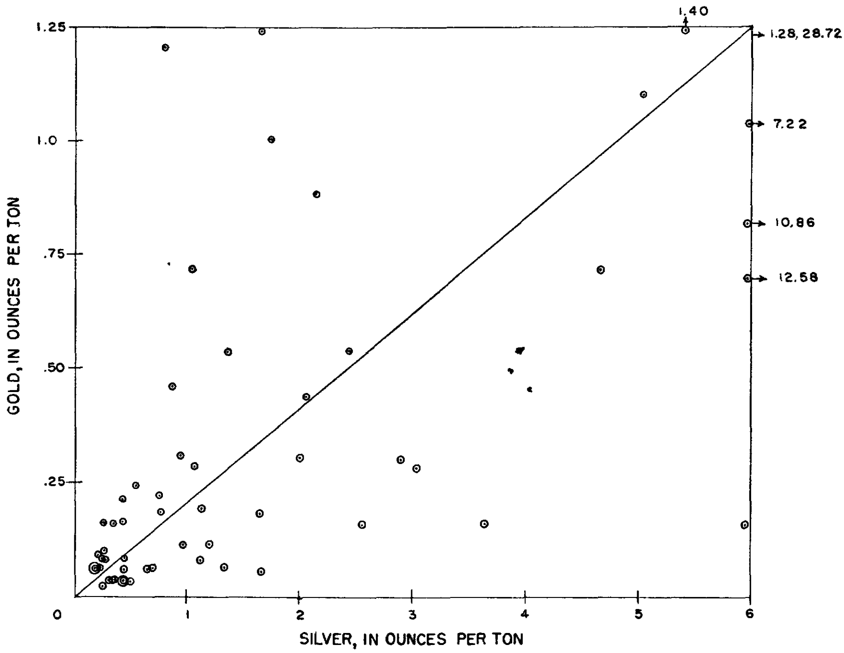

FIGURE 35.—Graph showing the relation of gold to silver in samples from the Wood vein.

PITCHBLENDE

Hard, lustrous pitchblende occurs as small discontinuous streaks and lenses on the footwall of the Wood vein. The maximum thickness of individual lenses observed by the writer is 4 inches; however, Bastin and Hill (1917, p. 245) reported ore bodies as much as 2 feet thick on the upper levels of the Wood mine. The pitchblende lenses are separated from other parts of the vein by a strong, heavily slickensided fracture (pls. 13 and 14). Sooty pitchblende was observed in postmineral slips near the hard pitchblende and on fracture surfaces at the shaft on the first level of the East Calhoun mine. On the same level sooty pitchblende coats the vein wall just east of the intersection of the Wood and Calhoun veins.

Megascopically, the pitchblende is hard, black, and lustrous. It appears massive but shows a colloform structure under a reflecting microscope. It has been brecciated and it occurs in veinlets and as aggregates of spheroidal grains. Most of the grains have rounded margins that are in part spheroidal, and many have been rotated. All spheroidal grains have both radial (syneresis) and circumferential cracks and some sections contain tiny, apparently massive, grains of pitchblende. They probably represent breccia fragments of larger areas of nearly uniform appearance. Most cracked grains are predominantly light gray, in part healed by a darker gray pitchblende, which indicates brecciation during deposition. Almost all the grains have a slight color banding parallel to the colloform layering; darker material occurs on the outside and is probably the result of the difference in oxidation. A little pale-yellow pyrite is intergrown with the pitchblende, but pitchblende is veined by pyrite in most sections studied. In some places the brecciated pitchblende is healed and cemented by quartz. Some pitchblende appears to replace quartz, but for the most part it does not. In the pitchblende-bearing sections studied, no minerals other than pitchblende, quartz, and pyrite were noted.

An analysis of pitchblende from the Wood mine (Hillebrand, 1891, p. 65–66) showed 58.51 percent UO_2 and 25.25 percent UO_3. The specific gravity is 8.068. Lead-uranium age determinations on two specimens from the Wood mine (Stieff and Stern, written communication, 1951) gave absolute ages of 57.3 and 60 million years.

BORNITE, SOOTY CHALCOCITE, AND COVELLITE

Minor amounts of bornite were observed in the Calhoun vein west of the East Calhoun shaft; none was detected under the microscope, however. The bornite is probably closely related to the chalcopyrite.

Sooty chalcocite was observed in both veins in extremely wet areas. It is probably supergene.

Thin brilliant-blue covellite coatings were noted on galena, pyrite, and chalcopyrite in the Calhoun and Wood veins. This supergene coating is apparently a district-wide phenomenon which has been observed by the writer in other mines in the district.

PARAGENESIS

The sequence of events in the formation of the veins is shown in figure 36. This sequence was determined from a megascopic study of the veins and examination of 20 polished sections.

Mineralization began with the deposition of gray, fine-grained quartz which silicified the wall rock. Essentially contemporaneous with the silicification, finely crystalline pyrite was formed in the wall rock, possibly from iron ions liberated from the rock by the altering solutions. Colloform masses of pitchblende were then deposited in open spaces. Movements along the vein fractured the pitchblende, and the fractures were healed by fine-grained quartz and pitchblende. Pale-yellow pyrite was deposited with the younger pitchblende. Strong movement in the vein brecciated the quartz-healed pitchblende and the pale-yellow pyrite. Subsequently, white massive quartz, yellow pyrite, comb quartz, and sphalerite with exsolved chalcopyrite were deposited in open spaces. Sphalerite replaced pyrite to a limited extent. Later movement along the vein fractured the minerals and

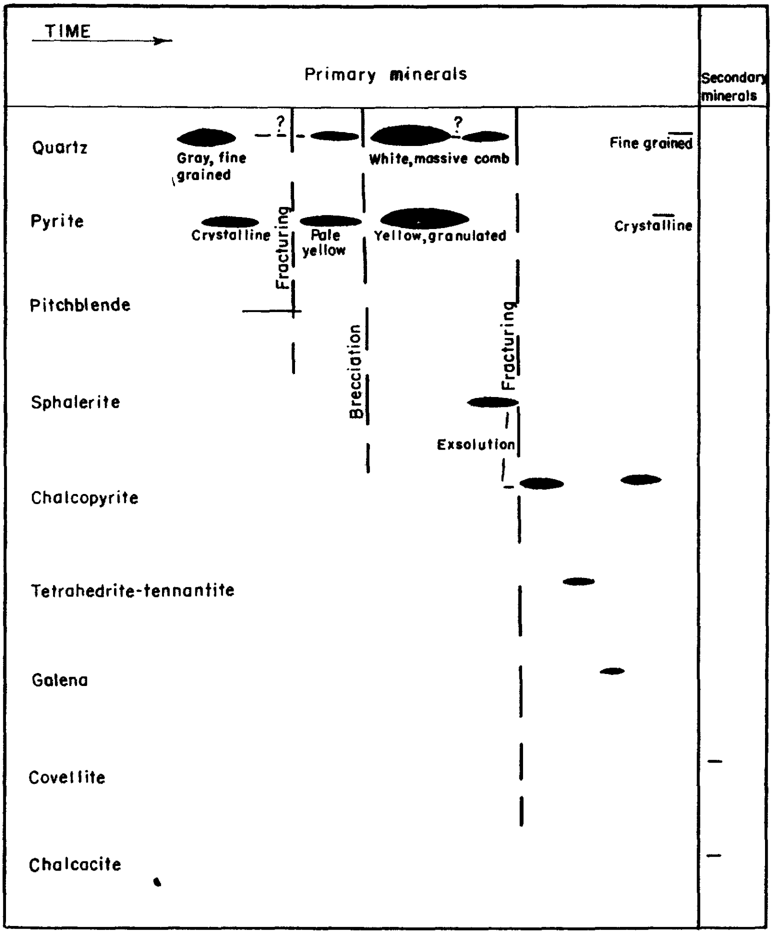

FIGURE 36.—Paragenesis of the vein minerals.

opened fissures in which chalcopyrite, tetrahedrite-tennantite, and galena were deposited. Chalcopyrite replaced sphalerite, pyrite, and, to a limited extent, quartz. Tetrahedrite-tennantite closely followed chalcopyrite, replacing it and the sphalerite. Galena filled open spaces surrounding other mineral grains and replaced sphalerite and gray copper. Galena was then replaced by late chalcopyrite.

