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GEOCHEMICAL EXPLORATION FOR GOLD DEPOSITS AT GOLDFIELD, NEVADA

By

Roger P. Ashley and William J. Keith
U.S. Geological Survey, Menlo Park, California 94025

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U.S. Geological Survey, Menlo Park, Calif. 94025

ABSTRACT

The main problem in geochemical exploration for gold ore bodies in the 40 km^2 hydrothermally altered area at Goldfield is to decide which of the many silicified ledges exposed are most likely to yield deposits with additional subsurface exploration. We conclude that the most efficient way to search for exploration targets is to collect rock samples from the ledges and analyze for the following elements in decreasing order of priority: gold, lead and silver, bismuth, and mercury. These elements form relict hypogene aureoles restricted to the ledges and are not appreciably redistributed during supergene leaching.

INTRODUCTION

The Goldfield mining district is located 250 km northwest of Las Vegas, Nev. The deposits are epithermal bonanza precious-metal lodes in volcanic host rocks. Total production is 4.2 million troy ounces (130,000 kg) gold, and 1.5 million troy ounces (46,000 kg) silver. The district includes 40 km^2 of hydrothermally altered rocks, of which only a few square kilometers have been productive. Elevations in the altered area range from 1,650 to over 2,000 meters; the climate is semiarid, transitional to arid at the lower elevations.

This presentation summarizes results of an extensive geochemical exploration program carried out by the U.S. Geological Survey between 1966 and 1971. These results have been published in a series of reports between 1968 and 1976. A complete annotated list of these reports is included. One reference pertaining to previous geochemical work (Wilson, 1944), as well as one other article summarizing U.S. Geological Survey work (Ashley and Keith, in press) are included. Other references are given in a separate list.

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GEOLOGY

Tertiary volcanic rocks of intermediate composition dominate the geology of the district (Ransome, 1909; Ashley, 1974, 1975; Ashley and Silberman, 1976). Lower Paleozoic argillites and shales, intruded by Jurassic quartz monzonite, underlie the volcanics and crop out in a few small inliers. Silicic flows and tuffs of Oligocene age surround these inliers. Elsewhere in the district the premineralization volcanic rocks are trachyandesite, rhyodacite, quartz latite and rhyolite flows and tuffs of lower Miocene age. Postmineralization tuffs, basinal sedimentary rocks, and basalt flows occur at the periphery of the hydrothermally altered area, but probably cover only relatively small extensions of the altered area.

Structural geology of the Goldfield district has been described by Ashley (1974). Intrusive centers and vents for the premineralization volcanic units lie along an elliptical trend elongate east-west that may mark a ring fracture zone formed early in the history of the Goldfield volcanic center, possibly at the time of eruption of one or more of the Oligocene units. The Lower Miocene volcanics covered this zone, and were broken by a north-northeast-trending set of shingle faults and a major N. 80° W.-trending fracture zone tangential to the south side of the ring fracture. All three of these fault and fracture systems localized hydrothermal activity and together determine the shape of the altered area. Most of the known ore bodies were found along an arcuate fracture zone that follows the inferred ring fracture, beginning at the southwest side and continuing around the west side to the north side. The largest ore bodies were located in a 1.3-km^2 area at the intersection of all three fracture systems, but none of these systems are clearly prominent in localizing or controlling the shapes of individual ore bodies.

