Geology of the Wood and East Calhoun mines, Central City district, Gilpin County, Colorado

By A. A. Drake, Jr.

Trace Elements Investigations Report 175

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology and Mineralogy

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Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGY OF THE WOOD AND EAST CALHOUN MINES, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO*

By

Avery A. Drake, Jr.

March 1955

Trace Elements Investigations Report 175

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

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GEOLOGY OF THE WOOD AND EAST CALHOUN MINES, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

By Avery A. Drake, Jr.

ABSTRACT

The Wood-East Calhoun mine area is underlain by complexly folded Precambrian gneiss and pegmatite. The major fold in the area 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 east- to northeast-trending faults that have been filled by precious metal-sulfide veins which have been worked chiefly for gold. The Wood vein occurs in an east-trending fault; the Calhoun vein occurs in a northeast-trending fault. Much of the uranium production of the Central City district has come from the Wood vein on Quartz Hill.

The veins consist chiefly of quartz; pyrite is the chief metallic mineral and chalcopyrite is next in abundance. Sphalerite, galena, tetrahedrite-tennantite, and pitchblende are locally present. Deposition began with alteration-stage quartz and pyrite followed in order 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 Central City district are zoned, with quartz-pyrite veins near the center and galena-sphalerite veins on the periphery. The known pitchblende bodies are in the transition between these, but paragenetically, the pitchblende is earlier than all other metallic minerals.

A trace element study of the ore indicates an association of zirconium and molybdenum with uranium, of bismuth, antimony, and arsenic with copper, and of cadmium with zinc.

The pitchblende and other ore minerals are concentrated in ore shoots. The shoots 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 thought to be a local constituent of the quartz-pyrite ores and to owe its origin to residual solutions from the quartz bostonite magma.

INTRODUCTION

The Wood vein was an intermittent source of pitchblende from 1872 to about 1916. The East Calhoun was one of the largest gold mines in the Central City district. Both properties have been idle since World War I. Because of the strategic importance of uranium and because little was known about the spatial and paragenetic behavior of pitchblende in the veins of the Central City district, the Geological Survey examined both properties in 1950 and carried on a program of detailed geologic study and sampling.

The veins in the Central City district are zoned with quartz-pyrite veins near the central part of the district, and galena-sphalerite veins on the periphery. The Wood vein is in the transition between these zones. The pitchblende deposits are spatially and probably genetically related to quartz bostonite porphyry dikes. Within the vein, pitchblende bodies occur in a westerly raking ore shoot that is 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 frequency of occurrence of individual bodies decreases with depth, 300 feet being the economic limit. No appreciable quantity of pitchblende was developed by the exploration, and it is improbable that economic quantities of pitchblende will be found in the future.

LOCATION

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, Gilpin County, Colo., (fig. 1). The mines are accessible from Colorado Highway 279 by about a quarter of a mile of unimproved road.

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 from the Wood mine, Guillotte (1944) examined the Wood and East Calhoun dumps in 1943, and 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. Armstrong (in preparation) studied the surface geology of Quartz Hill.

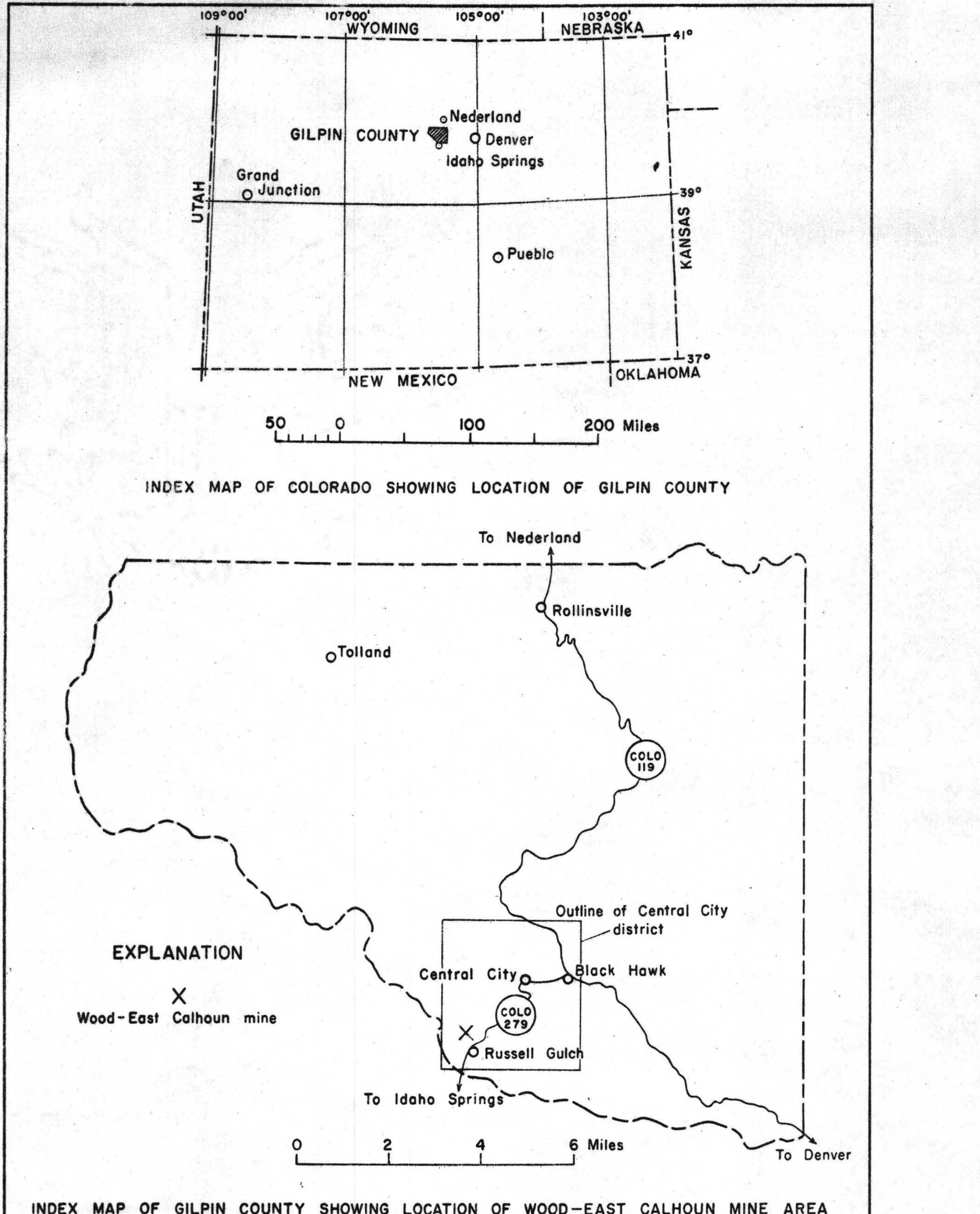


FIGURE 1.-INDEX MAPS SHOWING LOCATION OF WOOD-EAST CALHOUN MINE AREA, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

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) 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 in the transition zone between the two types of deposits.

FIELD WORK

The present investigation began in July 1952 and continued through October 1953. Geologic maps of accessible East Calhoun workings and the exploration headings were made and the working faces were examined and sampled after each round until the last week of January 1953. Thereafter, the workings were visited at least once a week and back samples were taken at appropriate intervals. Office and laboratory work was completed at the Geological Survey offices in Denver. A total of 605 samples were cut. The samples were assayed for uranium, gold, silver, copper, lead, and zinc and a semi-quantitative spectrographic analysis was run on a split of each sample.

The Defense Minerals Exploration Administration supervised the exploration, cut samples, and core-drilled at three locations. 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 was shown the writer by the personnel of the Denver Realty Company, present owners. All assays, chemical analyses, and spectrographic analyses were made by the Survey's Denver Laboratory. A. J. Martin, Supervising Engineer, Metals Economics Branch, U. S. Bureau of Mines, furnished the production data.

These investigations were made on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

GENERAL GEOLOGY

The Wood-East Calhoun mine area is nearly astraddle a northeast-trending anticline, which is the major structural feature of this part of the Central City district (fig. 2). The area is underlain by interlayered Precambrian gneiss and 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 pegmatite occur within the gneiss. These units, in general, dip gently away from the crest of the anticline and locally are 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. 2).

Steeply dipping faults that trend from east to N. 40° E. cut all the rocks (fig. 2). The faults are occupied by veins that average about one 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.

Precambrian rocks

The Precambrian rocks of the Wood-East Calhoun mine area 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 thought to be of metasedimentary origin. Bastin and Hill (1917) and Lovering and Goddard (1950) included these rocks in the Precambrian Idaho Springs formation. The granite gneiss, as described by Bastin and Hill, is a metamorphic rock of uncertain origin. This rock has the average composition of 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.

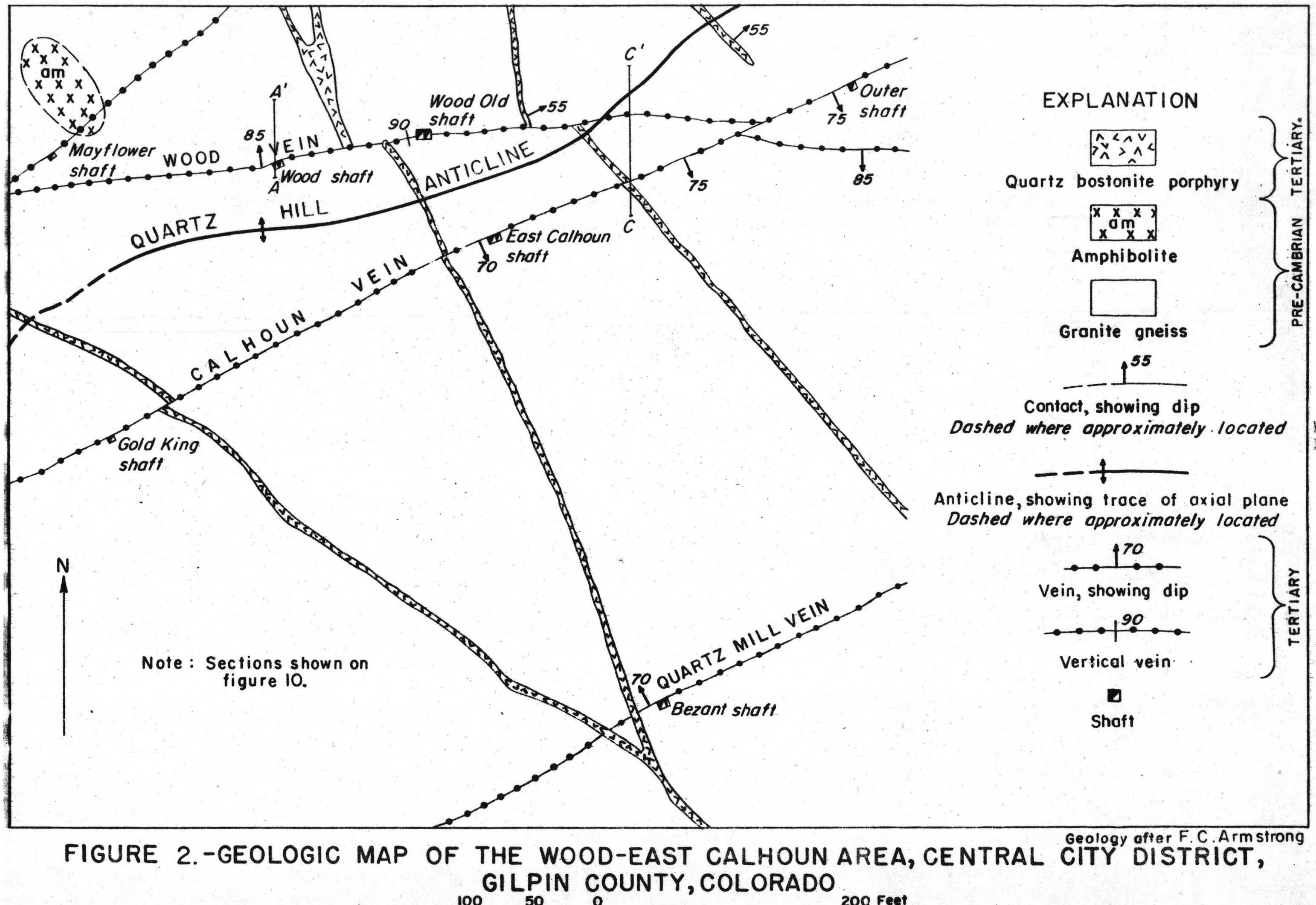


FIGURE 2.-GEOLOGIC MAP OF THE WOOD-EAST CALHOUN AREA, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

Biotite-quartz-plagioclase gneiss

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

The biotite-quartz-plagioclase gneiss is light gray 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 one foot in thickness. It is a fine-grained salt-and-pepper rock that contains as much as 5 percent pink garnet.