Coarse pyrite crystals were then deposited on earlier minerals in vugs. The sequence ended when gray to brown fine-grained quartz coated ore minerals in vugs. The final event in the formation of the veins was the coating of ore minerals by covellite and the deposition of sooty chalcocite. These secondary minerals were precipitated from cupriferous supergene solutions.

RESULTS OF SAMPLING

Plate 15 shows in graphic form the results of assays for uranium, gold, silver, copper, lead, and zinc in samples taken from the Wood vein. Table 6 shows assay data from 132 individual samples.

It was formerly thought that pitchblende occurred in small bodies randomly distributed through the vein. Plate 15 shows that uranium values are concentrated in one limited area of the vein, near the 520 raise. Negligible quantities are detected elsewhere. The uranium-bearing zone lies on the projection of the Wood ore shoot (fig. 34) as outlined by Moore and Butler (1952). The ore-shoot relationship is discussed on page 164.

The highest gold and silver assays are from samples cut in the uranium-bearing zone. The gold-uranium relation is of considerable interest in the Central City district. Many workers in the area have remarked on the inverse relation between gold and uranium content of the veins. Rickard (1913, p. 853) states:

> * * * it is axiomatic in these mines that as the pitchblende comes in the gold goes out, and, as a matter of fact, the pitchblende ores seldom contain more than $2 to $4 in gold.

This reported inverse relation does not occur in the Wood vein, at least in that part sampled in this study. Perhaps the miners sampled pitchblende and obtained poor gold assays. Another possible explanation is that pitchblende, which was deposited before the principal gold-bearing minerals, almost completely filled available open spaces where it was deposited, leaving little room for subsequent gold-bearing minerals. As less pitchblende was deposited at depth more space was available for later minerals.

Both pyrite and chalcopyrite contain gold and silver, as shown in tables 3 and 4. The pyrite apparently does not contain sufficient gold to constitute ore. Many samples of almost solid pyrite vein material showed very low gold assays. If pyrite contained enough gold to constitute ore, one would expect samples largely of pyrite to show ore-grade assays. It has been long known that gold and copper values are found together (Bastin and Hill, 1917, p. 109). This is generally true for the Wood vein, but the analysis of nearly clean chalcopyrite from the Wood vein (table 4) shows a low gold content. The writer believes that free gold may have been deposited almost contemporaneously with chalcopyrite and that the copper-gold relation may be more apparent than real.

Gray copper and chalcopyrite both contain silver. Galena is presumably argentiferous but is too sparse to be of economic interest either for lead or for silver. Moderate quantities of zinc are found, but at present zinc is of little economic importance.

TABLE 6.—*Some chemical analyses, fire assays, and semiquantitative spectrographic analyses of ore from the Wood vein*

[All assays and spectrographic analyses made by U. S. Geological Survey. Au and Ag in ounces per ton. U, eU, Cu, Pb, Zn, and Fe_2O_3 in percent. Other elements reported by group-number method. Zero (0) indicates that the element was looked for but not found]

