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Geochemistry of the altered area at Goldfield, Nevada, including anomalous and background values for gold and other metals

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INTRODUCTION

General

This report describes partial results of a geochemical sampling program carried out in the Goldfield mining district, Esmeralda and Nye Counties, Nev. Geochemical samples were collected from a 15-square-mile area at Goldfield which is underlain by hydrothermally altered volcanic rocks (fig. 1). This altered area contains the main productive district, which is located immediately northeast of the Goldfield townsite. It yielded almost all of the approximately $100,000,000 worth of gold, silver, and copper produced at this camp since 1903. Small areas located 2-4 miles north to northeast of the main district (fig. 1) account for production somewhere between $500,000 and $2,000,000. Two other small areas located about a mile to the east and southeast of the main district have total production probably less than $100,000. All of these areas with minor production are also within the Goldfield hydrothermally altered area.

Even though the area of hydrothermal alteration at Goldfield is much more extensive than the relatively few productive spots that have been discovered within it, the entire altered area has potential to yield new

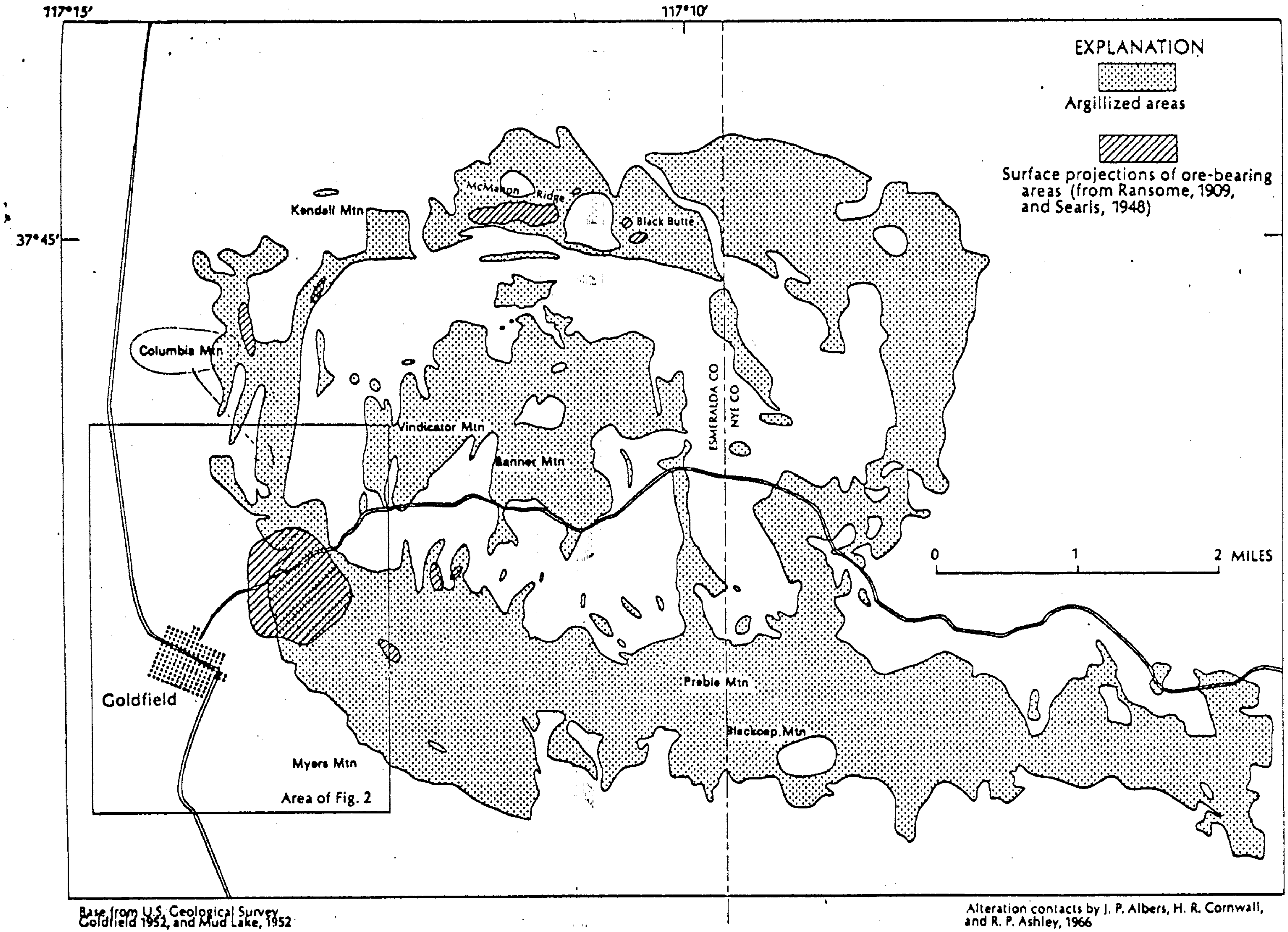

Figure 1.--Map of Goldfield, Nev., and vicinity, showing areas of hydrothermal alteration and ore deposits.

epithermal precious metal deposits. The known ore bodies were deposited during the later stages of hydrothermal alteration. Overall objectives of our geochemical studies at Goldfield are (1) to provide information useful for designing geochemical exploration programs in the altered area, and (2) to identify parts of the area that might be favorable for further exploration. This report attempts to fulfill the first of these two objectives; it builds on a previous geochemical orientation study (Ashley and Albers, 1969, 1972). The second objective will be the subject of a subsequent report.

