SPECTROGRAPHIC STUDY OF GOLD-QUARTZ ORES
FROM ALLEGHANY, CALIFORNIA

by

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INTRODUCTION

An investigation of the minor constituents in gold-quartz ores of the Sixteen-to-One mine, Alleghany, California, was undertaken with the hope that the distribution of the minor metals might be of some use in locating ore bodies. Before commencing such a study it was necessary to establish a practical technique for qualitative and quantitative spectrographic analysis of quartz ores.

The commercial gold ore of the Sixteen-to-One mine occurs as isolated, irregular masses of gold-bearing quartz in a large vein of barren quartz. No reliable structural or mineralogical control or indicator for ore-finding is known for this mine. There are several indicators which, when combined under favorable circumstances, may indicate ore, but they are not individually consistent, and may fail to indicate ore as often as not.

Previous work by H. J. Fraser (unpublished) on ore from the Mojave district, California, By H. D. B. Wilson (1941) on Goldfield, Nevada, ores, and R. M. Dreyer (1939) on cinnabar ores indicated that the minor metals in such deposits showed a zonal arrangement around some ore bodies. These examples are epithermal in type, whereas the Sixteen-to-

One is mesothermal and similar in many ways to Mother Lode gold-quartz veins. The extremely haphazard distribution of gold values made the Sixteen-to-One a desirable type of mesothermal deposit for investigation. Preliminary results obtained by Dehlinger indicated that the distribution of silver, bismuth, lead and tin appeared to show some correlation with that of gold. Accordingly, the present investigation was undertaken to obtain further information throughout the mine of the manner in which these four metals are distributed.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the enthusiastic and helpful support of Mr. C. A. Bennett, superintendent of the Sixteen-to-One mine, the generous financial aid given by this mine, and the assistance rendered by the mine staff, especially by Mr. W. V. van Doren, mine superintendent. Wilford Hart, mine engineer, supplied the assays used in this study. Rudolf von Huene contributed much time and patience to the design and construction of the electrodes used in the study. The instrument and equipment were supplied by the California Institute of Technology. Dr. M. F. Hasler and Mr. C. E. Harvey of the Applied Research Laboratories, Glendale, California, offered many helpful suggestions. The work was supervised by Prof. H. J. Fraser.

MINE DESCRIPTION

The Sixteen-to-One mine is located on the western slope of the northern Sierra Nevada, in the Alleghany gold district, Sierra County, California, about 15 miles northeast of the well-known Grass Valley-Nevada City gold district. The Alleghany district is largely underlain by ~~metamorphosed~~ Carboniferous (?) slates and schists which form the "bed-rock series". These rocks are overlain by Tertiary volcanics and sediments which constitute the "superjacent series". The ridges are capped by Tertiary rocks and the canyons are cut 2000 to 3000 feet into the "bed-rock series". There are several such canyons in the Alleghany district, and these expose ~~numerous~~ gold-quartz veins in the metamorphic rocks and cut through a number of the famous "auriferous gravel channels" in the lower Tertiary rocks.

The Sixteen-to-One vein occupies a thrust fault in the Tightner schist. The Tightner formation is composed of fine-grained amphibolite-chlorite-quartzose schists, believed by Ferguson (1932) to represent metamorphosed volcanics. The fault strikes approximately N 30° W, with local variations from 30° east of north to 50° west of north. The dip of the fault varies from 20° to 75° easterly, but in most parts is between 30° and 45°. The fault is considered by Ferguson (1932) to have a maximum displacement of 900 feet. The vein is cut by a number of steep reverse faults, striking parallel to the vein, and dipping westerly 60° to 90°. These faults displace the vein 5 to 10 feet in most cases, but one fault zone offsets the vein as much as 180 feet.

The Sixteen-to-One mine extends slightly more than a mile along strike and has been followed down the dip about 3000 feet without any pronounced change in character. There are several minor veins that join the Sixteen-to-One vein but these veins have been worked only to a small extent and have not contained appreciable amounts of gold. The main vein is predominantly barren quartz, containing at most only 3 or 4 percent sulphides, and generally less than one percent. Pyrite and arsenopyrite are the commonest sulphides; sphalerite, tetrahedrite, chalcopyrite, and galena often are present. Calcite, mariposite, ankerite, together with silicate and graphitic material representing engulfed or unreplaced fragments of wall rock, are present in considerable amounts in some parts of the vein.