Moderate to strong foliation is given to the rock by mineral orientation and compositional banding. Nearly all the rock contains conformable layers of pegmatite, a few inches to several feet thick.

Amphibolite

Amphibolite occurs as layers and lenses 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. Sub-parallel layering produces a fair to good foliation. Amphibolite lenses, now largely biotite schist, occur on the crests and troughs of northwest-trending warps in the more alaskitic granite gneiss.

Migmatite

Intimately interlayered rocks, termed migmatite in this report, were mapped west of the shaft on the fourth level of the East Calhoun mine. The unit is composed of biotite-quartz-plagioclase gneiss in layers 1 to 2 inches thick separated by granitic layers averaging about 1 inch thick. The unit has an appearance somewhat similar to the so-called "injection gneisses."

Granite gneiss

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

Bastin and Hill (1917) classified the rock as granite gneiss, but the composition of the specimens and thin sections examined by the writer more nearly approximate 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 always present, include magnetite (up to 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 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. Pegmatites in the biotite-quartz-plagioclase gneiss occur as distinct bodies in part large enough to map (fig. 6) and as discontinuous thin conformable layers.

Tertiary rocks

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 bostonites into three sub-types--quartz bostonite porphyry, non-porphyritic 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 sub-type of this area contains from 0.010 to 0.025 percent equivalent uranium and is 10 to 20 times more radioactive than the intruded Precambrian rocks.

Quartz bostonite

Four quartz bostonite dikes were mapped on the surface and underground in the Wood-East Calhoun mine area. The dikes trend northwesterly, dip moderately to steeply to the northeast, and range in thickness from one to perhaps 10 feet. Quartz bostonite is a lilac-colored fine-grained porphyritic rock that has a characteristic trachitoid texture resulting from the subparallel arrangement of feldspar phenocrysts in a groundmass of quartz and feldspar. The margins of dikes are finer-grained than the interiors; at places glass is present at contacts.

Syenitic bostonite

In the Wood drift east, about 22 feet west of the face (fig. 9), a relict 2- to 3-inch bostonite dike was found in what is now a northwest-striking vein. The dike is badly broken and completely obliterated on the north wall of the drift. Thin-section study shows that this dike has very little quartz, is high in mafic minerals, and that the phenocrysts are plagioclase. Based on Phair's (1952) classification this rock is a syenitic bostonite.

Structure

The principal Precambrian structure in the Wood-East Calhoun mine area is a broad, east-northeast trending anticline with gentle to moderate dipping limbs. Associated minor fold structures--warps and drag folds--essentially parallel the anticlinal axis, or transect it at an angle of sixty degrees. Mineral lineations, in general, parallel the fold axes.

Steeply-dipping Tertiary faults trend east, east-northeast, and northwest. The northwest faults served as loci for dike emplacement and the east and east-northeast faults are metallized (fig. 2). 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 relation between the Precambrian structures and the Tertiary faults.

Folds

The major structural feature is the Quartz Hill anticline. The trace of its axial plane in this area trends about N. 60° E. (fig. 2), but district-wide it averages about N. 30° E. (Sims, Drake, and Moench, 1953). Associated with this major structure are numerous 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. 3) shows four maxima = 10° N. 30° E., 5° S. 60° W., 5° N. 60° E., and 15° S. 25° W. These lineations, in general, parallel the major and minor folding in the area studied.

Joints

To avoid overcrowding, joints have not been plotted on figures 6 and 9. Instead, the poles to joint planes were plotted and contoured on the upper hemisphere of a Schmidt net (fig. 4). Three strong maxima 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 maxima probably represent statistical peak readings on the same joint set.

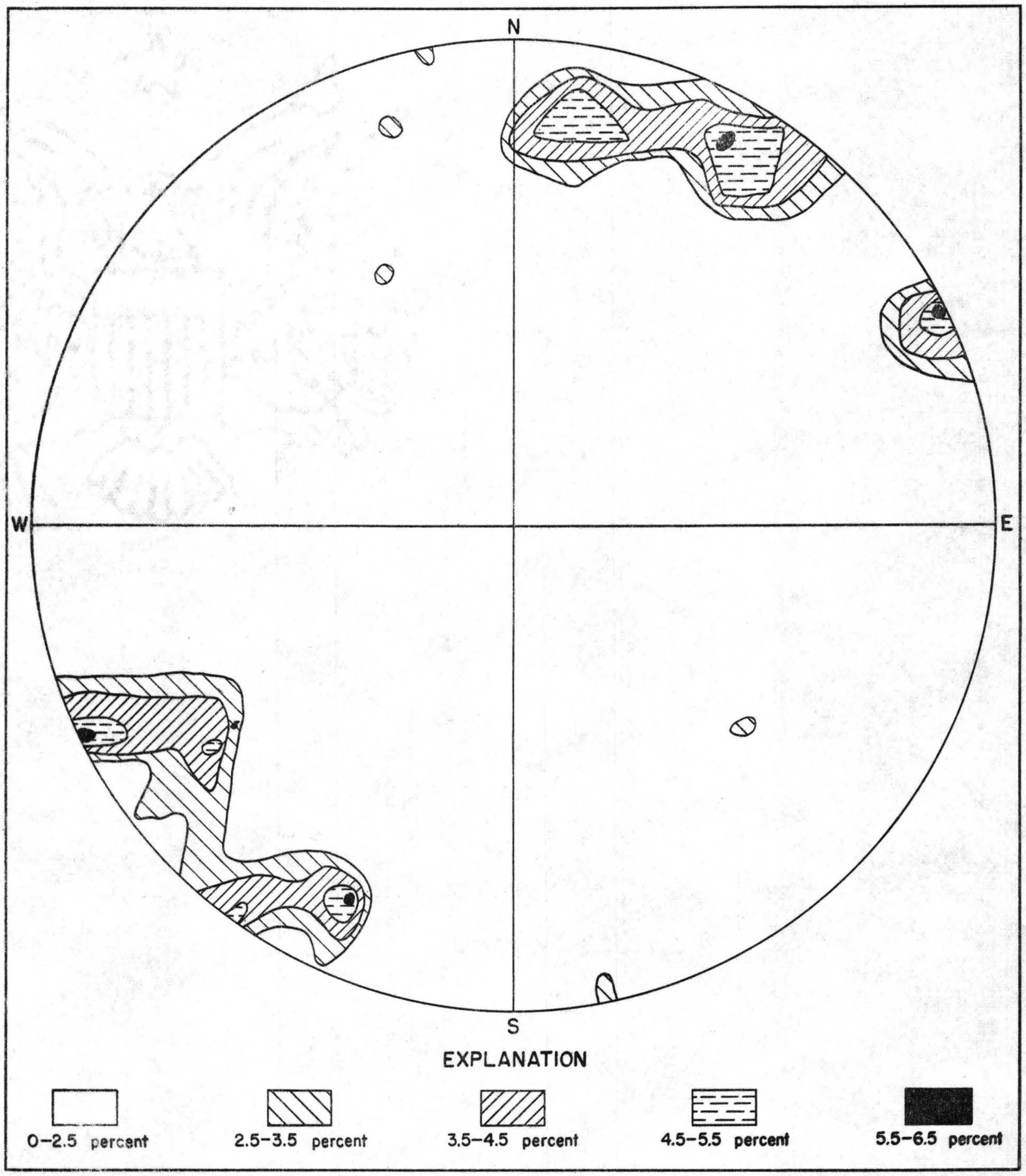


FIGURE 3-COUNTOUR DIAGRAM OF 110 LINEATIONS IN ROCKS OF THE EAST CALHOUN AND WOOD MINES

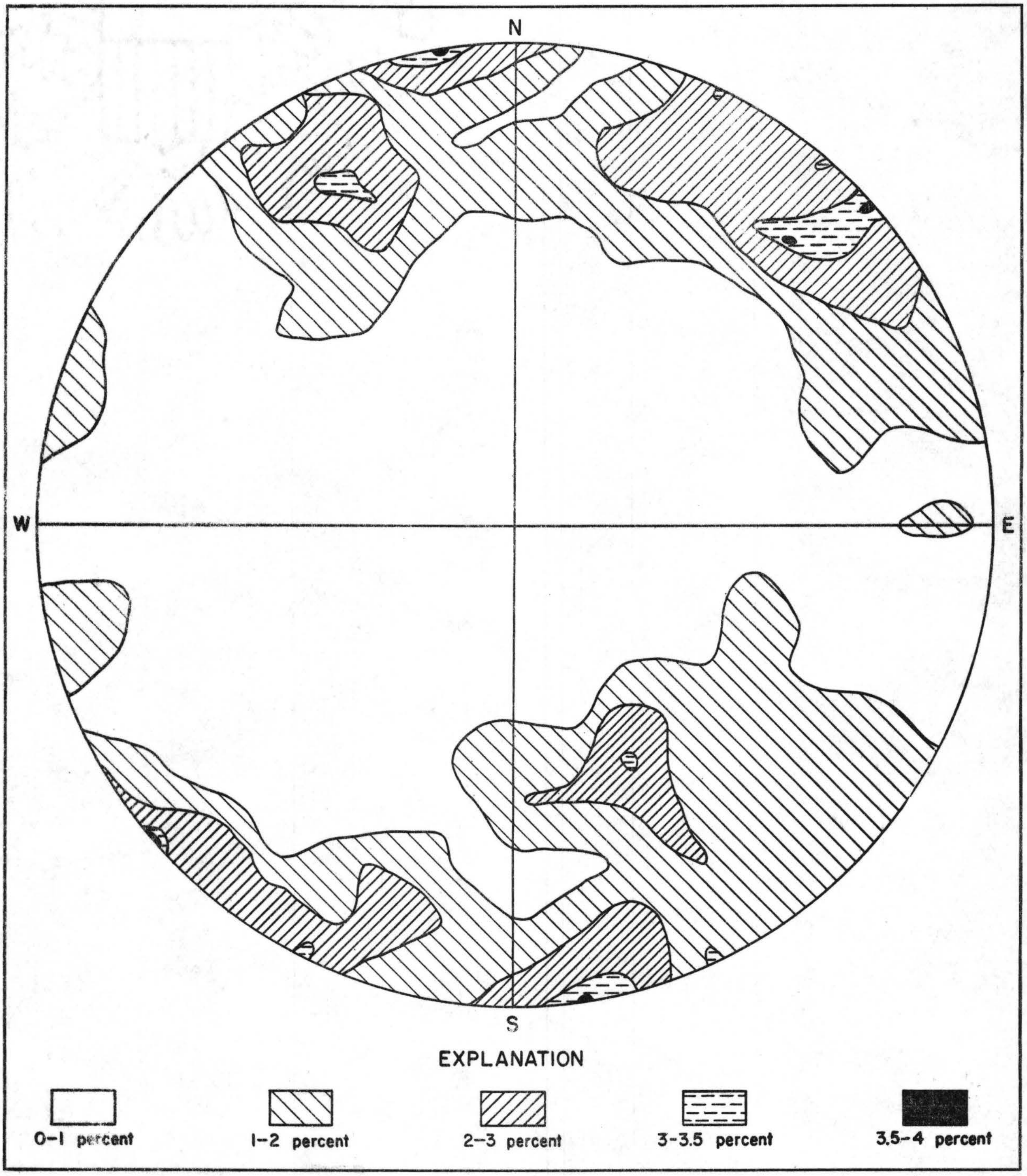


FIGURE 4.-CONTOUR DIAGRAM OF 386 JOINTS
Plotted On Upper Hemisphere Of Schmidt Net

Faults

The three principal faults in the Wood-East Calhoun mine area are the east-trending Wood fault, and the east-northeast-trending Calhoun and Quartz Mill faults. These faults are metallized and are the major veins of the area. Minor east-northeast to northeast-trending faults also are metallized. Several barren northwest-trending faults were mapped underground. The faults in order of age from oldest to youngest are northwest-trending, east-trending, 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 (Sims, Drake, and Moench, 1953). Minor ore brecciation and the development of gouge indicate that some post-mineral movement took place along the break. Neither the true direction nor amount of movement on the fault is known; but on the fourth level of the East Calhoun mine a bostonite dike has 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 horizontally about 12 inches to the west. On the same level, the south segment of a bostonite dike has been shifted a few inches to the west. From these data, it appears that relative 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 (fig. 6). 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 develops 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 is similar to that along the Calhoun fault. The Quartz Mill-Calhoun fault crossing cannot be seen now, but Sanderson (1909) observed no displacement at the intersection. The attitude of the two veins is such that their intersection is essentially horizontal with local flat plunges to the east or west.