Sample W—	Width (inches)	U	eU	Au	Ag	Cu	Pb	Zn	Fe_2O_3	Ti	Mn	As	Ba	Be	Bi	Co	Cr	Ga	Mo	Ni	Sb	Sc	Sr	V	Y	Zr	Cd	B	Sn	Ce
2	3	0	0.003	0.12	1.20	0.35	2.12	2.03	42.04	4	4	0	5	0	5	0	6	5	5	5	0	0	0	5	0	5	4	0	0	0
31	3	0	.002	<.10	0	<.05	<.01	0	21.63	4	4	0	5	0	0	6	6	6	5	5	0	0	0	5	0	0	0	0	0	0
36	7	0	.002	Tr.	.20	.12	.09	.35	12.57	3	4	0	4	Tr.	6	6	4	5	0	5	0	5	0	5	5	4	0	0	0	0
39	6	0	.000	Tr.	1.10	0	.77	.13	24.35	4	4	0	5	0	5	0	5	6	0	5	0	0	0	5	0	0	0	0	0	0
42	6	0	.002	1.00	1.74	.57	.22	0	23.93	4	4	0	4	0	4	0	5	5	5	5	0	0	0	5	6	5	0	0	6	0
44	4	0	.002	Tr.	Tr.	0	0	0	15.67	3	4	0	4	0	0	5	5	5	0	5	0	0	0	5	0	5	0	0	6	0
48	2	0	.002	.26	.92	.22	.10	0	18.98	4	3	0	4	0	5	6	6	5	0	5	0	0	0	5	6	5	0	0	6	0
50	3	0	.001	Tr.	.76	.11	.81	.42	53.78	4	4	0	6	0	5	6	5	5	5	5	4	0	0	5	0	5	0	0	0	0
53	3.5	0	.002	Tr.	Tr.	0	0	0	5.96	3	3	0	4	0	0	6	5	5	5	5	0	0	5	5	5	4	0	0	0	0
58	2.5	0	.001	.88	2.12	1.11	.43	1.00	53.79	4	4	0	5	0	4	6	5	5	5	5	4	0	0	5	0	5	0	0	0	0
59	18	0	.003	.22	.44	.17	.04	0	15.85	3	4	0	4	0	5	6	4	5	5	5	4	5	0	5	5	4	0	0	0	0
61	12	0	.002	Tr.	.44	1.46	.13	1.16	7.77	3	4	0	3	0	5	6	5	5	5	5	4	0	4	5	5	4	0	0	0	0
62	2	0	.002	Tr.	Tr.	0	0	.26	18.44	4	4	0	5	0	5	6	6	5	5	5	0	0	0	6	6	5	0	0	0	0
66	2	0	.001	Tr.	Tr.	0	.03	0	18.56	3	4	0	5	0	5	6	5	5	5	5	0	0	0	5	5	4	0	0	0	0
70	3	0	.001	Tr.	.12	0	0	0	33.18	4	3	0	5	0	5	6	5	5	5	5	0	0	6	6	5	5	0	0	0	0
74	6	0	.001	.02	.28	0	.62	1.52	31.61	4	4	0	4	0	5	6	5	5	5	5	0	0	6	6	5	5	0	0	0	0
76	2.5	0	.001	.04	.42	0	.16	.10	19.03	4	4	0	4	0	5	6	5	5	5	5	0	0	6	6	0	4	0	0	0	0
82	1.5	0	.001	Tr.	.10	0	0	0	27.56	4	4	0	5	0	5	6	5	5	5	5	0	0	0	6	5	5	0	0	0	0
84	12	0	.001	Tr.	.64	.12	.51	.74	29.95	4	3	0	5	0	5	6	6	5	5	5	0	0	6	6	5	5	5	0	0	0
89	4	0	.003	Tr.	.52	0	.59	.17	13.97	4	4	0	4	0	5	6	5	5	5	5	0	0	6	5	5	5	0	0	0	0
98	4	0	.001	.28	3.02	1.09	.64	2.03	26.72	4	4	0	4	Tr.	4	6	6	5	0	5	3	0	0	5	5	4	4	0	5	0
102	4	0	.002	Tr.	.24	0	0	.14	32.36	4	3	0	5	0	5	6	6	6	0	5	0	0	0	0	5	4	0	0	5	0
112	3	0	.002	Tr.	.28	0	0	0	35.57	4	3	0	5	0	5	6	6	6	0	5	0	0	0	0	0	6	0	0	5	0
117	12	0	.003	Tr.	.12	0	0	.08	16.12	3	4	0	5	Tr.	6	6	6	5	0	5	0	6	0	5	5	4	0	0	6	0
122	6	0	.001	Tr.	.40	0	0	0	30.91	4	3	0	5	0	5	0	6	6	0	5	0	0	0	5	0	5	0	0	6	0
125	2	0	.001	Tr.	.04	0	0	0	17.50	4	4	0	4	0	0	6	5	5	0	5	0	0	0	5	0	4	0	0	6	0
135	3.5	0	.001	.04	.42	0	.15	0	21.22	4	4	0	5	0	5	0	6	6	0	6	0	0	0	0	0	5	0	0	0	0
139	7	0	.002	Tr.	.14	0	0	0	13.94	4	4	0	4	0	5	6	6	5	0	6	0	0	0	6	0	5	0	0	0	0
142	21	0	.002	.70	12.58	1.93	3.31	2.77	25.96	4	4	3	5	0	4	0	6	5	0	6	3	0	0	5	0	5	4	0	0	0
146	8.5	0	.002	Tr.	.60	0	.70	1.43	5.99	4	4	0	4	0	5	0	6	5	0	6	4	0	6	5	5	5	5	0	0	0
147	7	0	.002	.16	5.94	1.37	2.10	9.60	22.17	4	4	3	5	0	5	0	6	5	0	6	3	0	0	5	0	4	4	0	0	0
154	7	0	.004	Tr.	Tr.	0	0	.11	5.79	3	4	0	4	0	0	6	5	5	0	6	0	6	5	5	5	4	0	0	0	0
156	10	0	.003	.06	.20	0	0	0	20.02	4	4	0	5	0	5	6	5	5	0	6	0	0	0	5	5	5	0	0	0	0
160	5	0	.001	Tr.	.44	0	0	0	31.29	4	4	0	5	0	5	6	5	5	0	6	0	0	0	5	0	5	0	0	0	0
172	8	0	.000	Tr.	.48	0	0	0	39.42	4	3	0	6	0	5	6	6	6	0	5	0	0	0	5	6	5	0	0	0	0
178	8	0	.003	Tr.	.66	.11	0	.03	4.82	4	3	0	4	Tr.	5	6	5	5	0	5	0	0	5	5	5	4	0	0	0	4
179	9	0	.003	Tr.	Tr.	0	0	.25	14.90	3	3	0	4	6	0	5	4	5	0	5	0	5	5	4	5	4	0	0	0	0
180	8	0	.004	Tr.	Tr.	0	0	.38	14.11	3	3	0	4	6	0	5	4	5	0	5	0	5	5	4	5	4	0	5	0	0
182	12	0	.001	Tr.	.36	0	0	0	32.62	4	3	0	5	Tr.	5	6	6	6	0	5	0	0	0	5	5	5	0	0	0	0
187	8	0	.001	Tr.	.28	0	0	.03	28.74	4	4	0	5	0	5	6	6	6	0	5	0	0	0	5	5	5	0	0	0	0
192	5	0	.003	Tr.	.16	0	0	.17	17.75	3	3	0	4	6	0	5	4	5	0	4	0	5	5	4	5	4	0	0	0	0
196	4	0	.000	.72	1.04	0	0	0	31.11	4	3	0	5	0	4	6	6	6	0	5	0	0	0	5	0	5	0	0	0	0