The gold distribution is unusual and spectacular. It is localized in very concentrated irregular masses or bunches of gold or of high-grade arsenopyrite-gold ore. These small bodies vary in value from a few dollars to several hundred thousand dollars. The richest part of the mine has been between the 600 and 1000 levels in the area between the Sixteen-to-One and Tightner shafts. There is considerable gold ore in the upper levels in the north end of the mine, and large amounts of gold have been produced from the lower levels in the south end. The total production of the mine is over $15,000,000.

The mine is worked with four shafts or winzes, and some 24 levels have been developed, the deepest being the 3000 level. Plate 1 is a sketch map of the principal mine workings. The drifts form a rough contour map of the vein in this horizontal projection.

SAMPLING

The sampling program was designed to include specimens from widely separated parts of the mine. Each group of samples (or suite) was chosen to illustrate the variation, under different conditions, of minor metal constituents in the quartz. Some suites were collected to show this variation perpendicular to the dip and strike of the vein. Other suites were collected to show the variation along the dip and strike. It was hoped that such a study of the large and small scale distribution of these minor metal constitutents would show a definite correlation with the distribution of gold values.

Collection of Samples

Several hundred samples were carefully collected, described, and labeled. Different types of samples were collected, including channel samples for fire assaying, chip samples for spectrographic analyses, and hand specimens for megascopic or petrographic study. Actually, only a part of the material collected has been studied to date.

A limited number of channel samples were cut across the full width of the mineralized vein, in representative localities. The location of these samples is shown in Plates 2-7.

A large number of chip samples were cut. An effort was made to cut only pure vein quartz, but in many places appreciable amounts of dark silicate, graphitic material, and often some sulphides were unavoidably included. Where the vein was narrow the chip samples were divided into foot lengths. About a dozen chips, approximately half an inch in size, were collected from each foot interval. Each such group of chips was separately packaged and labeled. For wide parts of the vein 2-foot lengths were used in the same manner. The location of these samples are are shown in Plates 2-7.

Hand specimens were collected wherever chip samples or channel samples were cut. They were taken a foot apart across the narrow parts of the vein and two feet apart across wider parts of the vein.

Description of Samples by Suites.

Suite G was collected on the 1700 level from the chute of stope 1735 within a few feet of where gold was found near the footwall. The specimens, including channel samples, chip samples, and hand specimens, were collected at one foot intervals across the vein to show any variation in the minor metal content perpendicular to the vein (plates 1 and 2).

Suite H was collected from a barren stope, 1709, above the 1700 level, to show the variation perpendicular to the vein. Channel samples, chip samples, and hand specimens were cut at foot intervals across the vein at this locality (Plates 1 and 2).

Suite I was collected from stope 1545, above the 1500 level, within ten feet of where gold was found near the footwall. Channel samples, chip samples, and hand specimens were cut every foot across the vein, to show any variation perpendicular to the vein at this locality (plates 1 and 3).

Suite J was collected from the 1000 level, at the chute of stope 1021, where considerable gold was found near the hanging wall. Chip samples and hand specimens were cut every foot across the vein. (Plates 1 and 4).

Suite K was collected from stope 1333, just below the 1100 level, in an area where the vein was barren. Channel samples, chip samples, and hand specimens were cut every foot across the vein to show any variation perpendicular to the vein at this locality (Plates 1 and 5).

Suite L was collected along the 800 level, through the richest part of the mine, from the Sixteen-to-One shaft to the Tightner shaft. Channel samples were cut for the southern half of this suite, and chip samples and hand specimens were collected for all localities (plates 1 and 4). Suite L was taken to study the large scale variation through this rich area.

Suite M was collected on 1150 north drift, from the face where considerable gold had been found, southward for 100 feet from the face. The first specimens were taken within a few feet of where the gold had occurred. Chip samples and hand specimens were collected. This suite was taken to show the local variation within a few feet of the gold, and also to show the variation within 100 feet along the drift (Plates 1 and 6).

Suite N was collected in stope 1072, between the 800 and 1000 levels, within a few feet of where high-grade ore was found close to the hanging wall. Chip samples were collected for every foot interval between the hanging wall and the footwall. One channel sample was cut for the 2nd, 3rd, and 4th foot interval from the hanging wall, and another was cut covering the 13th and 14th feet.

Suite O was collected along the 1700 level, at approximate intervals of 100 feet. This drift showed mediocre values concentrated at isolated localities. Chip samples and hand specimens were cut at one-foot or two-foot intervals across the vein. The suite was collected for comparison between typical low-grade quartz and quartz that carried local gold values (Plates 1 and 2).