Wood fault.--The Wood fault has been traced on the surface for about 1,000 feet (Sims, Drake, and Moench, 1953). It trends easterly and dips steeply either side of vertical. The presence of abundant gouge, intra-vein slip planes, and numerous slickensides indicates 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. 5). This diagram indicates nearly horizontal maxima 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 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 largely horizontal, the south wall having moved eastward relative to the north wall. Detailed geologic mapping of the surface (Armstrong, in preparation) shows that the south segments of two bostonite dikes have been shifted 30-40 feet to the east along the Wood fault. This apparent horizontal displacement, however, is probably exaggerated 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).

Minor faults.--The Wood exploration drift east (fig. 10) does not follow the Wood vein but instead is on a northeasterly split that dips steeply either side of vertical. This fault alines rather well with the Willowdale patented claim, and accordingly the writer herein names 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 southwesterly-trending split from the Wood fault. The writer's mapping shows numerous minor splits from the Wood fault that bear either northeasterly or southwesterly. Many connecting loops between parallel to sub-parallel 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 as characteristic of shearing complicates the picture of fault movement. This is mechanically resolved

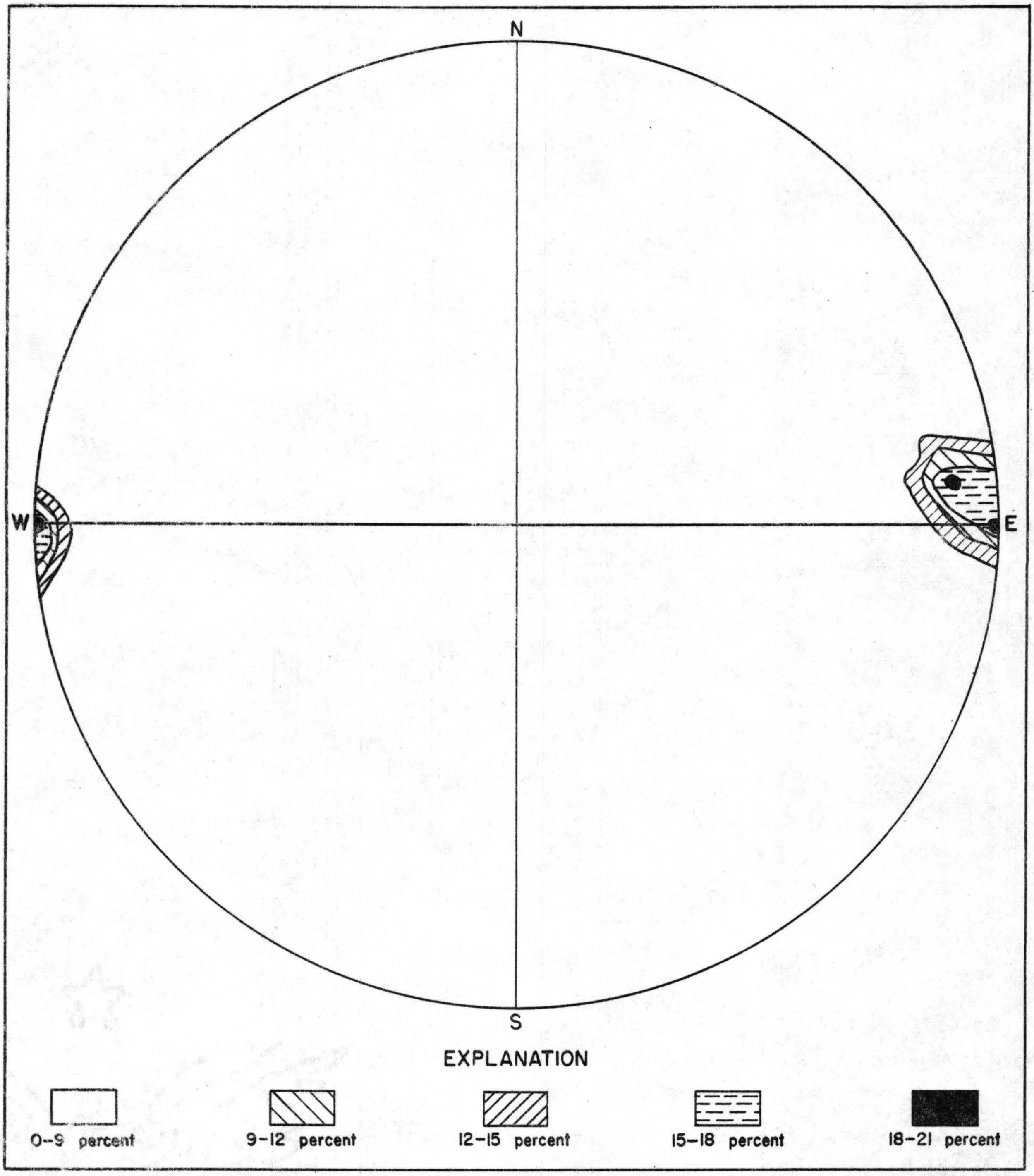


FIGURE 5.-CONTOUR DIAGRAM OF 70 SLICKENSIDES ON THE WOOD VEIN
Plotted On Lower Hemisphere of Schmidt Net

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 was relieved by movement along the Wood fault and shearing along the previously formed tension fractures; such movement would tend to realine any displaced units along the Wood fault and may account for the apparent lack of displacement. If the above type of fracturing took place, one would expect strong fracturing in the vicinity of Wood-tension fracture junctions. Such loci are actually 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(in preparation) believes that this fault extends both north and south of the Wood fault, but the writer mapped no structure underground that correlates with the Mayflower.

Structure of Tertiary dike rocks

The Tertiary dike rocks in the Wood-East Calhoun mine area fill steeply dipping fractures in the Precambrian rocks. The dikes have essentially the same attitude as the northwest-trending joint set and barren northwest-trending faults. This suggests, 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 Wood-East Calhoun mine area are found in veins that are thought to have 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 accounted for 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 two 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-East Calhoun mine area where transition veins contain pitchblende in addition to ores of gold, silver, copper, lead, and zinc.

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.

The uranium deposits of the Wood-East Calhoun area carry 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 do 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 development

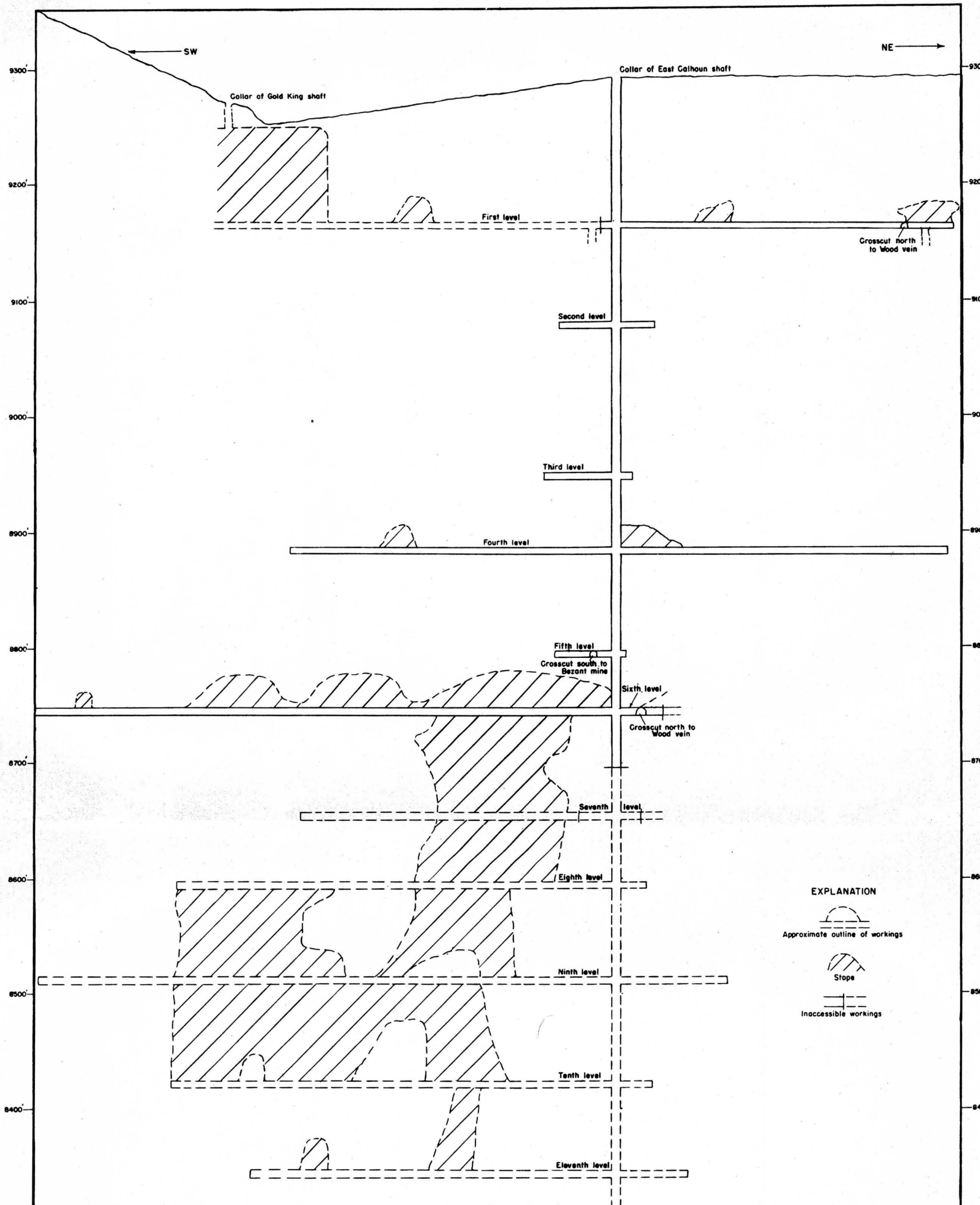
East Calhoun mine

The East Calhoun mine (fig. 6) probably was opened sometime in the 1860's. The mine was operated intermittently until World War I. It was last reopened in 1949, and a Defense Minerals Exploration Administration loan was granted in 1951.

The East Calhoun shaft is inclined about 70^{o} 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 (Sanderson, 1909), but as the vein was valueless the miners started sinking on the Quartz Mill vein which dips to the north. This vein was deveolped 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 of figure 7.