201	13.5	0	.004	Tr.	Tr.	0	0	.11	6.01	3	3	0	4	6	0	6	5	5	0	5	0	6	5	5	5	4	0	0	0	4
209	10	0	.003	.04	.32	.31	0	.05	6.81	4	3	0	3	6	5	6	6	5	0	6	0	0	5	5	5	4	0	0	0	4
215	12	0	.003	.22	.76	.49	0	.04	10.14	3	3	0	4	Tr.	5	6	6	5	5	6	0	0	5	5	5	4	0	0	0	0
222	16	0	.002	1.40	5.40	1.12	.48	.04	35.58	4	3	3	5	0	4	6	6	6	0	5	4	0	0	5	5	5	0	0	0	0
225	2	0	.004	.28	1.08	.60	0	2.82	18.49	4	4	0	4	Tr.	5	6	5	5	0	5	0	0	5	5	5	4	4	0	0	0
229	5	0	.001	.72	4.68	.46	.58	.03	32.12	4	3	3	5	0	4	6	5	6	0	5	4	0	0	5	6	5	0	0	0	0
231	11	0	.001	.10	.28	0	.11	.01	13.69	4	3	0	4	Tr.	5	6	6	6	0	5	0	0	0	5	5	4	0	0	0	0
232	24	.001	.006	.04	.14	.16	0	.07	10.65	4	4	0	4	6	5	6	6	5	0	6	0	0	5	5	5	4	0	0	0	0
235	7	.001	.012	Tr.	.10	0	0	0	7.71	3	4	0	5	0	5	6	6	5	0	5	0	0	0	5	5	4	0	0	0	0
236	6	.002	.005	.24	.52	.41	0	0	25.03	4	4	0	5	0	5	0	6	5	0	5	0	0	0	5	0	5	0	0	0	0
243	8	0	.003	0	0	.43	.24	0	14.19	4	4	0	4	0	0	0	6	6	0	5	0	0	5	5	5	4	0	0	0	0
248	6	0	.001	Tr.	.24	0	0	0	50.72	4	4	0	5	0	5	0	6	6	0	6	0	0	0	0	6	5	0	0	5	4
297	9.5	0	.002	Tr.	1.08	0	0	0	25.86	4	4	0	5	0	5	6	6	6	0	5	0	0	0	6	5	5	0	0	0	0
312	10	0	.001	1.20	.80	1.61	0	0	34.58	4	.4	0	6	0	5	6	6	6	0	5	0	0	0	6	6	5	0	0	0	0
320	7.5	0	.002	Tr.	.68	0	0	.50	25.80	3	4	0	4	0	4	6	5	6	5	5	0	0	0	5	6	5	0	0	0	0
324	6	0	.003	Tr.	.08	0	0	1.47	10.01	3	3	0	4	Tr.	Tr.	6	6	5	0	5	0	6	Tr.	5	5	4	5	0	0	0
336	12	0	.002	Tr.	.42	0	0	1.46	9.08	3	3	0	4	Tr.	5	6	6	5	0	5	0	6	0	5	5	4	5	0	0	0
345	6	0	.002	Tr.	.18	0	0	1.57	9.56	4	3	0	4	Tr.	5	6	6	5	0	5	0	6	0	5	5	4	5	0	0	0
347	11	0	.001	.08	1.12	0	.19	.22	30.39	4	4	0	4	0	5	6	6	5	5	5	0	0	6	5	5	5	0	0	0	0
357	10.5	0	.003	Tr.	.27	0	.16	.51	18.68	4	4	0	4	Tr.	5	6	6	6	0	5	0	Tr.	6	5	5	4	0	0	0	0
366	7	0	.002	Tr.	.32	0	0	2.32	10.52	4	4	0	4	Tr.	5	6	6	6	0	5	0	0	6	5	4	5	0	0	0	0
369	19	0	.002	Tr.	.32	0	0	1.91	11.42	3	3	0	5	Tr.	5	6	6	6	0	5	0	6	6	5	5	4	5	0	0	0
370	18	0	.002	.06	.20	0	0	0	12.35	4	4	0	5	Tr.	5	6	6	6	0	5	0	0	0	5	6	4	0	0	0	0
373	12	0	.002	.16	.27	.17	0	0	9.42	4	4	0	4	Tr.	5	6	6	6	0	5	0	0	6	6	5	4	0	0	0	4
374	8.5	0	.003	.16	.34	.26	0	0	9.32	4	4	0	4	Tr.	5	6	6	6	0	5	0	0	6	5	5	5	0	0	0	4
377	7.5	0	.003	.06	.23	0	0	.17	10.13	3	3	0	4	Tr.	5	6	6	6	0	5	0	6	6	5	5	4	0	0	0	0
385	6	0	.001	.06	.43	.17	0	1.19	25.08	3	3	0	5	0	5	6	6	6	0	5	0	0	0	0	0	4	0	0	0	0
390	12	0	.004	Tr.	.50	.10	.10	.30	17.99	3	4	0	4	Tr.	5	6	6	5	0	5	0	6	0	5	5	4	0	0	0	0
391	8.5	0	.002	Tr.	.40	.11	0	0	13.49	3	3	0	3	Tr.	5	6	6	5	0	5	0	5	6	5	5	4	0	0	0	0
395	6.5	0	.002	.09	.21	0	0	.47	12.76	3	4	0	4	Tr.	5	6	6	6	0	5	0	0	0	6	5	5	0	0	0	0
400	12	0	.002	.04	.33	.24	0	0	7.98	4	4	0	4	Tr.	5	6	6	5	0	5	0	0	0	5	5	5	0	0	0	0
406	5	0	.001	.19	1.13	0	0	0	46.44	5	3	0	6	0	5	6	5	6	0	5	0	0	0	5	0	5	0	0	0	0
424	11	0	.002	Tr.	.44	0	.09	1.66	20.28	3	3	0	4	6	5	6	6	5	0	6	0	6	Tr.	5	5	4	5	0	0	0
425	5	0	.006	Tr.	.64	0	.07	.07	12.66	3	3	0	4	6	5	6	6	5	0	6	0	0	Tr.	5	5	4	0	0	0	0
427	5.5	0	.002	Tr.	.36	0	0	0	24.47	3	3	0	5	0	5	6	5	6	0	6	0	0	6	5	6	5	0	0	0	0
439	5	0	.001	.54	2.44	1.83	.56	.68	47.11	5+	3+	3+	6	0	4−	6+	6	Tr.	5	5−	4+	0	0	5−	6+	5	0	0	0	0
444	7	0	.003	.12	.96	.66	0	.51	40.13	5+	2−	3	6+	0	5	6	6	Tr.	5	5−	4−	0	0	5−	5−	5	0	0	0	0
447	5.5	0	.001	.06	.68	0	0	0	14.52	4−	4+	0	6+	0	5	6	6	6+	0	6+	0	0	0	5−	0	6+	0	0	0	0
450	8	0	.001	.46	.88	.60	0	.45	30.73	5+	3+	3−	6+	0	5	6	6	Tr.	0	6+	0	0	0	5−	6	5−	0	0	0	0
456	9	0	.002	.18	.79	.19	0	0	23.53	4	3−	4+	5	0	5	6	6	6+	Tr.	6+	0	0	0	5−	6	5−	0	0	0	0
460	12	0	.001	Tr.	3.12	.35	1.31	.80	46.90	4−	3	0	6	0	4−	6	6+	Tr.	0	6+	0	0	Tr.	5−	6	5−	5	0	0	0
463	3.5	0	.002	.52	1.38	2.04	0	.23	31.08	4−	3+	3	6	0	5	6	6	6+	Tr.	6+	4	0	0	5−	6	5−	0	0	0	0
464	5	0	.003	.06	1.31	.37	.60	0	21.73	4+	3+	0	5−	0	5	6	6	6+	Tr.	6+	0	0	0	5−	6+	5+	0	0	0	0
465	4	0	.001	.06	1.69	.87	.51	.17	30.11	4−	3+	3−	6	0	5+	6	6+	6	Tr.	6+	0	0	0	5−	6+	5−	0	0	0	0
472	12	0	.002	.16	3.64	.37	.30	0	38.05	4	4	3+	5−	0	4−	6	6+	6	0	6+	0	0	0	5−	6+	5	0	0	0	0
475	8	0	.002	1.04	7.22	2.84	.71	.45	26.79	4	3+	0	5−	0	4−	6	6	6+	5−	5−	4+	6	0	5−	6+	5−	0	0	0	0
476	14	0	.003	.08	.42	.18	0	0	9.76	3−	4	0	4−	Tr.	5−	6+	5−	6+	Tr.	5−	0	6+	6	5−	5	4−	0	0	0	0
485	10	0	.003	.08	.26	0	0	0	14.43	4	4−	0	5+	0	5−	6	6+	6+	Tr.	6+	0	0	0	5−	5	5+	0	0	0	0
486	1.5	0	.000	.08	.28	0	0	.12	49.67	5+	4−	0	6+	0	5−	6	6	6+	5+	6+	0	0	0	5−	0	5−	0	0	0	0
515	12	0	.005	Tr.	.22	0	.12	1.97	8.45	4+	3−	0	3−	0	5−	5	5−	6+	0	6+	0	0	5+	5−	5−	5+	5+	0	0	0
521	6	0	.003	Tr.	.10	0	0	0	20.77	4+	4	0	5+	Tr.	5−	6+	5−	6+	5	5−	0	6	0	5−	5+	4−	0	0	0	0

TABLE 6.—*Some chemical analyses, fire assays, and semiquantitative spectrographic analyses of ore from the Wood vein*—Continued