A large area around the very high-grade ore in stope 1557 was sampled for suite P. This area included the 1300, 1500, and 1700 levels, and the intervening stopes. Channel samples, chip samples, and hand specimens were cut in the drifts, and chip samples and hand specimens were collected from the stopes. This suite was taken to study the variation of the minor metal constitutents in the quartz on all sides of the 1557 ore body. The same area had been sampled by grab sampling in 1940 by the writer, and the samples analysed by Dehlinger. These analyses encouraged the present investigation, but it was considered desirable to check and amplify this earlier sampling. The chip samples and hand specimens for Suite P were collected at one-foot or two-foot intervals, and the channel samples extended the full width of the mineralized vein (plates 1 and 7).

Suite Q was collected along the 1500 level and through 1525 raise to the 1300 level. A very concentrated bunch of high-grade gold ore was found at the 1525 chute. Chip samples and hand specimens were collected at one-foot or two-foot intervals at localities shown in Plates 1 and 5 to show the variation in minor metals around this high-grade bunch. (See Plates 1 and 5.)

Sample Preparation

Chip samples are carefully washed in water and then prepared for spectrographic analysis. They must be crushed andsplit to a suitable size for binocular microscope examination after which they must be pulverized and cut down to a sise suitable for spectrographic work. Several grinding and splitting operations are necessery to reduce the samples to this condition.

Chip samples are first coarsely crushed in an iron mortar and pestle. An eighth to a quarter inch size was found to be the optimum size for feed for the pulverizer. This size prevents excessive wear of the pulverizer plates.

The coarse crushed sample is ground in the rotary pulverizer with the plates set as far apart as possible. The resulting product contains a minimum of fine material and a maximum grain size of from 2 to 4 millimeters. A product with this grain size is easily studied and, if necessary, cleaned, under a binocular microscope.

The sample is split with a Jones splitter to about 10 grams, which is examined under the binoculars for impurities, especially sulphides, in the quartz. A few trial runs showed that by cleaning the samples, the amount of minor metals in this ore is generally reduced below the sensitivity of the instrument and the method. Accordingly, no cleaning was done for subsequent samples.

The 10 gram sample was pulverized with the plates set close together. When ground to minus 80 mesh, there is a minimum of iron filings adhering to the fragments, or admixed with the powder. If pulverized too fine, it is very difficult to remove this admixed iron. The pulverized sample is split with a Jones micro-splitter to about one gram, from which the iron filings are removed with an electromagnet.

The sample is pulverized in an agate mortar to considerably finer degree than 200 mesh. If the specimen is to be analysed qualitatively, it is ready for the spectrograph. If it is to be run as a quantitive analysis, powdered carbon is thoroughly mixed with the pulverized sample in the agate mortar.

SPECTROGRAPHIC INVESTIGATION

Spectrographic analysis necessitates a highly specialized technique, careful and consistent analytical procedure, properly prepared samples and good equipment. There are many variable factors that must be controlled as rigidly as possible. For this reason the materials used must be constructed to exact specifications. The following paragraphs briefly describe the preparation of electrodes and other materials, and outline the actual technique for qualitative and quantitative analysis. Many of the designs used for electrodes, and the general procedure of analysis are modified from those developed by the Applied Research Laboratories, builders of the spectrograph used in this study.

Preparation of Electrodes

The electrodes used are quarter inch National Carbon Company graphite spectrographic carbons, purchased in one foot lengths. After the electrodes have been cut to exact size and shape, they are soaked from 24 to 36 hours in *aqua regia*, rinsed, then soaked for 48 hours in distilled water which is changed several times during that period. This treatment eliminates most, although not all of the common impurities present. Titanium, boron, some copper, aluminum, and traces of a few other elements still remain.

Electrodes for qualitative work.-

Upper electrodes are merely quarter inch carbons filed flat as shown in Fig. 1a. Lower electrodes are carefully machined to a shape shown in Figure 1a. The lower electrode has a small cup shaped depression that is designed to hold the bead of molten silica after the thin side walls have burned away. The outer surface of the eletrode follows closely the inner contours in order to reduce the total carbon of the electrode to a minimum. It is desirable to have the carbon thick enough to be pre-arced for thirty seconds before arcing sample, and to burn for at least two minutes, yet thin enough to concentrate maximum heat around the sample. The neck should be as thin as possible to prevent heat conduction to the lower part of the electrode, yet strong enough to withstand the arcing until the sample is burned to completion. Carbons cut to the specifications given above meet these requirements in a very satisfactory manner.