Wood mine

The Wood is one of the oldest patented locations on Quartz Hill-number 232. It has been worked intermittently from the late 1860's to date. Pitchblende was first noted on the dump of the Old Wood shaft in 1871 (Pearce, 1895, p. 157-158).



Modified from Moore and Butler, 1952

FIGURE 7.—LONGITUDINAL PROJECTION OF THE EAST CALHOUN MINE, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

100 50 0 100 200 FEET

Datum is mean sea level

The Wood vein is developed by the Wood and Old Wood shafts on the west (fig. 2) and by the Ross shaft that is 320 feet east of the Wood vein--Calhoun vein junction. Moore and Butler (1952) mapped the 135-, 197-, and 275-levels of the wood mine (fig. 8); 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 (Armstrong, in preparation). The vein has been stoped from the surface to a point about 70 feet below the collar of the shaft (Armstrong, in preparation). All 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 (fig. 6), and by the exploration workings on the sixth level of the East Calhoun mine (fig. 9).

Production

East Calhoun mine

The total production of the East Calhoun mine is not known. Table 1 shows the production from the Jefferson-Calhoun vein from 1902-15. This includes 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 vein.

Wood mine

There are no records of the total production from the Wood mine. Table 2 shows the substantiated pitchblende production.

The writer could find 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 exceptionally, the gold content was very high, one assay showing 35 ounces.

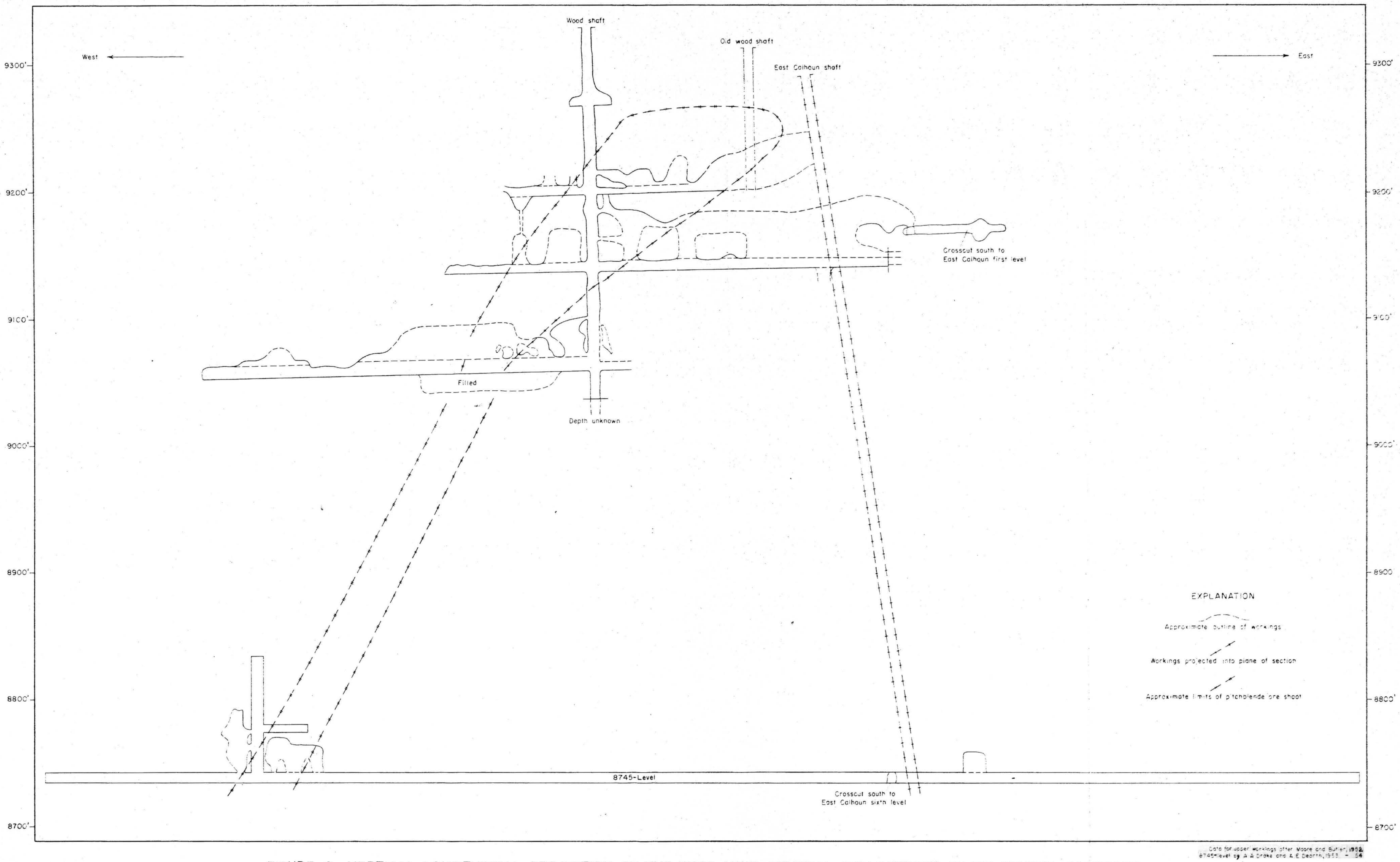


FIGURE 8.-VERTICAL LONGITUDINAL PROJECTION OF THE WOOD MINE, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

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, Colorado.

Table 2. --Substantiated pitchblende production from the Wood vein.

Year	Crude ore shipped (tons)	Concentrates shipped (tons)	Gold (ounces)	Silver (ounces)	U_3O_8 (pounds)	Remarks
1871 1/	0.10				120	Hand sorted
1872 1/	3.10				3,720	Do.
1873 1/	2.70				2,254	
1884 1/	3.00				4,200	
1894 1/	?				?	Pearce purchased a quantity of ore.
1897 1/	17.00				27,000	Not fully substantiated.
1898 1/	33.00				7,920	
1913 1/	.20				200	
1916 1/	10.00				1,200	
1940 1/	.50	35 3/	53.60 3/	77 3/	135	
1953 2/	17.40				800	
TOTAL	87.00	35	53.60	77	47,549	

1/ Armstrong (in preparation)

2/ Operator's estimate, probably high. This ore was not shipped, as quantity was not great enough to be economic.

3/ A. J. Martin, Metals Economics Branch, U. S. Bureau of Mines, Denver, Colo.

General character of the veins

The veins of the Wood-East Calhoun mine area are for the most part single well-developed fault fissures ranging from half an inch to 24 inches in width, with few to many subparallel veinlets and slips which form rather complex lodes. Outward from these fissures the wall rocks are replaced for a few inches to a few feet. Exceptionally, the wall rock is silicified and pyritized to widths as great as 6 feet; on the average, however, the altered zone is about 18 inches wide. The east-trending veins, such as the Wood, show a marked tendency to form both 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 cases nearly completely replaced by ore minerals. The lode zones are in general rather 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--especially pyrite--and numerous sets of crosscutting veinlets and slip planes indicate repeated movement. Deposition in open cavities is shown by the pronounced development of comb structure in the vein quartz and the abundant deposition of ore minerals as crystals and encrustations 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-developed fault fissure that ranges in width from half an inch to 18 inches. It consists of pyritized silicified wall rock, fragments, gouge, pyrite, and quartz, with spotty chalcopyrite and sphalerite and, exceptionally, a little sooty pitchblende. Individual streaks of quartz and ore minerals seldom exceed 3 inches in width. The silicified and pyritized halo averages about 18 inches, but may be as much as 5 feet wide. The vein is rather tight--much more so than the Wood--and shows little evidence of much post-mineral movement; however, 1-3 inches of gouge is present along the walls and along a few oblique post-mineral 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.

In general, the Calhoun vein 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 (1909) 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 (fig. 10). 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, numerous crosscutting veinlets and slip planes, abundant slickensides, and strong gouge indicate repeated movement (fig. 11). Deposition in open cavities is shown by colloform structure in the pitchblende, the pronounced development of 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 the textures of the ore minerals. The vein thickens near acute fissure intersections because of the shattering of the intervening wedge of rock.

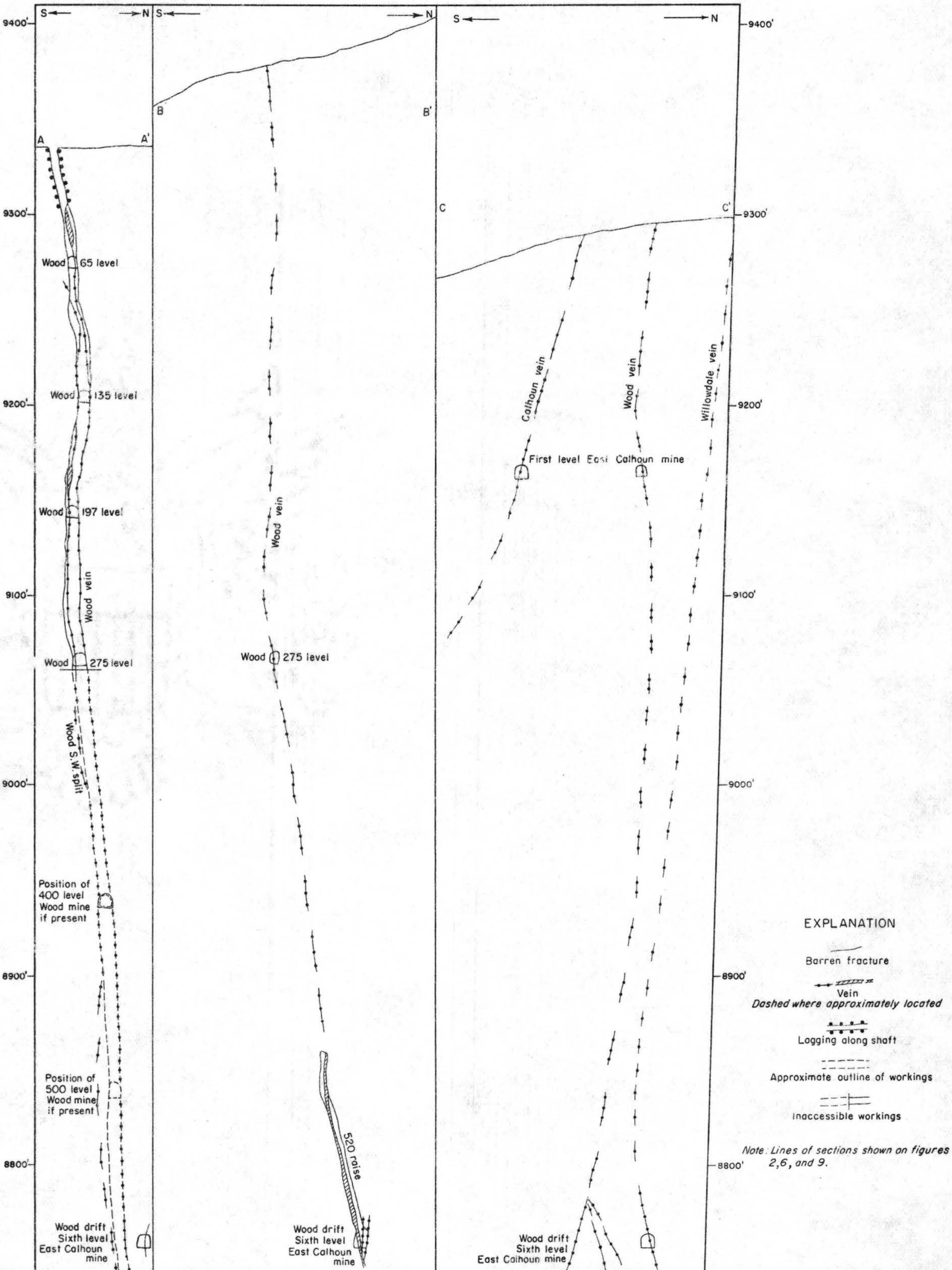


FIGURE 10.—GEOLOGIC SECTIONS ACROSS THE WOOD EXPLORATION DRIFT, EAST CALHOUN MINE, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