Sample W—	Width (inches)	U	eU	Au	Ag	Cu	Pb	Zn	Fe_2O_3	Ti	Mn	As	Ba	Be	Bi	Co	Cr	Ga	Mo	Ni	Sb	Sc	Sr	V	Y	Zr	Cd	B	Sn	Ce
524	3	0	0.000	0.04	0.50	0	0	0	41.75	4−	4−	0	6+	0	5	5−	5−	6	5−	5	0	0	0	5−	0	6+	0	0	0	0
533	2	0	.089	0	0	0	0	0	2.30	4	4	0	3−	Tr.	0	6−	Tr.	5−	0	0	0	Tr.	5+	5−	5	4−	0	0	0	0
534	3	0	.02	Tr.	.16	0	0	.50	16.72	4	4−	0	4	Tr.	5−	6+	Tr.	6+	5	6+	0	0	Tr.	6+	5−	4−	0	0	0	0
535	6	0	.01	Tr.	.04	0	0	0	18.02	4−	4−	0	5+	Tr.	0	5−	6−	6	4−	5−	0	0	Tr.	6+	5−	5+	0	0	0	0
537	12	0	.002	Tr.	.18	0	0	0	23.04	4	5+	0	5+	0	5−	6	6−	5−	5	6+	0	0	Tr.	6+	6+	5+	0	0	0	0
553	6	0	.002	.06	.70	.27	0	0	18.75	3	4−	0	5+	Tr.	5	5−	Tr.	5−	5	5−	0	6+	Tr.	5	5	5+	0	0	0	0
561	24	0	.004	Tr.	.12	0	.42	.86	12.34	3−	4−	0	4−	6−	6+	6+	6+	6+	0	6+	0	6+	0	5−	5	4	0	0	0	0
562	14	0	.001	Tr.	.26	0	0	0	30.70	4	4−	0	5	0	5	6+	Tr.	6	5	6+	0	0	0	6+	6+	5+	0	0	0	0
563	12	0	.002	.04	.36	0	0	.07	25.82	4	5+	0	5+	0	5	6+	Tr.	6	5−	6+	5−	0	Tr.	6+	6+	5	0	0	0	0
568	12	0	.004	.18	1.64	1.03	.22	.14	23.16	4+	5+	0	5+	Tr.	5+	6+	Tr.	6+	5−	6+	0	6	0	6+	5−	4−	0	0	0	0
572	(1)	0	.01	.82	10.86	4.67	.30	.26	45.82	4−	4	0	5−	0	3	6+	Tr.	6	5	6	0	0	0	5−	5	5	0	0	0	0
573	2	.15	.13	.30	2.90	2.81	.11	.21	41.43	4−	5+	3−	6+	0	4−	5−	6−	Tr.	5	5+	0	0	0	5−	5	5+	0	0	0	0
574	(2)	.23	.25	Tr.	3.36	7.40	.08	.87	37.13	4−	4−	3+	5−	0	5+	5−	6−	Tr.	4	5+	0	0	0	5−	5	5+	0	0	0	0
575	10	.006	.012	Tr.	.08	0	0	0	8.64	3−	4−	0	5+	6	0	6+	5	5−	5−	5	0	6+	0	5	5	5+	0	0	0	0
576	8	.003	.006	Tr.	4.44	9.27	0	1.66	28.77	3−	4−	2−	6+	0	5	0	5−	0	4	5−	0	0	0	6+	0	5+	0	0	0	0
577	6	9.94	9.3	.16	2.54	1.55	0	0	36.96	3−	4	0	4	6	5+	0	6−	0	4+	5−	0	0	6+	5−	4−	3	0	0	0	0
578	20	.010	.021	1.21	1.64	.97	0	.19	19.50	4+	4−	0	4+	0	5+	0	6−	6+	5−	6+	0	0	6+	6+	5−	5+	0	0	0	0
579	(3)	.002	.004	Tr.	Tr.	0	0	0	3.03	4+	4	0	4+	0	0	0	6−	5−	0	0	0	6	5+	6+	5	4	0	0	0	4−
580	(4)	.021	.026	Tr.	.08	0	0	0	8.56	4+	4−	0	5+	6−	6+	5−	6−	5−	5−	5	0	0	6	5−	5−	4	0	0	5	0
581	--------	.010	.017	Tr.	.14	0	0	.23	11.49	4	4−	0	4+	Tr.	5−	5−	6−	5−	5+	5−	0	5−	5	5−	5	5	0	0	0	4−
582	--------	.000	.006	1.10	5.02	8.15	.19	3.32	39.87	5+	4−	3	6+	0	4−	6+	6−	Tr.	5+	6+	0	0	0	6+	0	5	4	0	0	0
583	--------	3.76	3.60	Tr.	.54	0	.05	.03	27.26	3−	4	0	5+	6−	5−	0	6−	Tr.	4−	5−	0	6+	6+	6−	5−	4−	3	0	0	0
584	--------	.008	.012	Tr.	Tr.	0	0	0	9.17	3	3	0	3−	6	0	5−	6−	5−	0	6+	0	5	4−	5+	4	5+	0	0	0	4+
585	--------	.006	.006	Tr.	Tr.	0	0	0	10.55	3−	3+	0	3−	6	0	5−	6−	5−	0	5−	0	5	4	5+	4	4−	0	0	0	4+
586	9	.003	.004	.30	2.00	.29	.17	.16	41.46	4	4−	0	5	0	4−	5−	6−	6+	5	5−	0	0	0	5−	5−	5	0	0	0	0
587	21	.003	.005	Tr.	.10	0	0	.14	9.12	4+	4−	0	5+	6	Tr.	0	6−	5−	0	6+	0	6	Tr.	5−	5	5+	0	0	0	0
588	4	.006	.008	Tr.	.10	0	0	.07	12.74	4+	4	0	4	0	5−	5−	6−	6+	5−	6+	0	6	6+	5−	5	4	0	0	0	0
589	20	.002	.006	1.28	28.72	6.71	1.67	.55	23.69	3−	4	0	5	Tr.	3	6+	6+	6	5	5−	0	Tr.	0	5	5−	5+	0	0	5	0
590	15	.002	.005	Tr.	Tr.	0	0	0	4.65	3−	3−	0	4+	6	5	5−	5−	6	Tr.	5+	0	Tr.	5+	5	5	4	0	0	0	0
591	12	.002	.005	Tr.	.40	0	.05	1.57	13.07	3	3	0	4−	6	5	5	4+	5−	5−	4−	Tr.	5−	5+	5+	5+	4−	5+	0	0	0
592	6	0	.003	Tr.	.20	.07	0	.12	8.33	3−	4+	0	4	6	5−	5−	4−	6+	Tr.	4	0	6+	5	5	5	4−	0	0	0	0
593	3	0	.002	0	0	0	0	0	3.49	3−	4+	0	4	6	0	6+	5−	6+	6+	5−	0	Tr.	4−	5	5	4	0	0	0	0
594	17	.01	.009	.16	.44	.22	0	.34	9.86	4+	4	0	4	6	5	0	6+	5−	Tr.	6+	0	0	6+	5	5−	4	0	0	0	0
595	(5)	0	.001	.44	2.06	1.82	.05	.47	51.46	5	4+	2	6	0	4−	5−	6+	6	4−	5	5+	0	0	5	Tr.	0	0	0	0	0
596	20	0	.003	Tr.	0	0	0	0	6.61	4+	4	0	4+	0	5−	6+	6+	5−	0	5−	0	0	5+	5−	5+	4−	0	0	0	0
597	13	0	.004	Tr.	0	0	0	.22	8.07	4	4+	0	4+	0	5−	6+	5−	5−	0	5−	0	0	5	5−	5−	4−	0	0	0	0
598	24	.002	.005	Tr.	0	0	0	0	2.92	4+	4+	0	3−	0	0	6+	6+	5−	0	5	0	0	5+	5−	5−	4−	0	0	0	0
599	12	.002	.005	Tr.	0	0	0	.03	5.58	4+	4	0	4+	0	0	6+	6+	5−	0	5−	0	0	5−	6+	5−	4−	0	0	0	0
600	2.5	.004	.007	Tr.	0	0	0	0	6.84	3−	3−	0	4+	0	0	5−	5−	5−	5−	5	0	6+	5	5	5+	4+	0	0	0	0

[1] DDH-2-Core. [2] Grab. [3] Grab (rock). [4] Grab (gouge). [5] Core.