The electrodes used to produce an iron spectrum are made by using a quarter inch cold rolled steel rod for the lower, and a quarter inch carbon for the upper electrode.

Electrodes for quantitative work-

The upper electrodes are quarter inch carbons filed flat on the lower end, then drilled to receive a short eighth inch carbon, as shown in Figure 1b. They were designed in this manner to facilitate the flow of relatively cold gases away from the arc plasma. The self-absorption of the spectral lines is considerably reduced if the cold gases are allowed to flow away easily from the arc. Furthermore, upper electrodes designed in this manner tend to prevent the deposition of material on the electrode and thus help stabilize the upper part of the arc on the lower point of the eighth inch carbon stub. The stabilization of the arc is very important, for the largest errors in analyses are due to irregularities in the arc.

The lower electrodes are prepared on a precision lathe according to the pattern shown in Figure 1b. As in the qualitative electrodes, the carbon left in the eletrode is the minimum amount necessary to produce an electrode sufficiently strong to be pre-arced for five seconds, and then still hold together until a four milligram sample is arced to completion. The small amount of carbon will concentrate the heat around the sample and will tend to depress the carbon background of the film. The centerpost is designed to concentrate the arc on this point until the sample in the electrode cup is fused. The addition of powdered carbon to the sample causes a fairly even distribution of the sample over this platform after fusion.

The upper electrode used in producing the iron spectrum is similar to the ordinary quantitative upper electrode. The lower electrode is the high streaming velocity type developed by Hasler (1941). These electrodes are illustrated in Figure 1c.

Spectrographic Technique

The general spectrographic technique was modified from that used in the Applied Research Laboratories, and is similar to the method used by Wilson (1941) on the Goldfield ores. The powdered sample is burned by using the electrodes described above, under controlled width of slit and exposure conditions. The sample is mixed with powdered carbon when it is run for quantitative analysis. This carbon is prepared by evaporating and roasting a sucrose solution to caramel, then successively grinding and cooking it until it is completely reduced to carbon. The light emitted from the arc passes through the slit, and is diffracted from the grating to the camera. Eastman par speed 35 millimeter moving picture film is very satisfactory for recording the spectrum. The film is carefully developed, especially for quantitative work, and then is read on the projector comparator.

Qualitative technique-

The electrodes, both upper and lower, are pre-arced for 30 seconds at standard arcing conditions. Then enough sample to burn about two minutes is placed in the cup. The arcing conditions are as follows:

Sector diaphram position -------------------------- 1 and 3
Slit width --- 0.02 mm.
Rotating sector ------------------------------------ 25%
Amperage --- 10 amps
Time --- 2 mins approx.
Screen --- out
Lens --- in

The sample is arced for one minute in position 1 on the diaphram, then arced until completion in position 3. The amount of the sample should be adjusted so that it will take about one minute for the complete arcing; thus the two spectra produced will be of essentially equal intensity. The camera is not moved, but the spectra placed by changing the diaphram position. An iron spectrum is placed between these two spectra by moving the sector diaphram back to position 2, again without changing the camera. It is very important not to touch the camera, but to place the spectra entirely by means of the sector diaphram, so that there will be perfect aligment of the unknown spectra with the iron spectrum to permit exact measurement of the wavelengths of the unknown spectral lines. The arcing conditions for the iron spectrum are as follows:

Sector diaphram position -------------------------- 2
Slit width --- 0.02 mm.
Rotating sector ------------------------------------ 100%
Amperage --- 5 amps.
Time --- 15 sec.
Screen --- out
Lens --- in

When unknown samples are arced according to the qualitative method outlined above, spectral lines of the more volatile elements are found concentrated in the upper spectrum, and lines of the more refractory elements are more enhanced in the lower one. Three such samples can be placed on each film by successively placing the camera at positions 3, 6, and 9.

Quantitative technique- The electrodes used for quantitative analysis are pre-arced for 5 seconds at standard arcing conditions. Then the sample is mixed with powdered carbon, by careful grinding in an agate mortar. Eight milligrams of this mixture is weighed out, divided into two parts, and each part is placed on a lower electrode cup. The base of the eletrode is tapped lightly to help distribute the powder more evenly in the cup. A drop of absolute ethyl alcohol is placed on the sample and electrode, to spread the sample more evenly and to prepare the electrode and sample for sugar solution treatment. A drop of sugar solution (1/40 cc.) is added to cement the powder to the eltrode. When the sugar is dry, the electrode is ready for arcing. The conditions of arcing are as follows.