The ore occurs in ledges, which are silicified zones composed mainly of quartz, with varying amounts of alunite, kaolinite, diaspore, pyrophyllite, and pyrite. High-grade metallization consists of famatinite, tetrahedrite-tennantite, bismuthinite, tellurides, and native gold, which form breccia fillings in broken parts of the ledges. Low-grade metallization is disseminated through silicified rock around the high-grade areas. Some ore occurred also in advanced argillic rocks adjacent to the ledges. These rocks are soft, with quartz subordinate to alunite, and in addition contain kaolinite or pyrophyllite, or both, or in some parts of the area, K-mica. The silcified and advanced argillic zones are enclosed by less intensely altered rocks containing quartz, K-mica, kaolinite, and pyrite. This zone is generally of the phyllic-argillic type, but locally lacks kaolinite, or K-mica. Montmorillonite-bearing argillized rocks surround the phyllic-argillic rocks and separate them from propylitized or locally unaltered rocks. These argillized rocks contain some quartz, kaolinite, K-mica, and pyrite in addition to montmorillonite, and commonly contain some relict phenocrystic feldspar as well. The pyrite ubiquitous in these altered rocks is converted in the oxidized zone to hematite, goethite, and jarosite, so all material available for surface sampling is more or less limonitic. Oxidized ores contain native gold and locally silver halides or various oxidation products derived from tellurium minerals and bismuthinite. The altered area contains hundreds of silicified zones that have not yet yielded ore bodies; hydrothermal zonation and mineral assemblages are similar in both productive and nonproductive parts of the area.

ORIENTATION STUDY

We first collected rock samples from the walls of an opencut made along a stoped vein at the Combination mine, in the main productive part of the district, to provide data for an orientation study (see Ashley and Albers, 1975, for details). Results for 26 elements were examined in detail. Gold, tellurium, and zinc were determined by atomic absorption, arsenic and antimony by colorimetric methods, mercury by atomic absorption vapor detector, and all other elements by six-step semiquantitative spectrographic analysis. The orientation study showed that low-grade and subeconomic but anomalous metallization is restricted to the silicified zones, forming relict hypogene halos around the ore bodies. These halos do not, however, extend into surrounding argillized rocks in most places. The distribution patterns shown by Au, Ag, Pb, Bi, Hg, As, and Cu reveal these relict hypogene aureoles. Several elements associated with hypogene ores are leached and redistributed during supergene oxidation, including arsenic, copper, molybdenum, and zinc, in order of increasing mobility. Arsenic and copper still show relict hypogene aureoles reasonably well, but molybdenum shows only vestiges of hypogene patterns, and zinc is completely redistributed. All of these elements occur with limonite in fractures, but none form coherent supergene halos in either silicified or nearby argillized rocks. Correlation studies also revealed a Au-Ag-Pb-Bi-Hg-Cu hypogene element association and an As-Cu-Mo-Fe supergene association. Thus, the orientation study showed that the most efficient way to search for exploration targets in the altered area utilizing rock samples is to restrict collecting to the silicified ledges and analyze for gold. Because gold distribution is spotty, even in ore-grade rocks, it is worthwhile to obtain lead and silver analyses as well. Bismuth, mercury, arsenic, and copper are of decreasing importance for locating hypogene aureoles. Molybdenum is of little use and zinc of no use. Several other potentially useful indicator elements include Sb, Te, Se, Sn, and Tl. These elements were not fully evaluated because of difficulties in obtaining reliable analyses or lack of low-cost methods having the analytical sensitivity required.

GEOCHEMICAL CHARACTERIZATION AND EXPLORATION OF THE HYDROTHERMALLY ALTERED AREA

While awaiting analytical results for the orientation study, we collected 1,954 samples at the intersection points of a 500-foot (152-m) grid (see Ashley and Keith, 1973, for details). About 10 percent of the samples were alluvial gravel from dry washes; the remaining 90 percent were about half rock samples and half soil samples. About 80 percent of the soil-covered parts of the area are colluvial soils composed of angular fragments, mainly pebble and cobble size, of silicified rock from the ridge crests, in a fine-grained matrix of quartz and clays derived from argillized rocks exposed on the upper slopes. The remaining 20 percent of the soil-covered parts of the area are residual soils which represent montmorillonitic argillized rocks, usually with a surface pavement of colluvial unaltered or silicified rock fragments. Although about 45 percent of the samples collected were bedrock samples, only about 30-40 percent of the altered area is actually rock outcrops. This discrepancy exists because we collected soil samples from holes dug to depths of 35-50 cm, and at many localities we encountered and sampled bedrock at these depths.