40 20 0 120 Feet

Datum is mean sea level

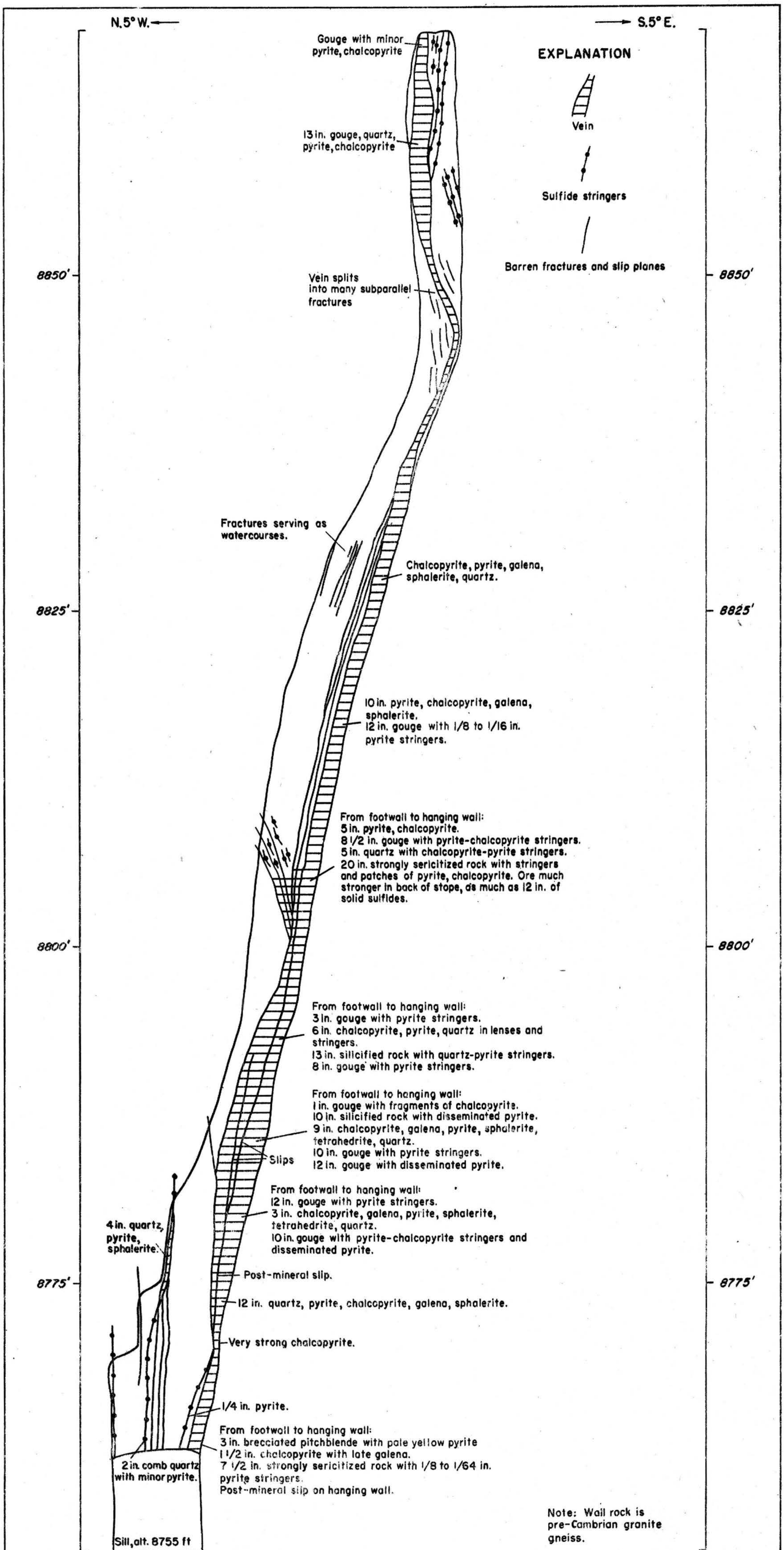


FIGURE 11.—GEOLOGIC SECTION OF THE WOOD 520-RAISE

Geology by A.A. Drake, 1953

10 5 0 10 20 Feet

Datum is mean sea level

Similarly thickened parts of the vein are also present between parallel fissures. The vein is stronger on strike changes to the northeast indicating that wider fissures were produced by movement so oriented as to move the south wall east. No obvious dip control was noted; however, the vein appears to be stronger on steep dips to the north.

Willowdale vein

The Willowdale vein, a hanging-wall split off the Wood (fig. 9), 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. In general, however, it is a much weaker structure and carries sparse amounts of ore minerals.

Mineralogy

The veins in the Wood-East Calhoun mine area 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 thought to have 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 is seen to cement 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 last type of quartz to form was 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 largely cubic in habit. Nearly everywhere observed, this pyrite veins pitchblende or pitchblende-quartz breccias; 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 with gray to brown fine-grained quartz. Gold and silver occur in type III pyrite (table 3). The other types of pyrite also may carry gold and silver, but data concerning them are not available.

Table 3.--Gold and silver content of pyrite, East Calhoun and Wood veins, Central City district, Gilpin County, Colorado.

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

1/ Armstrong (in preparation)

2/ Sized, superpanned, and hand picked. Analysis by U. S. Geological Survey Denver Laboratory.

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, Wood and Calhoun veins, Central City district, Gilpin County, Colorado.

Locality	Au	Ag
	(ounces per ton)	
East Calhoun mine, 6th, level, Calhoun vein, 800 feet west of shaft. 1/	0.90	33.80
East Calhoun mine, 6th level, Wood exploration drift, Wood vein, 500 feet west of crosscut. 2/	.34	17.60

1/ Armstrong (in preparation).

2/ Analysis by U. S. Geological Survey Denver Laboratory.

Sphalerite

Sphalerite veins cut quartz and pyrite, and sphalerite crystals fill fractures and vugs. The sphalerite is largely the dark, iron-rich variety, marmatite (table 5), but "resin jack" also is present. "Resin Jack" is found in vugs as small tetrahedrons that have been deposited on dark sphalerite. Under the reflecting microscope, sphalerite veins cut quartz and pyrite, fill open spaces, and corrode pyrite along mutual boundaries suggesting replacement. Chalcopyrite veinlets traverse sphalerite, and relict islands of sphalerite are found in chalcopyrite. Tiny blebs and needles of chalcopyrite are distributed through the dark sphalerite. Most of this chalcopyrite is thought to be the result of replacement, but some may have been exsolved. Sphalerite contains small amounts of gold and silver (table 5).

Tetrahedrite-Tennantite

Gray copper is moderately abundant in both the Calhoun and Wood veins. It is steel gray, has a red streak and can be mistaken for hematite. In polished section the mineral has a greenish cast suggesting 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 suggest replacement.

Table 5.--Analyses of sphalerite, Wood and Calhoun veins, Central City district, Gilpin County, Colorado.

Locality	Au (ounces per ton)	Ag	Fe (percent)	Cu	Pb
East Calhoun mine, 6th level, Calhoun vein, 800 feet west of shaft 1/.	0.16	0.76			
East Calhoun mine, 6th level, Wood exploration drift, Wood vein, 500 feet west of crosscut 2/			17.03	4.26	.30

1/ Armstrong (in preparation).

2/ Analysis by U. S. Geological Survey, Denver Laboratory.

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 in turn is cut by chalcopyrite veinlets. Relict islands of pyrite, sphalerite, and chalcopyrite occur in the galena. Galena streaks were also noted along cleavage of pyrite, sphalerite, and chalcopyrite. Relict islands of galena also were seen in chalcopyrite.

Gold and silver

Gold and silver are definitely carried by pyrite, chalcopyrite and sphalerite, and probably also by tetrahedrite-tennantite and galena. It is not known, however, whether these metals are carried mechanically or in solid solution. Free gold also is present. Miners at the East Calhoun mine have panned gold from ore from the 520 stopes (figs. 8 and 9). The gold is a "flour" type and, according to the miners, is lost by normal milling practice. No gold was seen in polished section. The gold-silver ratio in samples from the Wood exploration drift is 1:5 (fig. 12).

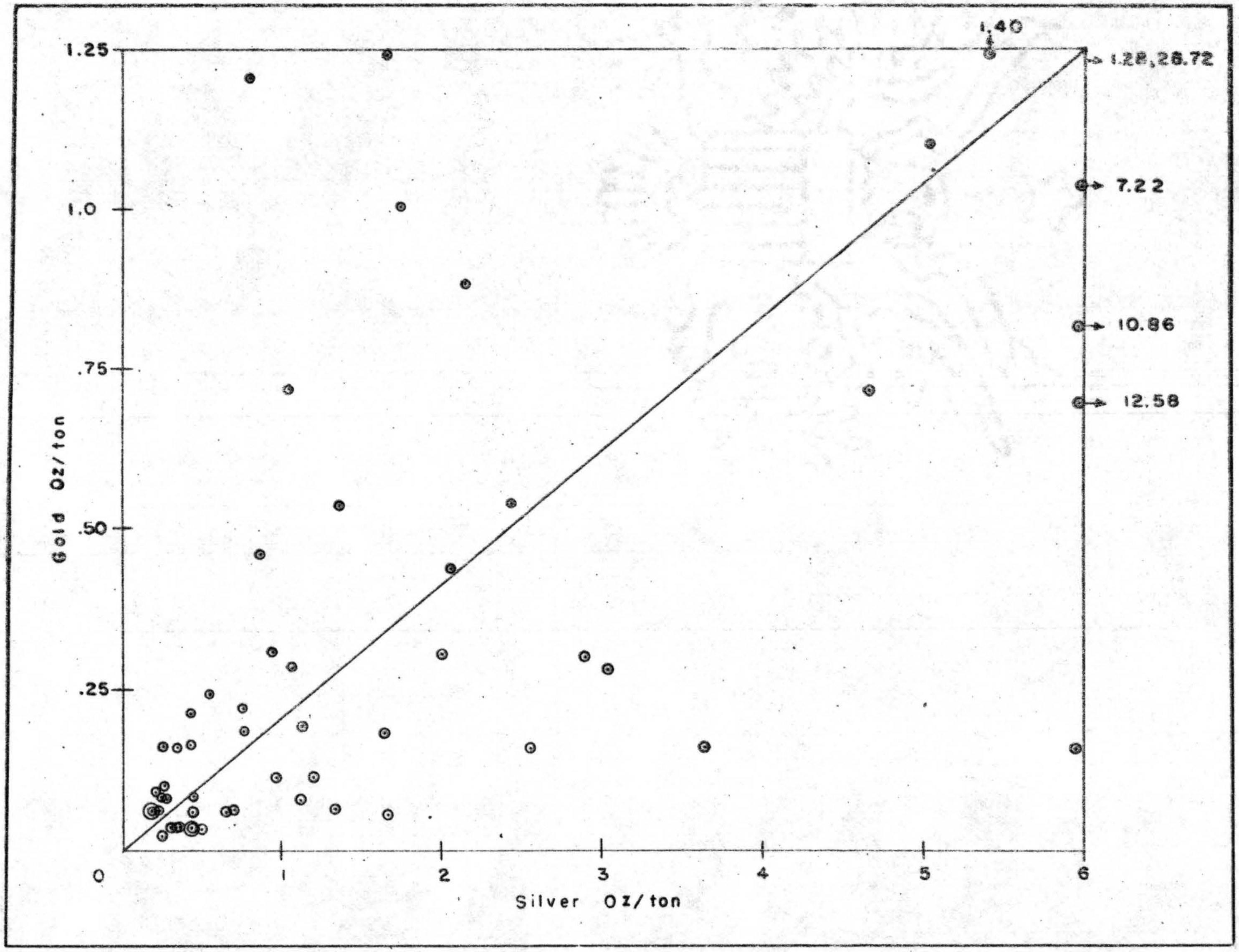


FIGURE 12— GRAPH SHOWING THE RELATION OF GOLD TO SILVER IN SAMPLES FROM THE WOOD VEIN.