Sector diaphram position	2
Slit width	0.06 mm.
Rotating sector	8%
Amperage	10 amps.
Time	45-75 sec.
Screen	out
Lens	in

The large variation in time is due to the use of slight modifications in the shape of the lower electrodes. The electrodes cut to the dimensions in Figure 1b.should burn for 70-75 seconds with 4 milligrams of sample. Two arcings are made for each spectrum to cut down the errors caused by the wandering and uneven burning of the arc. Spectra of four samples, in duplicate, are placed on each film.

An iron spectrum for film calibration and film alignment was placed in the center of each film, as this was the position found to be most convenient. The iron spectrum was arced under the following conditions:

Sector diaphram position	2
Slit width	0.06 mm.
Rotating sector	5%
Amperage	10.6 amps.
Time	4 secs.
Screen	out
Lens	out

Film Development

The process of film development is a simple one, with the emphasis upon the consistency of the strength of solutions and time of development, to assure uniform results. The film is developed for about three minutes in half strength Eastman D 11 developer, washed from one half to one minute in short stop solution, and fixed for ten minutes in hypo solution. For quantitative work a careful check of developing solution temperature is kept, and the developing time is varied; a longer time is requåred for lower temperatures than for higher ones. The curve for time-temperature control given by Wilson (1941) was used in this investigation. Such precautions will keep the film density quite constant. With a constant temperature control it is possible to keep the density so uniform that the film need be calibrated but once for each day's work. Actually in this work, calibration was made for every film read quantitatively, so that such close control őf development was unnecessary.

Film reading

When dry the films are read in the projector comparator. For qualitative analysis, the sensitive lines are readily identified by means of the iron spectrum and the master plate. For semi-quantitative work the method and tables developed by the Applied Research Laboratories are used.

For quantitative analysis, the density of lines and background are read by the densitometer. In order to express these values in their true intensities relative to each other, it is necessary to treat them in the following manner. The film must be calibrated for variations in developing by plotting known intensity values of lines against their densitometer readings (called "transmission values"). The plot is made on log-log paper. True intensity readings of other lines may then be read from the resulting curve. The second step is to decide upon an internal standard, which may or may not be added to the sample, and to express all intensities as the ratio:

$$\frac{\text{intensity of element}}{\text{intensity of internal standard}}$$

This treatment will allow the intensity ratios of any film to be compared with those of any other film read in the same manner. The intensity ratios may be translated into percentage amounts by using working curves based on analyses of known samples.

It was found desirable to construct a celluloid form for the upper part of the calibration ("gamma") curve, in order to draw consistent curves quickly and accurately. The necessary computations to arrive at the intensity ratios have been described in detail by Wilson (1941). It was found that these could be done much more rapidly by means of a calculating board designed by Harvey of the Applied Research Laboratories.

Very little quantitative work was done in this study, as qualitative results seemed fully adequate in view of the very limited amounts of silver, lead, bismuth, and tin present in the samples.

SUMMARY OF RESULTS OF SPECTROGRAPHIC ANALYSES

More than 130 samples were analysed spectrographically, for the most part in duplicate. The analyses are shown in Tables 1 to 10 and the locations of the different samples in Plates 2 to 7. Assays of the channel samples are included with the spectrographic analyses.

Silver, bismuth, lead, or tin were detected in only 25 of the samples. Suites G, H, I, K, N, and Q showed none of these minor metals. Suites J and M showed a few traces of silver and tin. Specimen M11-14 of Suite M was within one foot of massive gold ore, but showed only a trace of silver and a little tin. Silver was found in two samples of Suite L; specimens L-1 to L-4 were in barren vein but beyond this point the vein picked up rapidly in values, and within 15 or 20 feet of L-10 and L-11 there was extremely rich high-grade ore. The richest part of the mine was in this area.

Suite P showed silver present in 19 out of 80 samples. The samples containing silver showed no definite zonal arrangement with respect to high-grade ore. In all the suites there was no correlation between the gold assay values and presence or amount of minor metals. In general, however, minor metals were detected only in the richer parts of the mine, so that there was a broad correlation of gold with minor metals.