Geologic setting

Goldfield is the site of an early Miocene volcanic center composed of trachyandesitic, rhyodacitic, quartz latitic, and rhyolitic flows and tuffs (Ransome, 1909; Albers and Cornwall, 1968). Underlying pre-Tertiary rocks consist of Ordovician Palmetto Formation siliceous shales, argillites, and limestones extensively intruded by Mesozoic quartz monzonite. Palmetto Formation and quartz monzonite appear at the surface only in a few inliers in the western part of the area. A preliminary detailed geologic map provides the geologic information used in this report (Ashley, 1971), and forms the base for plate 1. The stratigraphic units referred to in this report are those of plate 1. Of particular interest here are the prealteration (preore) units, because they host the ore bodies, and because the prealteration volcanic units record a series of volcanic events that set the stage for hydrothermal alteration and ore deposition. Postalteration (postore) units generally occur around the periphery of the altered area. They are of interest here only for determining the history of supergene alteration in the area.

This "plate 1" is apparently not in "UBhs" possession

The stratigraphic units we will deal with in this report include, from oldest to youngest, the quartz monzonite, Vindicator Rhyolite, Goldfield latite, Sandstorm Rhyolite, Milltown Andesite, Goldfield dacite, and landslide deposits (see explanation, pl. 1). The quartz monzonite has fairly constant and roughly equal proportions of quartz, sodic plagioclase, and orthoclase, and 1-15 percent biotite. Much of the rock is notably leucocratic, with only 1-5 percent biotite. The Vindicator Rhyolite consists of a rhyolitic welded tuff and a rhyolite flow, the Goldfield latite consists of quartz latitic tuffs and a flow, the Sandstorm Rhyolite consists of rhyolitic air-fall tuffs and one or more flows, and the Goldfield dacite consists of relatively homogeneous porphyritic rhyodacite and minor rhyodacitic tuff breccia. The Milltown Andesite, however, contains both trachyandesite and rhyodacite flows and tuffs in abundance, and minor amounts of quartz latite and basalt. Although some flows in the Milltown Andesite approach the Goldfield dacite in composition, the average composition is probably somewhat closer to trachyandesite (see Ransome, 1909, p. 50, 52, and 56 for analyses). The unit termed "landslide deposits" is a breccia, locally very coarse, composed of debris from the Milltown Andesite and from the Goldfield dacite. Milltown Andesite debris is the more abundant. Throughout the text, the foregoing rock units will be referred to as "quartz monzonite," "Vindicator Rhyolite," "latite," "Sandstorm Rhyolite," "Milltown Andesite," "dacite," and "andesite-dacite breccia." All these units except the last one were originally named by Ransome (1909), although he called the quartz monzonite "alaskite." The units with names capitalized have been given formation status in the Lexicon of Geologic Names of the United States (Keroher and others, 1966). The other names, whether new (Ashley, 1971) or from Ransome, are informal. Several other units, including one with formation status (Espina Breccia) appear in the map explanation included with prealteration, preore units. These units are not considered here because they yielded too few samples to make useful data subsets. We will not consider any of the postalteration units in detail. A discussion of postalteration geologic events follows, centering on the history of erosion and supergene alteration.