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 (1917, p. 245) reported 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 (figs. 9 and 11). Sooty pitchblende was observed in post-mineral slips near the hard pitchblende. Sooty pitchblende also was observed on fracture surfaces at the shaft on the first level of the East Calhoun mine; and on the same level it coats the vein wall just east of the Wood-Calhoun vein intersection.

Megascopically, the pitchblende is hard, black, and lustrous. It appears to be massive, but the reflecting microscope shows a colloform structure. The pitchblende occurs in veinlets and as aggregates of spheroidal grains. All of the pitchblende has been brecciated. Most grains have rounded margins, in part spheroidal. Many grains have been rotated. All spheroidal grains have both radial (syneresis) and circumferential cracks. In some sections tiny, apparently massive grains of pitchblende are noted. These probably represent breccia fragments of larger areas of nearly uniform appearance. Most cracked grains are predominantly light gray and are in part healed by a darker gray pitchblende, which suggests brecciation during deposition. Almost all grains have a slight color banding parallel to the colloform layering, the darker material occurring on the outside. This phenomenon probably results from difference in oxidation. A little pale-yellow pyrite is intergrown with the pitchblende, but in most sections studied pitchblende is veined by pyrite. In places the brecciated pitchblende is healed and cemented by quartz. Some pitchblende appears to replace quartz, but for the most part 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) 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, 1952, p. 707) gave absolute ages of 57.3 and 60 million years.

Bornite

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

Sooty chalcocite

Sooty chalcocite was observed in both the Wood and Calhoun veins in extremely wet areas. It is probably supergene.

Covellite

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

Paragenesis

The succession of events bringing about the formation of the veins is shown in figure 13. 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 contemporaneously 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 these 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 degree. Renewed movement along the vein fractured the minerals and opened fissures in which chalcopyrite, tetrahedrite-tennantite, and galena were deposited. Chalcopyrite replaced sphalerite, pyrite, and, to a limited degree, quartz. Tetrahedrite-tennantite followed chalcopyrite closely, replacing it and the sphalerite. Galena filled open spaces around other mineral grains and replaced sphalerite and gray copper. Galena was then replaced by late chalcopyrite.

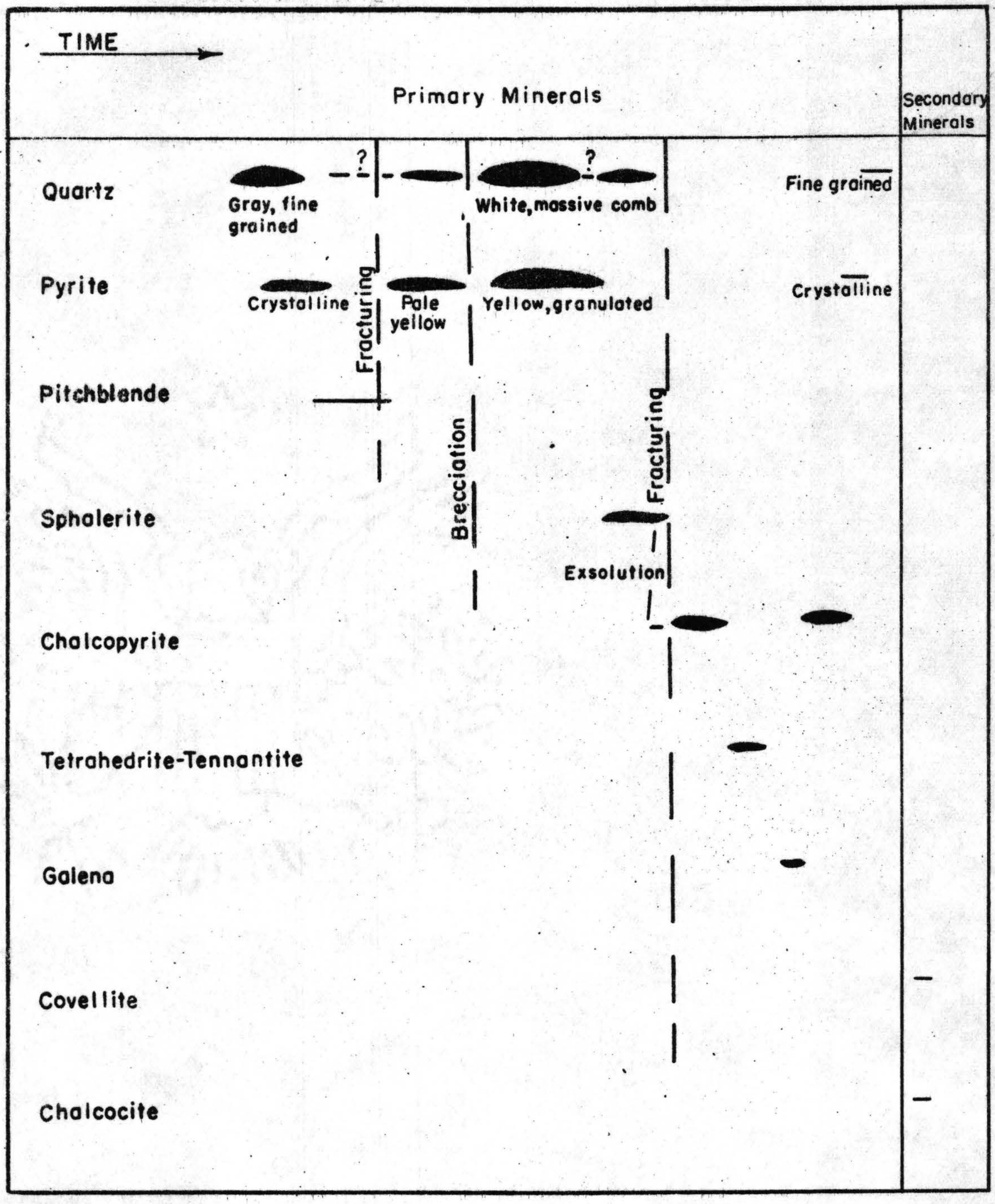


FIGURE 13.- PARAGENESIS OF THE VEIN MINERALS

Coarse pyrite crystals were then deposited on earlier minerals in vugs. The sequence ended with gray to brown fine-grained quartz which coated ore minerals in vugs.

The final event in the history of the vein formation 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

Figure 14 presents in graphic form the results of assays for uranium, gold, silver, copper, lead, and zinc in samples taken from the Wood vein. Table 6 presents assay data from 132 individual samples.

In the past, it was thought that pitchblende occurred in small bodies more or less randomly distributed through the vein. A study of figure 14 shows that uranium values are concentrated in one limited area of the vein, near the 520-raise. Only negligible quantities are detected elsewhere. The zone of uranium occurrence lies on the projection of the Wood ore shoot (fig. 8) as outlined by Moore and Butler (1952). The ore-shoot relations will be discussed later.

The highest gold and silver assays come 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 $2.00 to $4.00 in gold."

This reported inverse relation does not hold true for the Wood vein, at least for that part sampled in this study. Perhaps, the "old timers" sampled pitchblende and got poor gold assays. Another possible explanation is that pitchblende, which was deposited before the main 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, there was more space for later minerals.

Both pyrite and chalcopyrite have been shown to be auriferous and argentiferous (tables 3 and 4). The pyrite, however, does not appear to carry sufficient gold to constitute ore. Numerous samples of almost solid pyrite vein material showed very low gold assays. If pyrite were auriferous enough to make ore, one would

Table 6 .—Some chemical analyses, fire assays, and semi-quantitative spectrographic analyses of ore from the Wood vein. 1/

ELEMENTS 2/

Sample number	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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-102	4	0	0.002	Tr.	0.24	0	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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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

1/ All assays and spectrographic analyses made by P. R. Barnett, G. W. Boyes, Jr., P. J. Dunton, S. P. Furman, W. D. Goss, R. G. Havens, E. C. Mallory, Jr., J. McGurk, W. Mountjoy, W. W. Niles, J. P. Schuch, J. L. Siverley, D. L. Skinner, and J. Wahlberg of the U. S. Geological Survey Denver Laboratory.

2/ Au and Ag, in oz./ton. U, eU, Cu, Pb, Zn, and Fe_2O_3, in percent. Other elements reported by "group-number" method.

Table 6.--Some chemical analyses, fire assays, and semi-quantitative spectrographic analyses of ore from the Wood vein. --Continued

ELEMENTS

Sample number	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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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

Table 6 .—Some chemical analyses, fire assays, and semi-quantitative spectrographic analyses of ore from the Wood vein. —Continued

42a

Sample number	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
																	ELEMENTS													
W-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
W-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
W-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
W-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
W-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
W-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
W-524	3	0	.000	.04	.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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-572	DDH-2 core.	0	.01	.82	10.86	4.67	.30	.26	45.82	4-	4	0	5-	0	3	6+	Tr.	6	5	6	0	6	0	5-	5	5	0	0	0	0
W-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
W-574	Grab.	.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
W-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
W-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
W-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
W-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
W-579	Grab (rock).	.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-
W-580	Grab(gouge).	.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
W-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-
W-582		.006	.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
W-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
W-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+
W-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+
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-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
W-595	Core.	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
W-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
W-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
W-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
W-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
W-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

expect samples, largely of pyrite, to show ore-grade assays. It has been long known that gold and copper values run together (Bastin and Hill, 1917). This is generally true for the Wood vein; however, the analysis of nearly clean chalcopyrite from the Wood vein (table 4) is low in gold. The writer believes that free gold possibly was deposited nearly contemporaneous with chalcopyrite, and that the copper-gold relation may be more apparent than real.

Silver is carried by both gray copper and chalcopyrite. Galena is presumably argentiferous, but is too sparse to be of much interest either for lead or for silver. Moderate quantities of zinc are found, but at the present time zinc is of little economic interest.

TRACE ELEMENTS

Distribution patterns of trace elements in the ore from the Wood exploration drift were made from semi-quantitative 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 zirconium and molybdenum with uranium; bismuth, antimony, and arsenic with copper; and cadmium with zinc.

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, 1952, p. 18) is used in this report and is shown by the following data:

Group No.	Percent
1	10 to 100
2	1 to 10
3	0.1 to 1
4	0.01 to 0.1
5	0.001 to 0.01
6	0.0001 to 0.001

Table 7.--Threshold values of elements included in the semiquantitative method.

Element	Percent	Group number	Parts per million
Ti	0.001	5	10
Mn	.0005	6	5
As	.1	3	1000
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	1
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 various samples on 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 (0) has been used to signify 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. 15).

The two samples containing the highest uranium also show high zirconium--("group number" 3) (table 6 and fig. 16). The average zirconium content of all samples is within group 5 or 4 (fig. 15). A chemical analysis of pitchblende from the Wood mine showed 5.47 percent zirconia (Phair, 1952, p. 17). Hillebrand (1891) found that a pitchblende from the Central City district contained 7.59 percent zirconia. 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 pitchblendes from several localities.

The direct relation of uranium and zirconium is of some interest. Phair (1952, p. 45) believed 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. These solutions mingled with regional solutions and rose along the planes of weakness provided by the porphyry dikes and reacted with and leached part of the uranium present. If, as Phair believed (1952, p. 22), the uranium in the quartz bostonites is tied up in 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 uranium and molybdenum is present in samples from the Wood vein. Samples of the uranium-bearing part of the vein near the 520-raise contain more molybdenum than is normal (figs. 14, 15, and 16). A molybdenum-uranium relation has been noted in other areas--at Climax (R. U. King, oral communication, 1954), in the Henry Mountains (Riley and Shoemaker, 1952, pl. 47), at the Happy Jack mine, Utah (T. G. Lovering, oral communication, 1954), and in British Columbia (Drake, previous work). 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 do little more than point out the molybdenum-uranium association and note that they both were deposited early in the paragenetic sequence.