TRACE ELEMENTS

Distribution patterns of trace elements in the ore from the Wood exploration drift were made from semiquantitative spectrographic analyses to guide uranium prospecting and to aid in the interpretation of ore genesis. Table 6 presents the data obtained from the analysis of 132 samples. Results of this study show an association of bismuth, antimony, and arsenic with copper, of cadmium with zinc, and indicate an association of zirconium and molybdenum with uranium.

Threshold values, shown in table 7, are those attained in the spectrographic laboratories of the Geological Survey. A "group-number" method of reporting results of spectrographic analyses (Riley and Shoemaker, written communication, 1952) is used in this report and is shown by the following data:

Group no.	*Percent*
1	10 –100
2	1 – 10
3	.1 – 1
4	.01 – .1
5	.001 – .01
6	.0001– .001

TABLE 7.—*Threshold values of elements included in the semiquantitative method*

Element	Percent	Group no.	Parts per million
Ti	0.001	5	1
Mn	.0005	6	5
As	.1	3	1,000
Ba	.0001	6	1
Be	.0001	6	1
Bi	.001	5	10
Co	.0005	6	5
Cr	.0005	6	5
Ga	.001	5	10
Mo	.001	5	10
Ni	.0005	6	5
Sb	.05	4	500
Sc	.001	5	10
Sr	.0001	6	5
V	.001	5	10
Y	.001	5	10
Zr	.001	5	10
Cd	.005	5	50
B	.005	5	50
Sn	.001	5	10
Ce	.05	4	500

In the tabulations of the elements in samples (table 6), plus and minus signs after group numbers show the relative position within the group: plus, toward the upper limit of the range indicated; and minus, toward the lower limit. A zero indicates that the element was looked for but not found.

The most marked apparent variation in trace-element content occurs, as one would expect, between samples of strong vein and samples of altered and sparsely mineralized rock. The vein samples contain a nearly uniform suite of trace elements, and, except for arsenic, antimony, bismuth, cadmium, zirconium, and molybdenum, show no appreciable variation in quantity (fig. 37).

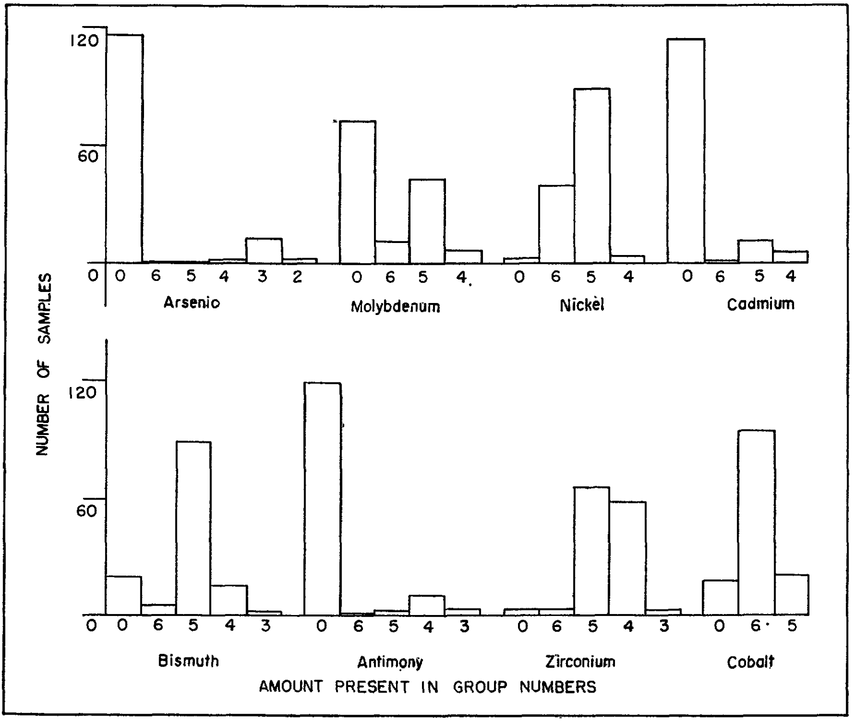

FIGURE 37.—Distribution histograms of some elements in 132 samples from the Wood vein.

The two samples having the highest uranium content also show a high zirconium content (group no. 3, table 6, and fig. 38). A picked sample of pitchblende (eU, 13 percent) contained X.O percent zirconium (group no. 2). The average zirconium content of all samples is within group 4 or 5 (fig. 37). A chemical analysis of pitchblende from the Wood mine showed 5.47 percent zirconium (Phair, written communication, 1953). Hillebrand (1891, p. 65–66) found that a sample of pitchblende from the Central City district contained 7.59

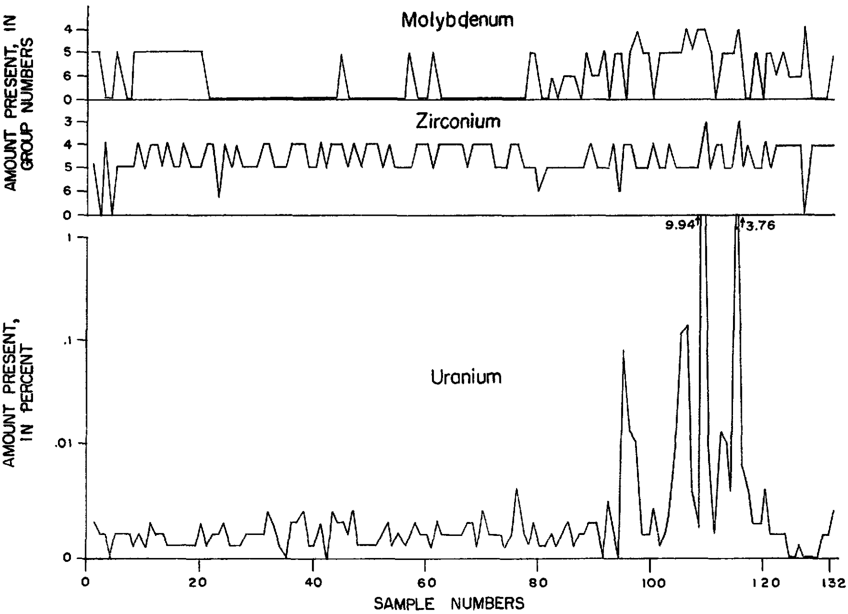

FIGURE 38.—Graph showing the relation of molybdenum and zirconium to uranium in samples from the Wood vein.

percent zirconium. R. H. Campbell (oral communication, 1954) found that samples from Gold Hill, Colo., containing appreciable uranium also were high in zirconium. T. G. Lovering (oral communication, 1954) has found similar uranium-zirconium relations in the spectrographic study of pitchblende from several localities.

The suggested uranium-and-zirconium relation is of economic interest. Phair (1952, p. 45) believes that most of the pitchblende now found in veins of the Central City district had its source in late-stage uranium-rich differentiates of quartz bostonite magma. The solutions mingled with regional solutions and rose along the planes of weakness provided by the porphyry dikes; they reacted with and leached part of the uranium. If, as Phair (1952, p. 22) believes, the uranium in the quartz bostonite is associated with zircon, it is not unreasonable to assume that zirconium would also be picked up by the solutions and deposited with the pitchblende.