The above analytical determinations are in striking contrast to those obtained in a preliminary examination during 1941 of specimens collected by the writer from the same locality as that of Suite P. These earlier analyses showed relatively substantial amounts of silver, bismuth, lead, and tin in this area of the mine, where as the samples used in this study

(Dontinued on page 27).

TABLE 1

Results of analyses of samples in Suite G.

Suite & sample No. *	Type of sample	Type of analysis	Analysis
G -1	c.s.	fire	Au .01 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
G - 2	c.s.	fire	Au .01 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
G - 3	c.s.	fire	Au .005 oz.
	chip	spec.	No Ag,Bi,Pb,Sn.
G - 4	c.s.	fire	Au .005 oz.
	chip	spec.	No Ag,Bi, Pb,Sn.
G - 5	c.s.	fire	Au .015 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.

* Samples are numbered from the hanging wall to the footwall of the vein, each number representing a one-foot length.

C.S. denotes channel sample.

TABLE 2

Results of analyses of samples in Suite H.

Suite and * sample no.	Type of * sample	Type of analysis	Analysis
H - 1	c.s. chip	fire spec.	Au .01 oz. No Ag,Bi,Pb,Sn.
H - 2	c.s. chip	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
H - 3	c.s. chip	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
H - 4	c.s. chip	fire spec.	Au .175 oz. No Ag,Bi,Pb,Sn.
H - 5	c.s. chip	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
H- 6	c.s. chip	fire spec.	Au .01 oz. No Ag,Bi,Pb,Sn.

* See Table I.

TABLE 3

Results of analyses of samples in Suite I.

Suite and * sample No.	Type of * sample	Type of analyses	Analysis
I - 1	c.s. chip	fire spec.	Au .01 oz. No Ag,Bi,Pb,Sn.
I - 2	c.s.	fire	Au .005 oz.
I - 3	c.s. c.s.	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
I - 4	c.s.	fire	Au .005 oz.
I - 5	c.s. chip	fire spec.	Au trace. No Ag,Bi,Pb,Sn.
I - 6	c.s.	fire	Au .005 oz.
I - 7	c.s. c.s.	fire spec.	Au .015 oz. No Ag,Bi,Pb,Sn.

* See Table I.

TABLE 4

Results of analyses of samples in Suite J

Suite and * sample No.	Type of sample	Type of analysis	Analysis
J - 1	chip	spec.	No Ag,Bi,Pb,Sn.
J - 3	chip	spec.	Ag trace? No Bi,Pb,Sn.
J - 6	chip	spec.	Ag trace? No Bi,Pb,Sn.

* See Table I.

TABLE 5

Results of analyses of Samples in Suite K

Suite and * sample No.	Type of * sample	Type of analysis	Analysis
K - 1	c.s. chip	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
K - 2	c.s.	fire	Au trace
K - 3	c.s.	fire	Au .005 oz.
K - 4	c.s.	fire	Au .005 oz.
K - 5	c.s. chip	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
K - 6	c.s. c.s.	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.
K - 7	c.s.	fire	Au .005 oz.
K - 8	c.s.	fire	Au .005 oz.
K - 9	c.s.	fire	Au..005 oz.
K - 10	c.s. chip	fire spec.	Au .005 oz. No Ag,Bi,Pb,Sn.

* See Table I.

TABLE 6

Results of analyses of samples in Suite L #.

Suite and * sample No.	Type of " sample	Type of analysis	Analysis
L - 1	c.s.	fire	Au trace
L - 2	c.s.	fire	Au .025 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn
L - 3	c.s.	fire	Au .005 oz.
L - 4	c.s.	fire	Au .015 oz.
	c.s.	spec.	Ag present, Pb Trace, No Bi, Sn.
L - 5	c.s.	fire	Au .005 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
L - 6	c.s.	fire	Au .005 oz.
L - 7	c.s.	fire	Au .03 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
L - 8	c.s.	fire	Au .005 oz.
L - 9	c.s.	fire	Au .01 oz.
L - 10	c.s.	fire	Au .005 oz.
L - 11	chip	spec.	Ag present, no Bi,Pb,Sn.

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* For location of samples see Plate 4.
\# Samples L - 12 to L-20 were not analysed.
" See Plate I.

TABLE 7

Results of analyses of samples in Suite M #.

Suite and * sample No.	Type of sample	Type of analysis	Analysis
M - 10	chip	spec.	Ag trace? Sn trace? no Bi,Pb.
All-14	chip	spec.	Ag trace? Sn present, no Bi,Pb.

* For location of samples, see Plate 6.