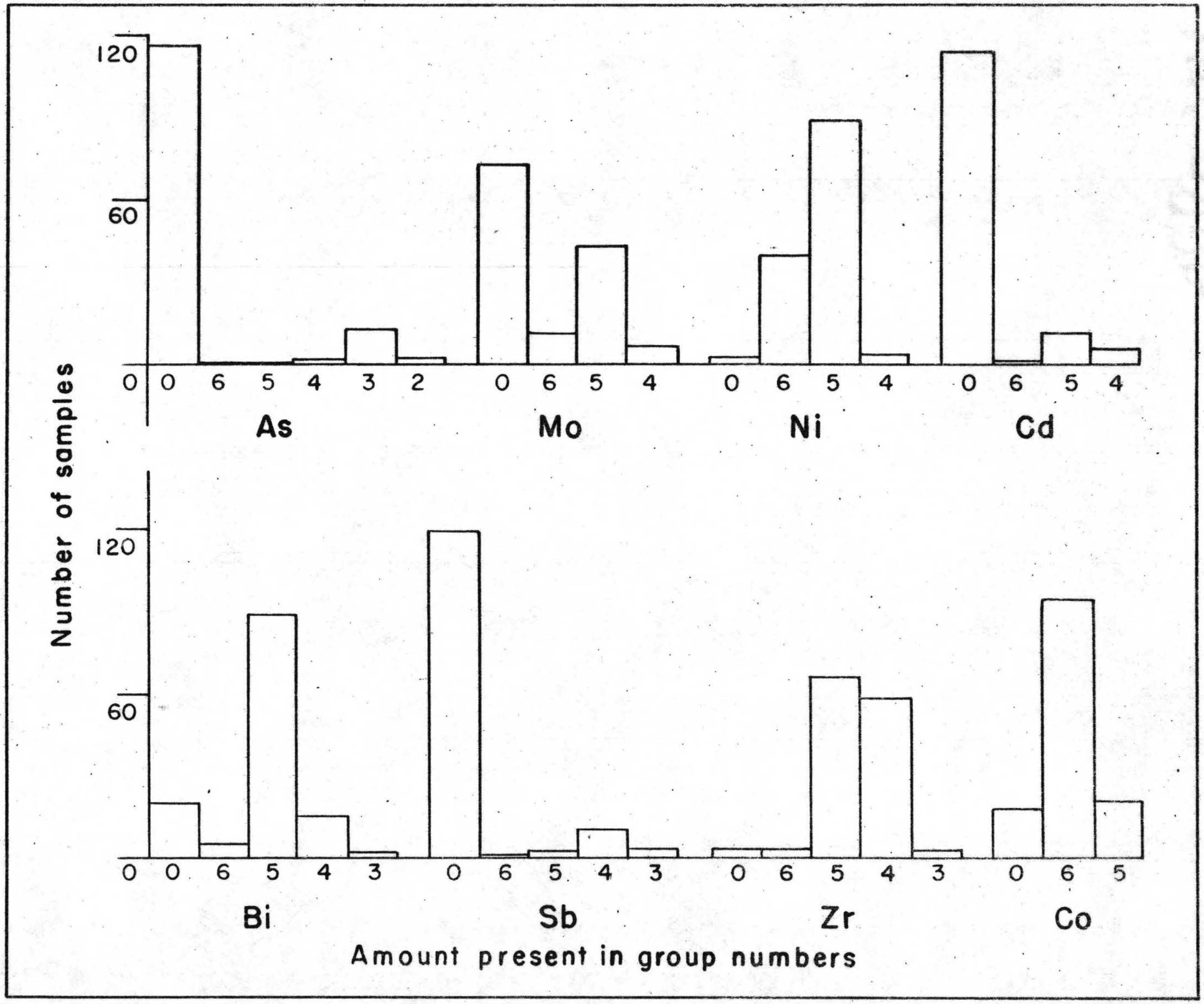


FIGURE 15.-DISTRIBUTION HISTOGRAMS OF SOME ELEMENTS IN 132 SAMPLES FROM THE WOOD VEIN

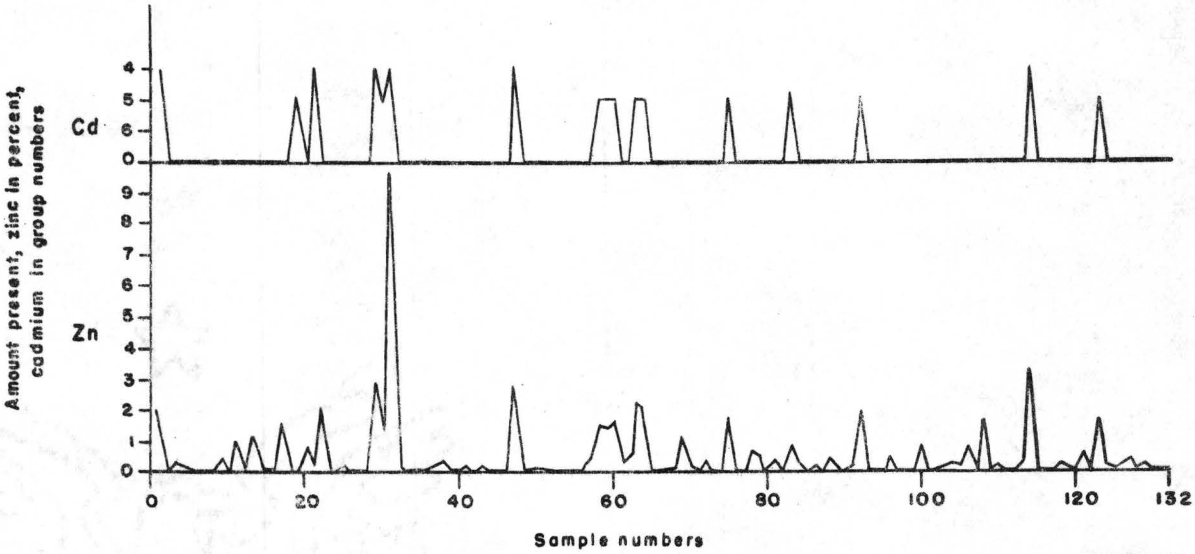


FIGURE 17.— GRAPH SHOWING THE RELATION BETWEEN ZINC AND CADMIUM IN SAMPLES FROM THE WOOD VEIN.

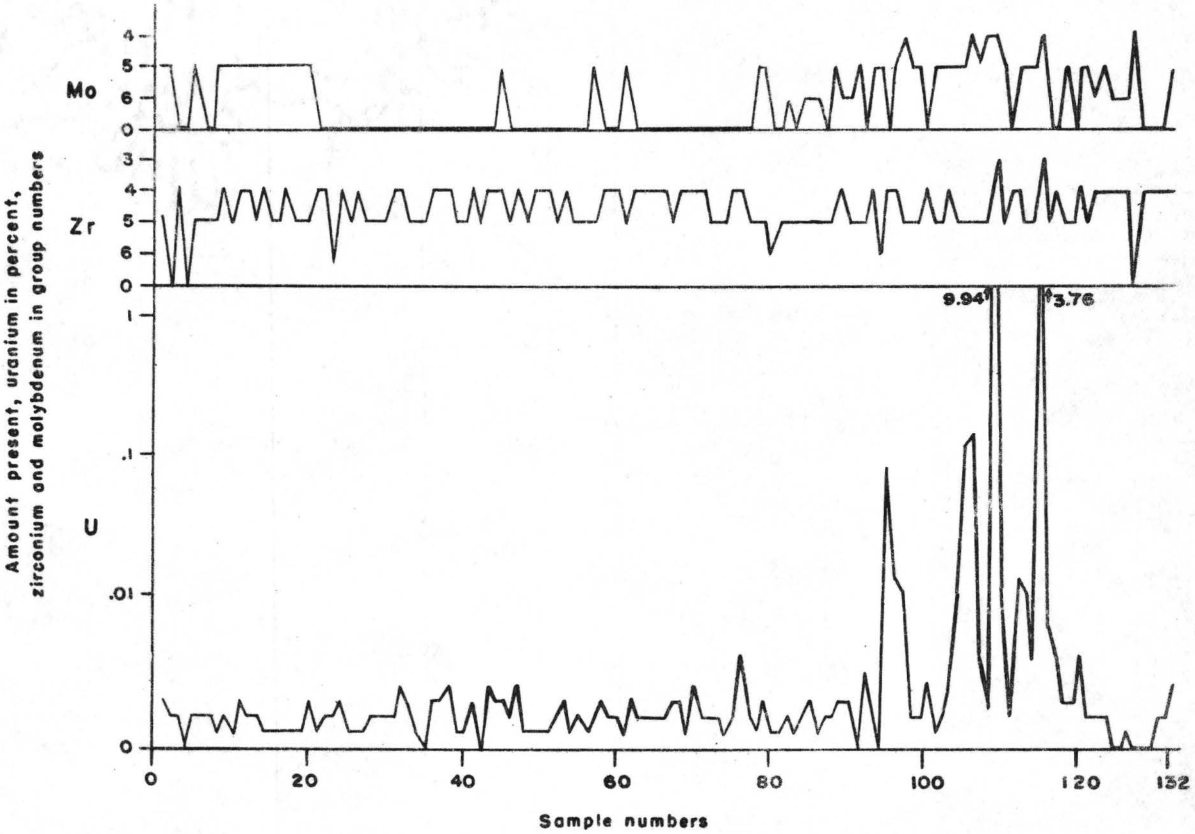


FIGURE 16.— GRAPH SHOWING THE RELATION OF MOLYBDENUM AND ZIRCONIUM TO URANIUM IN SAMPLES FROM THE WOOD VEIN.

Cadmium is locally present in the Wood ores (table 6) and may be quantitatively correlated with zinc (fig. 17). Sphalerite contains a large proportion of all cadmium, up to 4.5 percent (Rankama and Sahama, 1950, p. 708), and is thought to occur in sphalerite in the Wood ores.

In the Wood ores, arsenic, antimony, and bismuth occur in varying quantities (fig. 15). In general, they correlate rather well with copper (fig. 18). Inasmuch as tetrahedrite-tennantite is present in the vein, it seems reasonable to relate 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 thought, therefore, that the bismuth present in the Wood ore is in tetrahedrite-tennantite.

Nickel and cobalt minerals frequently are associated with uranium deposits (Everhart and Wright, 1953). Minerals containing these elements have not been identified, however, in the Central City district. Samples of the Wood ore contain (reported by group number) 6 to 4 nickel, averaging 5; and 6 to 5 cobalt, averaging 6 (fig. 15). The four high 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 as they were pulverized in steel grinding machines and the amounts of these constituents present are within 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-bearing and non-pitchblende bearing parts of the Wood vein. Unfortunately, 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. In general, the alteration progresses outward from a pyritized and silicified zone, through a silicified zone, to an argillic zone. At most places, pyritization is stronger where the wall rock originally contained a large proportion of mafic minerals, suggesting that at least part of the pyrite was formed from iron ions liberated by the altering solutions.