A tenuous relationship between molybdenum and uranium exists in samples from the Wood vein. Samples of the uranium-bearing part of the vein near the 520 raise contain more molybdenum than normal (figs. 37 and 38). A molybdenum-uranium relation has been noted in other areas: at Climax (King, oral communication, 1954), in the Henry Mountains (Riley and Shoemaker, written communication, 1952), and at the Happy Jack mine, Utah (Lovering, oral communication, 1954). The writer has noted the same relationship in British Columbia. Sparse molybdenite has been found in the Central City district (Bastin and Hill, 1917, p. 105), and, where present, was the first mineral to crystallize. The writer can only point out the molybdenum-uranium association and note that both were deposited early in the paragenetic sequence.

Cadmium is locally found in the Wood ores (table 6) and is correlated with zinc (fig. 39). Sphalerite contains a large proportion of

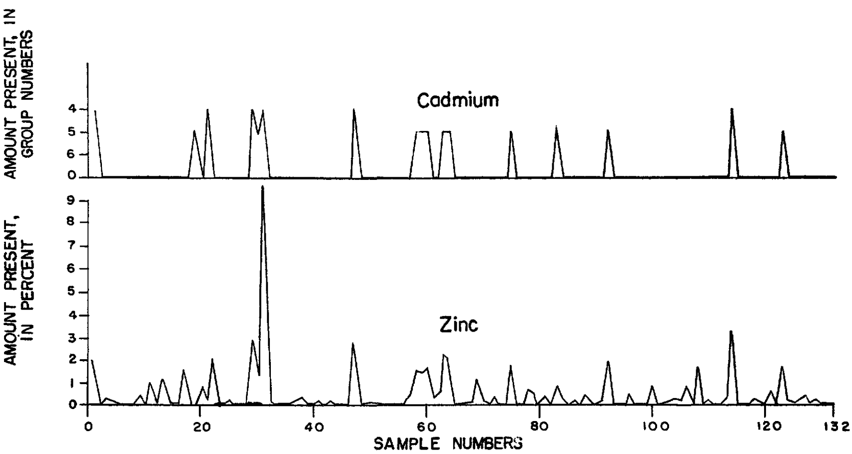

FIGURE 39.—Graph showing the relation of zinc and cadmium in samples from the Wood vein.

cadmium, as much as 4.5 percent (Rankama and Sahama, 1950, p. 708). Sphalerite in the Wood ores probably contains this proportion of cadmium.

In ores from the Wood vein arsenic, antimony, and bismuth vary in quantity (fig. 37) and generally correlate well with copper (fig. 40). Inasmuch as tetrahedrite-tennantite occurs in the vein, it seems reasonable to correlate the amount of arsenic and antimony in samples directly to the amount of gray copper present. Bismuth is grouped with arsenic and antimony and, in general, behaves in a similar manner (Rankama and Sahama, 1950, p. 738). Tetrahedrite may contain bismuth, commonly less than 2 percent, whereas bismuthian tennantite may contain as much as 13 percent bismuth (Palache, Berman, and Frondel, 1944, p. 379). It is believed, therefore, that the bismuth in the ore from the Wood vein is in tetrahedrite-tennantite.

Nickel and cobalt minerals frequently are associated with uranium deposits (Everhart and Wright, 1953, p. 88). Such minerals have not been identified in the Central City district, however. Samples of ore from the Wood vein contain (reported by group no.) 6 to 4 nickel, averaging 5, and 6 to 5 cobalt, averaging 6 (fig. 37). The four high-

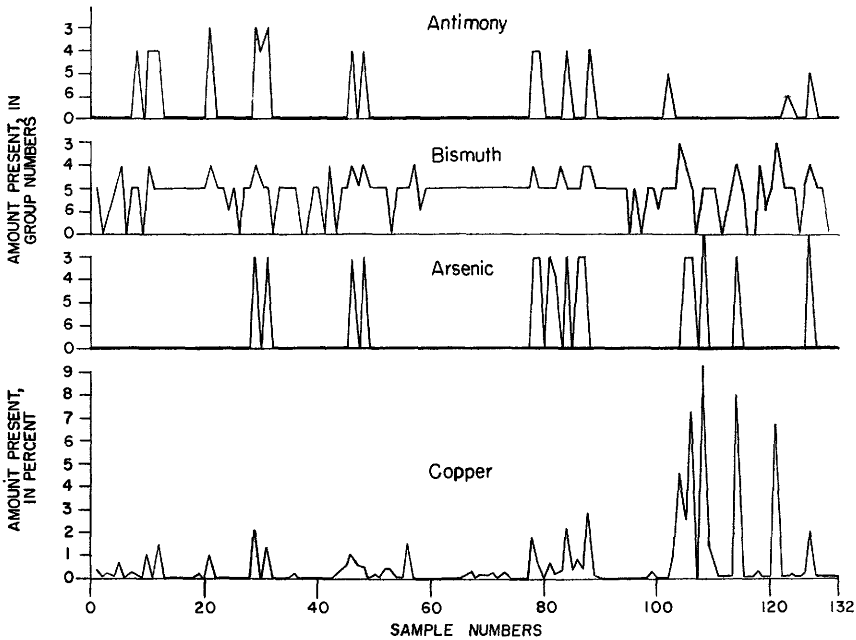

FIGURE 40.—Graph showing the relation of copper, arsenic, bismuth, and antimony in samples from the Wood vein.

nickel samples were taken from altered rock that contained hornblende. It is not certain that all the reported nickel and cobalt was originally in the samples because the samples were pulverized in steel-grinding machines and the amounts of nickel and cobalt they contain are within the limits of contamination set by Myers and Barnett (1953, p. 828).

WALL-ROCK ALTERATION

Particular effort was made to detect a difference in the wall-rock alteration between pitchblende- and nonpitchblende-bearing parts of the Wood vein, but no difference was detected.

Megascopically, the wall rocks are silicified, pyritized, and altered to argillic minerals. The width of alteration varies directly with the vein strength, ranging from about 6 inches to 5 feet, and averaging about 18 inches. The alteration progresses generally outward from a pyritized and silicified zone through a silicified to an argillic zone. At most places, pyritization is stronger where the wall rock originally contained a large proportion of mafic minerals, indicating that at least part of the pyrite was formed from iron ions liberated by the altering solutions.

Microscopic study shows that the plagioclase feldspars were generally the first to be affected; they are sericitized and in part altered to green montmorillonite. Mafic minerals are bleached and altered to chlorite(?). Microcline is last to be affected and is in part sericitized. Some kaolinite is present and appears to be late.

ZONING

The mineralogy of the Wood, Calhoun, Willowdale, and Quartz Mill veins changes from essentially quartz-pyrite in the east to quartz-pyrite - chalcopyrite - sphalerite - galena - tetrahedrite - tennantite in the west. This mineralogic change along strike is part of the larger hypogene zoning pattern of the Central City district (Leonard, 1952, p. 1274–1275). In simplified form, it is a core of quartz-pyrite veins surrounded by a shell of galena-sphalerite veins. The veins mapped in this report lie in the transitional area between these major zones.

It is also expected that mineralogic changes should occur vertically along the veins. Evidence indicates that such a change takes place in the Wood-Calhoun group of veins. The Calhoun vein, on the upper levels of the East Calhoun mine, is largely filled by quartz and pyrite. Chalcopyrite, gray copper, galena, and sphalerite are moderately abundant in the Calhoun vein below the fourth level. Similarly, the Wood vein above the 197 level consists principally of quartz and pyrite (Moore and Butler, 1952); galena and sphalerite are below that level. This change in vein mineralogy with depth indicates that the transition zone at this locality dips to the east.