The generally negative results of the grid sampling confirmed the conclusion of the orientation study that sampling is best restricted to the silicified ledges. Argillized rocks show few anomalous values, even in previously productive areas. Grid-sampling anomalies consist of at most a few contiguous samples and are in some cases difficult to interpret because of the variety of materials collected. Colluvial soil samples generally show minor element contents similar to those of nearby argillized rocks because the portion analyzed, constituting all material smaller than 80 mesh, is dominated by minerals from the argillized rocks. Many of the stream alluvium samples, none of which are anomalous, probably contain mainly minerals from disintegrated unaltered or propylitized rocks in the sizes smaller than 80 mesh. Although the grid sampling was unsuccessful as a geochemical exploration tool, the data for bedrock samples can be used for geochemical characterization of the altered area; that is, for determining background values in various stratigraphic units and alteration zones in the whole area or parts of it, and for showing overall changes in element concentrations with increasingly intense alteration (Ashley and Keith, 1973a). Colluvial soil and stream alluvium samples might provide useful information at Goldfield or in similar altered areas, but experimentation would be required to determine the best size fraction, density fraction, and analytical procedure.

As a result of delays in obtaining some analyses, the orientation and grid-sampling studies were completed concurrently. Subsequently, following the conclusions of the orientation study, we selected composite chip or grab samples from 1,014 sites at variable spacing on silicified ledges throughout the altered area (see Ashley and Keith, 1976, for details). Data for 323 grid sites on silicified ledges were combined with these results for a total of 1,337 localities on silicified ledges. The 323 grid sites, futhermore, were used to define threshold levels for Au, Ag, Pb, Bi, Hg, As, Cu, and Mo, because sampling is not biased by variations in the ledges observed in the field, and because sampling density is roughly proportional to abundance of silicified zones from place to place throughout the altered area. Log-probability plots for these elements (Lepeltier, 1969), however, do not show breaks except in the cases of mercury and copper. Mercury has an excess of high values above the 96 percentile whereas copper has a deficiency of high values above the 84 percentile. In the absence of breaks in the frequency distributions, threshold values were set arbitrarily at two standard deviations above the mean (97.5 percentile). This was also done for mercury and copper because the difference between the 96 and 97.5 percentile for mercury is small, and copper has no excess of high values. Correlation analysis of both the 323 samples and the entire 1,337-sample data set produced results largely similar but not identical to the orientation study; here Au-Ag-Pb-Bi-As-Cu form a hypogene element association and As-Cu-Mo-Fe again form a supergene association. Differences in some hypogene element correlations suggest in turn that paragenesis in smaller ore bodies and anomalous ledges away from the main productive area was similar but not identical to that in the large lodes (Ashley and Keith, 1976).

From results of the selective sampling, we defined three anomalous areas mainly on the basis of anomalous gold, silver, and lead, but including some anomalous bismuth, mercury, and arsenic values (Ashley and Keith, 1976). One area covers the western part and another the northern part of the arcuate belt on the west side of the altered area that includes most of the known ore bodies. Although anomalous values in these areas are scattered and the majority of samples are not anomalous, nonproductive ledges commonly show values similar to those from nearby productive ledges, suggesting that at least some may be worthwhile prospecting for new ore bodies. The third anomalous area is located about 6 km east of the town of Goldfield, extending from Preble Mountain eastward for about 3 km. This area has no past production; anomalous values within it are also scattered.

Mercury shows anomalous values in the eastern and northeastern parts of the altered area, largely unaccompanied by other elements. Copper appears to be rather evenly distributed throughout the district, owing to supergene leaching. Molybdenum is strongly associated with iron, but neither molybdenum nor iron is correlated with occurrence of anomalous gold.

In spite of the large amount of sampling we did in the Goldfield altered area, our sampling is generally not sufficiently dense to allow us to confidently pinpoint specific ledges, other than some previously productive ones, as worthy of exploration effort. This result is not surprising because we are seeking very small ore bodies within a large, potentially productive area. More detailed sampling of the ledges within the three anomalous areas might delineate some worth further exploration.

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