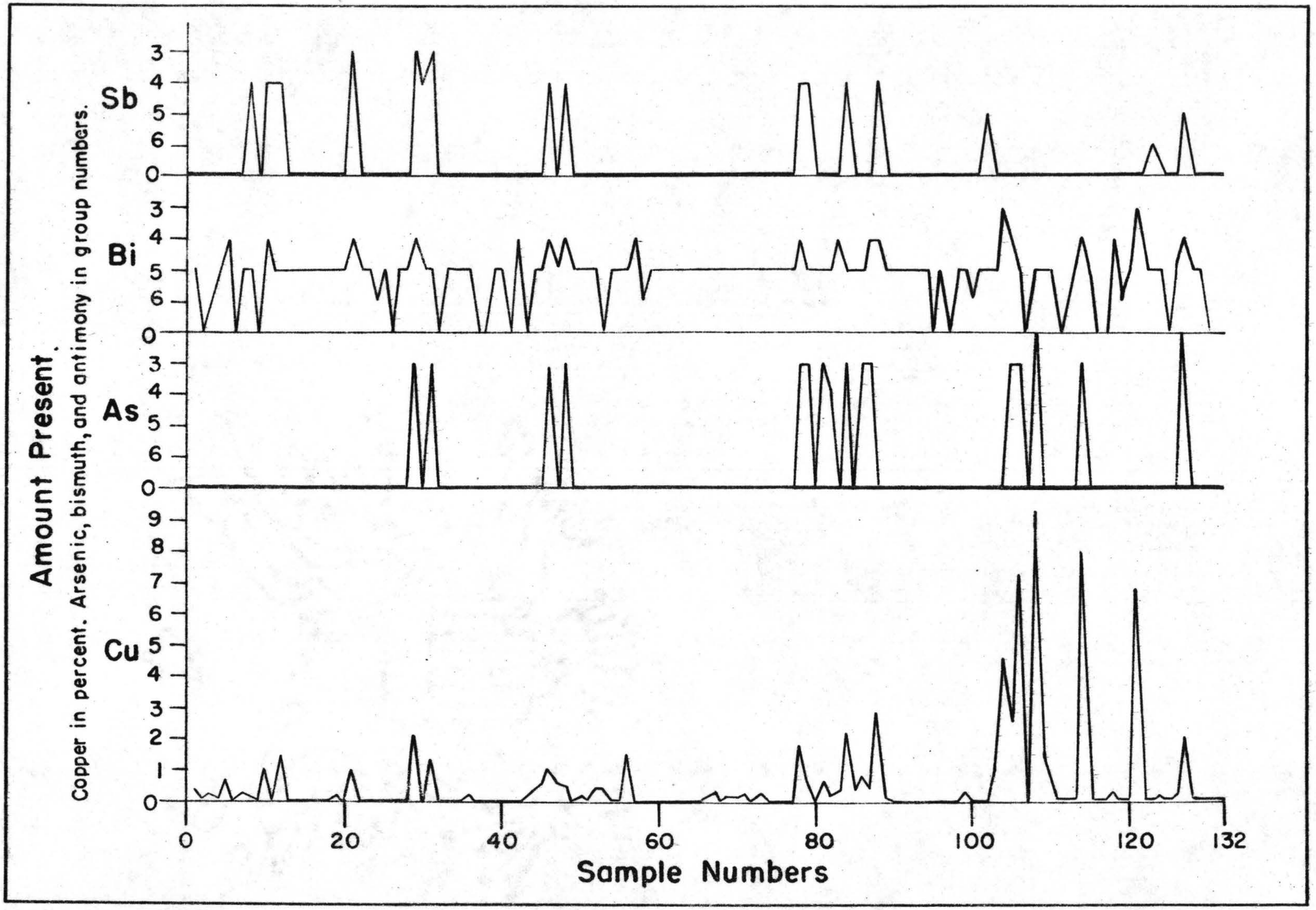


FIGURE 18.- GRAPH SHOWING THE RELATION BETWEEN COPPER, ARSENIC, BISMUTH, AND ANTIMONY IN SAMPLES FROM THE WOOD VEIN

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. A detailed study of wall rock alteration in these and other veins in the Central City district currently is being carried on by E. W. Tooker of the Geological Survey, and the results of this work will be presented in a later publication.

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 change in mineralogy along strike is part of the larger hypogene zoning pattern of the Central City district (Leonard, 1952). In simplified form, the zoning consists of a core of quartz-pyrite veins surrounded by a shell of galena-sphalerite veins. The veins mapped in this study lie in the area transitional between these major zones.

It also is expected that changes in mineralogy should occur vertically along the veins. Evidence suggests that such a change does take place for 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); below that level galena and sphalerite are present. This change in vein mineralogy with depth suggests that the transition zone at this locality dips to the east.

Leonard (1952) found that the known 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 expected that pitchblende will be closely related to copper-bearing minerals and sphalerite both in space and time. In the

Wood vein, the spatial relation generally holds true. In specimens studied by the writer, however, the pitchblende is earlier in the paragenetic sequence than both chalcopyrite and sphalerite. Bastin and Hill (1917, p. 123-124) report that chalcopyrite is intergrown with pitchblende in specimens from the Wood vein, suggesting that they were deposited essentially contemporaneously. These conflicting data suggest that the questionable relation between pitchblende and the zoning theory remain 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 pre-mineral faults. Factors influencing the development of open spaces include: the competency of the wall rock, the presence of a northwest-trending joint set, changes in strike and dip, and intersections and near-intersections of individual fractures.

Openings along the fractures were best developed where the faults intersected relatively brittle wall rocks. In order of favorability, at the Wood and East Calhoun mines, the most favorable wall rocks are granite gneiss, pegmatite, migmatite, bostonite, amphibolite, and biotite-quartz-plagioclase gneiss.

Another feature favorable for the development of open spaces is the presence of a strong northwest-trending joint set (fig. 4) in the country rocks. The intersection of the veins with joints of this set plunges about 70° S. 80° W. This plunge approximates the rake of the shoots shown by the stope outlines on figures 7 and 8. Theoretically, the rocks should be intensely broken at the intersection of the two fractures. The favorable open space so created 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 sub-parallel fissures. These bodies are attributed to open spaces produced by the shattering of the rock between the fissures.

The principal ore shoot in the East Calhoun mine--between the sixth and tenth levels--is on the Quartz Mill vein. The stope outlines on the longitudinal projection (fig. 7) suggest that the ore body raked about 75°-80°, S. 70° W. It had a stope length of 100-300 feet, and a rake length of 450 feet. Miners at the property generally ascribe this shoot to the Calhoun and Quartz Mill vein intersection. It is difficult to conceive, however, how such a flat intersection could create a steeply raking open space. Sanderson (1909), in a private report on the Bezant mine, outlined an ore shoot in the Quartz Mill vein with the same general attitude as the shoot mined in the East Calhoun mine. As has previously been mentioned, this shoot lines up 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 over most of its explored length. It is thought that much of this stoping was done in the oxidized zone, and that the ore here was mechanically enriched in gold. Moore and Butler (1952) outlined a pitchblende shoot on the upper levels of the Wood mine. Pitchblende bodies found in the exploration done during the writer's study, line up rather well with the projected rake of this shoot (fig. 8). As has been previously mentioned, gold, silver, and other values also were found to be greatest in this area. Therefore, it is thought that the pitchblende shoot outlines a general ore shoot. It must be remembered that pitchblende occurs as relatively small pods, lenses, and kidneys scattered through the vein; therefore, the pitchblende shoot only outlines ground favorable for the occurrence of pitchblende bodies.

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 over widths as much as 5 feet. Mineral deposition occurred in two general stages--quartz-pyrite and galena-sphalerite.

Pitchblende, one of the first minerals emplaced, apparently was a local phase of the general quartz-pyrite stage of mineralization. Alsdorf (1916, p. 273) thought that the precious metal-sulfide veins were later than the pitchblende veins, and that (1916, p. 270) the pitchblende veins were cut across, followed, and obliterated by subsequent faulting and precious-metal vein filling. The pitchblende bodies observed in this study certainly show every indication of being deposited prior to the main precious metal-sulfide filling, but lie in the same vein, and even in the same ore shoot as the later minerals. Therefore, the writer believes that the pitchblende represents an early local variant of the quartz-pyrite stage of mineralization. It is difficult to reconcile the observed field and paragenetic relations with Leonard's (1952) hypogene zoning theory. Of course, such factors as telescoping can be applied to show that it is possible to have pitchblende 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 Phair's (1952) hypothesis 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 bring about reducing conditions. 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 (in preparation) classified the ore deposits of Quartz Hill as xenothermal, largely on an inferred temperature of formation. His temperature-of-formation references were based on the presence of exsolved chalcopyrite in sphalerite (chalcopyrite and sphalerite supposedly unmix at about 350^{o}-400^{o} C, Edwards, 1947) and on the UO_2-UO_3 ratio of the pitchblende (pitchblende with a relatively high UO_2 percentage presumably indicate 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 development of comb structure in places indicate that the conditions of formation were somewhat shallower than most mesothermal types.

AGE

Bastin and Hill (1917, p. 93) considered the ore deposits of the Central City district to be early Terriary 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, 1952, p. 707). These data confirm the early Tertiary age postulated by Bastin and Hill.

FUTURE OF THE MINES

The exploration carried on 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 rather well explored, it is thought that there is little chance for substantial new uranium production. The ore shoot outlined in this study 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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CONTENTS

RESERVES

Moore and Bulter (1952) on the basis of 5 channel and 3 chip samples, estimated 40 tons of indicated ore below the 135-level and 40 tons of inferred ore above the 135-level of the Wood mine. For both indicated and inferred ore they estimated an average width of 6 inches and an average grade of 0.27 percent U_3O_8.

Armstrong (in preparation) believes, and the writer concurs, that previous operators would not have left much high-grade ore in faces and backs, and that any sampling done in such workings would not give a true picture of the unmined vein material. A method of arriving at the average grade of material excavated from a mine is to divide the total production by the total material removed, and to extrapolate this grade to the unmined portions of favorable areas in the mine. Using this method, Armstrong inferred that the Wood vein contained 85,000 tons of 0.189 percent U_3O_8 over a mining width of 5 feet above the East Calhoun sixth-level crosscut. The crucial factor of this method of calculation was the assumption that pitchblende-rich areas were randomly distributed through the Wood vein. Unfortunately, exploration disproved the random distribution theory, at least for the lower portion of the Wood vein.

Approximately 600 feet of drifting west of the sixth level crosscut (the east drift is ignored in this treatment as it is not on the Wood vein) exposed an estimated 800 pounds of uranium. Using the same method of calculation as Armstrong used, 25,200 cubic feet of material, or 2,100 tons, was excavated in driving this drift. This rock had an average grade of something less than 0.0002 percent uranium. Using the same method and taking an average vein width of 6 inches, the vein matter removed had an average grade of about 0.003 percent uranium. About 115 tons of vein material were removed by raising, subleveling, and stoping in the favorable pitchblende area (vein width 6 inches, tonnage factor 12) to get 800 pounds of uranium. Therefore, this material had an average grade of 0.0034 percent uranium. Combining the tonnage removed to reach the favorable area, 170 tons, and the tonnage removed from the favorable area, 115 tons, it may be seen that 285 tons were moved to get 800 pounds (0.4 tons) of uranium. This material had an average grade of 0.0014 percent uranium.

Approximately 500 tons of vein material should be present in the favorable area between the sublevel off the 520-raise and the 275-level of the Wood mine. Using the average grade of material removed from the favorable area, 0.003; about 3,000 pounds of uranium could be recovered, if the above material was mined. Therefore, the writer assigns 3,000 pounds of inferred reserves to the Wood vein. Pitchblende bodies may, of course, occur more frequently at higher altitudes in the favorable area, but there is no assurance that they will. Gold and silver values also occur in this area, but a test stope did not pay expenses. The writer feels that the economics are such as to disallow any further work on the Wood vein.

RECOMMENDATIONS

The writer believes that economic considerations fail to justify any further exploration on the Wood vein. If, however, it is decided to carry on more work, it is suggested that it be concentrated in the shoot structure as outlined on figure 8. This structure can best be explored by a raise up its projected rake. The drift on the reported fifth level of the Wood mine might be encountered in this raising. It is not known if the Wood mine is completely drained; therefore, suitable precautions should be taken in raising.

Another place favorable for exploration is on the first level of the East Calhoun mine (fig. 6). The east face of the drift on the Wood vein should be advanced about 150 feet east. This drifting might cut the pitchblende shoot that was mined in the Ross shaft.

The writer thinks that any further exploration on Quartz Hill should be confined to the veins that have been little developed between the Wood and German veins. He can see no reason why any veins in the area should not contain pitchblende; therefore, those that have not been mined offer the most promise.

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