Leonard (1952, p. 1274–1275) found that the major pitchblende occurrences of the Central City district are concentrated in the transition zone; Wallace and Campbell (oral communication, 1954) believe that pitchblende is genetically related to a zoning sequence. Emmons (1927, p. 35), in his classic zoning sequence, placed uranium above copper and below zinc, overlapping both; consequently, it is to be expected that pitchblende will be closely related to copper-bearing minerals and sphalerite in space and time. In the Wood vein, the spatial relationship generally holds true. In specimens studied by the writer, however, the pitchblende is earlier in the paragenetic sequence than chalcopyrite and sphalerite. Bastin and Hill (1917, p. 123–124) report that chalcopyrite is intergrown with pitchblende in specimens from the Wood vein, indicating that they were deposited almost contemporaneously. The questionable relation between pitchblende and zoning is open for further study.

ORE SHOOTS

Mapping and sampling in the East Calhoun and Wood mines show that minable ore is not uniformly distributed throughout the veins. Most of the ore bodies occur in shoots that apparently are the result of deposition within open spaces along premineral faults. Factors influencing the formation of open spaces include the competency of the wall rock, a northwest-trending joint set, changes in strike and dip, and intersections and near-intersections of individual fractures.

Sharply defined openings occurred along the fractures where the faults intersected relatively brittle wall rocks. At the Wood and East Calhoun mines the most favorable wall rocks are granite gneiss, pegmatite, migmatite, bostonite, amphibolite, and biotite-quartz-plagioclase gneiss, in that order.

Another feature favorable for the formation of openings is a strong northwest-trending joint set (fig. 31) in the country rock. The intersection of the veins with joints of this set plunges about 70° S. 80° W. This approximates the rake of the shoots shown by the stope outlines on figures 33 and 34. Theoretically, the rocks should be intensely broken at the intersection of the two fractures. Favorable openings should occur along the plunge of the intersection.

A relationship between the steepness of dip and strength of vein was noted, particularly on the Calhoun and Quartz Mill veins. In general, the steeper the dip, the stronger the vein. The Wood vein is stronger and richer where it changes strike toward the northeast.

Small, local ore bodies are found near the intersections and near-intersections of branching and subparallel fissures. These ore bodies are attributed to the open spaces produced by the shattering of the rock between the fissures.

The principal ore shoot in the East Calhoun mine, between the 6th and 10th levels, is on the Quartz Mill vein. The stope outlines on the longitudinal projection (fig. 33) indicate that the ore body raked about 75°–80°, S. 70° W. The stope length was 100–300 feet, and the rake length, 450 feet. Miners at the property generally ascribe this ore shoot to the intersection of the Calhoun and Quartz Mill veins. It is difficult to imagine how such a flat intersection could create a steeply raking open space. Sanderson,[7] in a report on the Bezant mine, outlined an ore shoot in the Quartz Mill vein having the same general attitude as the ore shoot mined in the East Calhoun mine. As previously mentioned, this ore shoot alines with the stoped ground below the East Calhoun sixth level. The writer believes that the ore mined below the East Calhoun sixth level was a continuation of the Bezant ore shoot.

The Wood vein has been stoped on the upper levels throughout most of its explored length. Much of this stoping probably was done in the oxidized zone and the ore here was mechanically enriched in gold. Moore and Butler (1952) outlined a pitchblende ore shoot on the upper levels of the Wood mine. Pitchblende ore bodies found

[7] Sanderson, H. S., op. cit.

in the exploration done during the writer's study are well alined with the projected rake of this ore shoot (fig. 34). As previously mentioned, gold, silver, and other minerals in this area were of greatest commercial value. Therefore, it is believed that the pitchblende outlines a general ore shoot. It must be remembered that pitchblende occurs as relatively small pods, lenses, and kidney-shaped ore bodies scattered through the vein; therefore, the pitchblende ore shoot only outlines ground favorable for the occurrence of pitchblende.

ORIGIN

The Wood, Calhoun, Quartz Mill, and Willowdale veins were filled by minerals deposited from hydrothermal solutions. Repeated movement along the veins throughout the period of ore deposition reopened channels through which the vein-forming solutions could migrate. Deposition of minerals by fracture filling and by replacement of earlier minerals was generally restricted to the zone of fracturing, although the wall rock is silicified and pyritized for widths as much as 5 feet. Mineral deposition occurred in two general stages: quartz-pyrite and galena-sphalerite.

Locally veins of pitchblende apparently were formed during an early phase of the general quartz-pyrite stage of mineralization. Alsdorf (1916, p. 270, 273) believes that these pitchblende veins were cut by subsequent faults and obliterated by formation of precious-metal-sulfide veins. The pitchblende ore bodies observed in this study certainly indicate deposition before the main precious-metal-sulfide filling, although they lie in the same vein and even in the same ore shoot as the later minerals. Therefore, the writer concurs with Alsdorf that the pitchblende was deposited locally in the quartz-pyrite stage of mineralization. It is difficult to reconcile the observed field and paragenetic relationship with the hypogene-zoning theory of Leonard (1952). Such factors as telescoping can be applied to show that it is possible for pitchblende to be deposited as the first metallic mineral and still be genetically related to a zoning sequence. No evidence of telescoping was noted in the mines.

The writer prefers the hypothesis of Phair (1952) that residual solutions from the differentiation of a quartz bostonite magma mingled locally with regional hydrothermal solutions and rose along the faults. Pitchblende was deposited when the temperature was lowered sufficiently to allow chemical reduction. The pitchblende was preceded in deposition by quartz and a little pyrite. Recurrent movement reopened the veins to allow the deposition of the later precious-metal-sulfide ores.

It is difficult to assign these deposits to one of the usual pressure-temperature classifications. Armstrong (written communication, 1956) classified the ore deposits of Quartz Hill as xenothermal, largely on an inferred temperature of formation. His temperature-of-formation inferences were based on the presence of exsolved chalcopyrite in sphalerite (chalcopyrite and sphalerite supposedly unmix at about 350°–400°C, Edwards, 1947, p. 98) and on the UO_2–UO_3 ratio of the pitchblende (pitchblende with a relatively high UO_2 percentage presumably indicates a high-temperature origin, Tomkeieff, 1946). The writer prefers to classify the deposits as leptothermal (Graton, 1913, p. 536–540). The deposits have many characteristics of the mesothermal zone, yet plentiful vugs and the growth of comb structure in some places indicate that the conditions of formation were somewhat shallower than most mesothermal types.

AGE

Bastin and Hill (1917, p. 93) believe the ore deposits of the Central City district to be of early Tertiary age. Recent absolute age determinations on two pitchblende specimens from the Wood mine by the Pb^{206}–U^{238} ratio method gave ages of 57.3 and 60 million years, respectively (Stieff and Stern, written communication, 1951). These data confirm the early Tertiary age postulated by Bastin and Hill.

FUTURE OF THE MINES

The exploration during this investigation failed to develop economic quantities of pitchblende in the Wood vein. Pitchblende apparently decreases in abundance with depth, and, as the upper parts of the Wood vein have been well explored, probably there is little likelihood of substantial new uranium production. The ore shoot outlined in this report contains moderate gold and silver values, but the vein material generally is not now economic. If conditions for gold mining become favorable in the future, small quantities of pitchblende probably will be produced as a byproduct.

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