Eleven other samples in this suite were not analysed.

TABLE 8

Results of analyses of samples in Suite N.

Suite and sample No.	Type of " sample	Type of analysis	Analysis
N - 1 *	chip c.s.	spec. fire	No Ag,Bi,Pb,Sn. Au .01 oz.
N - 2 #	chip c.s.	spec fire	No Ag,Bi,Pb,Sn. Au .005 oz.

* Covers the 2nd, 3rd and 4th feet down from the Hanging wall.
# Covers the 13th and 14th feet down from the hanging wall.
" See Plate I.

TABLE 9

Results of analyses of samples of Suite P.

Suite and * sample No.	Type of * sample	Type of analysis	Analysis
P - 1	c.s.	fire	Au .03 oz.
	c.s.	spec.	Ag, Pb present, No Bi,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 2	c.s.	fire	Au .01 oz.
	c.s.	spec.	Ag, Pb present; no Bi,Sn.
	chip	spec.	No Ag,Bi,Pb; Sn trace.
P - 3	c.s.	fire	Au trace.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 4	c.s.	fire	Au .005 oz.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 5	c.s.	fire	Au .005 oz.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 6	c.s.	fire	Au .005 oz.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 7	c.s.	fire	Au .045 oz.
	c.s.	spec.	Ag,Pb present; no Bi, Sn.
	chip	spec.	Ag present; no Bi,Pb,Sn.
P - 8	c.s.	fire	Au trace.
	chip	spec.	Ag trace; no Bi,Pb,Sn.
P - 9	c.s.	fire	Au .01 oz.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 10	c.s.	fire	Au .005 oz.
	c.s.	spec.	Ag present; no Bi,Pb,Sn.
	chip	spec.	Ag trace; no Bi,Pb,Sn.
P - 11	c.s.	fire	Au .005 oz.
	c.s.	spec.	Ag, Bi present: no Pb,Sn.
	chip	spec.	No Ag, Bi,Pb,Sn.
P - 12	c.s.	fire	Au .025 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 13	c.s.	fire	Au .015 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 14	c.s.	fire	Au .005 oz.
	c.s.	spec.	No. Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.

TABLE 9 (cont'd)

Suite and * sample No.	Type of # sample	Type of analysis	Analysis
P - 15	c.s.	fire	Au .005 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 16	c.s.	fire	Au .01 oz.
	c.s.	spec.	No Ag,Bi,Pb,Sn.
	chip	spec.	Ag present; no Bi,Pb,Sn.
P - 17	chip	spec.	No Ag,Bi,Pb,Sn.
P - 18	c.s.	fire	Au .05 oz.
	c.s.	spec.	Ag,Pb present; no Bi,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 19	chip	spec.	No Ag,Bi,Pb,Sn.
P - 20	c.s.	fire	Au .01 oz.
	c.s.	spec.	Au,Pb, present; no Bi, .
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 21	c.s.	fire	Au .005 oz.
	c.s.	spec.	Pb trace; no Ag,Bi,Sn.
	chip	spec.	No Ag,Bi,Pb,Sn.
P - 22	c.s.	fire	Au .005 oz.
	chip	spec.	No Ag,Bi,Pb,Sn.

Samples P-23 to P-60 were all analysed by the spectrograph, but only those that showed positive results are tabulated below.

P - 25	chip	spec.	Ag trace; no Bi,Pb,Sn.
P - 28	chip	spec.	Ag trace; no Bi,Pb,Sn.
P - 31	chip	spec.	Ag trace; no Bi,Pb,Sn.
P - 37	chip	spec.	Ag. present; no Bi,Pb,Sn.
P - 41	chip	spec.	Ag present; no Bi,Pb,Sn.
P - 43	chip	spec.	Ag present; no Bi,Pb,Sn.
P - 49	chip	spec.	Ag present; no Bi,Pb,Sn.
P - 56	chip	spec.	Sn present; no Ag,Bi,Pb.
P - 59	chip	spec.	Ag present; no Bi,Pb,Sn.

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* For location of samples see Plate 7 .

\# See Table I.

TABLE 10

Results of analyses of samples in Suite Q.

Suite and * sample No.	Type of sample	Type of analysis	Analysis
Q - 1 #	chip	spec.	No Ag, Bi, Pb, Sn.

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* For location of sample see Plate

Samples Q-2 to Q-19 were not analysed.

from identical localities, also collected by the writer, show none of these elements, or at best an occasional trace. These widely divergent results prompted a rechecking of the samples used in the preliminary analyses. Five of the original 24 samples, chosen at random, were analysed by the writer. The check analyses give only one tenth the intensity for the minor element. Nevertheless silver was found in appreciable amounts in all five samples. Duplicate samples of the preliminary analyses sometimes showed wide variations, but the variation between samples from different localities was several times greater.

It seems apparent from the results of the recheck study that:

a. The preliminary samples may have contained more silver than the samples used in the present study,

b. There was some variation either in the method or in the sensitivity of the instrument such that identical samples showed only 1/10 as much silver.

c. The method of obtaining the sample for analysis from the original sample failed to overcome completely the highly erratic distribution of silver in the quartz ore. The present methods of sample preparation likewise do not overcome completely erratic distribution of silver in the quartz.

One possible cause of wide divergence of results between the preliminary and present studies is that the earlier samples contained more silver. Samples used in the preliminary study were grab samples and a relatively small amount of quartz was taken from each specimen and prepared for spectrographic samples. However, it seemed unlikely that these grab samples should be consistently high in minor metals, especially when every effort was made both underground and in the laboratory to select pure quartz. Samples were prepared for analysis in much the same manner then as now. At first the samples used in the present study were cleaned of all sulphide and other impurities under the binocular microscope. It was found that this treatment removed the minor metal constitutents in many but not all of the samples cleaned, below the sensitivity of the spectrograph. Accordingly, this treatment was abandoned. Both sets of samples were cleaned with the electromagnet, so that the effect of this process should be cancelled out. Trial analyses showed, moreover, that cleaning by the electromagnet had no effect on the minor metal content of the quartz. It is possible, but improbable, that the preliminary samples were accidentally "salted" from the equipment used in preparing them for the spectrograph. There does not appear to be any adequate geological explanation why samples collected at different times from identical localities in the same drifts and stopes should show any such variation in values.

Another possible cause for the wide divergence between the preliminary and present studies appears to be variation in the analytical method or in the sensitivity of the spectrograph. The latter suggestion may be ruled out as highly improbable, because of the physical basis of the grating spectrograph.

In general, the technique used in the present study was the same as that used in obtaining the preliminary analyses. The electrodes were improved; this should show more uniform results, not a decrease in sensitivity. The arc conditions were very similar, and in the course of the present work these were varied sufficiently to discover any significant difference between the two methods. The exposure conditions and film development were essentially the same, and no change in sensitivity could be found there.

The writer is unable to offer any adequate explanation of the great discrepancy between his analyses and those made during the preliminary investigation. Although he was unable to confirm the quantities of silver present in the preliminary analyses, still he found more in these samples than in practically any collected later.

CONCLUSIONS

Spectrographic analyses of Sixteen-to-One quartz ore appear at present to be valueless as applied to the problem here investigated. In the first place the minor metals are not present in sufficient amounts. Secondly these elements, when present, are too erratically distributed to assure consistent results, especially for quantitative measurements. Furthermore, the results of the present study are unsatisfactory because the precise reasons for the wide divergence between this and the preliminary study have not been discovered.

If the Sixteen-to-One vein does not contain appreciable amounts of minor metals, as this study indicates, in what way is it different from the veins in Goldfield and in Mojave? It was pointed out earlier that mineralization in the Alleghany district is mesothermal in type, whereas the Goldfield and Mojave districts are epithermal. This probably means that the Sixteen-to-One vein was formed in a relatively longer period of mineralization, under higher pressure and temperature conditions. Perhaps these more intense and longer-lasting conditions favor the formation of much purer quartz, whereas the "dumping" or "telescoping" precipitation in epithermal mineralization results in a greater variety of elements present in the quartz, or associated with it as microscopically fine sulphides.

In conclusion it may be said that this study has not demonstrated a practical method for the quantitative analyses for the minor elements in the Alleghany type of gold-quartz ores and that the method in its present state is of no value in ore-finding at the Sixteen-to-One mine. Further work on this problem may very possibly result in more consistent analyses, but the amounts of minor metals are still not sufficient to use the method in ore-finding.

These conclusions, however, apply only to this specific problem. The use of the spectrograph in mining problems is still in the experimental stage. The writer is of the opinion that further work will show many ways in which quantitative spectrographic analyses will be of great value in the field of mining. They may in large part replace chemical determinations in ore analysis and in control of mill products. Even today the spectrograph is extensively used as an analytical control during the refining of many metals.

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