Various pieces of geologic evidence indicate that erosion reached hydrothermally altered rocks along the south side of the altered area, at levels above the present topographic surface, between 14 and 16 million years ago, 4-7 million years after the hydrothermal alteration and ore deposition took place (Silberman and Ashley, 1970). Silicic air-fall tuffs at least partly cover this old erosion surface. Erosion removed the tuffs and continued into the altered rocks, with perhaps one or two brief interruptions, until at least 10-12 million years ago, by which time the erosion surface had reached a position close to the present topographic surface. The 10- to 12-million-year-old erosion surface was covered by basalt flows of that age. The basalt had been removed, at least from the southeastern part of the area, when the Thirsty Canyon Tuff was deposited around the periphery of the Goldfield Hills 6-7 million years ago. Rocks at and near the present erosion surface in the southeastern part of the area have been exposed to oxidation three times: first between 10 and 16 million years ago, again between 6 and 10 million years ago, and again at the present time. The south-central and southwestern parts of the area have been exposed to oxidation at least twice: between 10 and 16 million years ago and at the present time. Over the central and western parts of the area, the erosion surface present 14-16 million years ago had reached altered rocks in some places, but was probably at least 1,000 feet above the present topographic surface except along the western edge of the area. Starting 14-16 million years ago and continuing until about 10 million years ago, silicic tuffs, tuffaceous sediments, and basalt flows accumulated over the central, western, and northern parts of the area. These materials were certainly partly removed during earlier periods of erosion, but were not stripped away until the present episode of erosion which began 6-7 million years ago. Altered rocks were locally eroded before 6-7 million years ago, but probably at levels substantially above the present topographic surface. Thus, the central and western parts of the area are presently undergoing oxidation and leaching for the first time. This may also be true along the northern edge of the area, but it is also possible that altered rocks exposed at McMahon Ridge and Black Butte were oxidized once before, prior to the deposition of tuffs and flows which began 14-16 million years ago.

We recognize three types of hydrothermally altered rocks, which form concentric zones around faults and fractures: silicified rocks form adjacent to the faults and fractures and are surrounded by illite-kaolinite-bearing argillized rocks, which in turn are surrounded by montmorillonite-bearing argillized rocks. Previous work by Harvey and Vitaliano (1964) and by one of us (Ashley and Albers, 1973) has provided the criteria for distinguishing these three alteration zones in the field. In addition, we obtained X-ray diffractograms and thin sections for 254 altered rock samples taken throughout the altered area, to confirm that alteration mineralogy does not change markedly from place to place, and to make sure that we have been consistent in assigning the altered rock samples collected for chemical analysis to one of the above three categories.

In the following description of the altered rocks, we use the term "illite" to refer to a group of clay minerals having $d_{(001)}$ approximately equal to 9.9Å that do not expand when treated with ethylene glycol. We do not distinguish between 1 M_d and 2 M_1 polymorphic forms, both of which occur in these rocks. The term "kaolinite" refers to any member of the kaolinite group except halloysite (kaolinite, nacrite, dickite). We have not attempted precise identification of kaolinite-group minerals. The term "montmorillonite" refers to a group of expandable clay minerals having $d_{(001)}$ approximately equal to 14.7 to 15.5Å (samples air dried).

Low-grade altered rocks form the bulk of material found within the hydrothermally altered area. These rocks are soft and bleached, though more or less stained by limonite or jarosite as a result of oxidation. Low-grade hydrothermally altered rocks generally contain quartz, montmorillonite, kaolinite, and illite, with relict plagioclase representing various proportions of the original plagioclase. These rocks correspond to the montmorillonite subzone of the argillized zone defined by Harvey and Vitaliano (1964). They ~~commonly~~ are poorly exposed, forming residual soils except at the very edge of the altered area, where wisps of argillized material extend along fractures into otherwise massive and well-exposed unaltered volcanic rocks. Supergene jarosite seems to be restricted to these low-grade argillized rocks and gives them a distinctive pale-yellow color at many localities. Veinlets of supergene gypsum also are characteristic.

As grade of alteration increases, the montmorillonite-bearing assemblage gives way to a quartz-illite-kaolinite assemblage accompanied by little or no relict mineral material. These rocks are generally moderately hard, are often moderately well exposed, and look bleached but are usually stained to pastel reds, purples, or yellow browns by limonite. These rocks form the illite-kaolinite subzone of the argillized zone defined by Harvey and Vitaliano (1964). Variations in alteration mineralogy occur particularly in the most intensely altered part of this subzone, where adularia and opal occur locally. In the discussion of results, where we use the term "argillized " rocks, we refer to both montmorillonite and illite-kaolinite subzones.

The highest grade altered rocks are the silicified zones, composed mainly of fine-grained (0.002-0.02 mm) light- to dark-gray quartz. These zones are generally tabular because they formed along prealteration fractures that conducted the hydrothermal solution(s). They form scattered craggy outcrops throughout the altered area. In addition to quartz, alunite and kaolinite commonly occur in these rocks, usually preferentially replacing former plagioclase of alkali feldspar phenocrysts or glassy fragments. Some rocks contain alunite or pyrophyllite, or both, with or without diaspore or kaolinite. We have seen relict unoxidized altered rock only within massive parts of some silicified zones; several centimeters of oxidized material must always be broken away from the surface of the outcrop to expose such material. The depth of thorough oxidation, however, is generally at least several tens of feet throughout the altered area, and oxidation extends along fractures to depths of at least 1,000 feet. Unoxidized material within a few feet of the surface is very scarce, and none of the samples collected for this study are unoxidized. In the oxidized altered rocks limonite replaces former pyrite, otherwise unoxidized and oxidized altered rocks have the same mineral assemblages, suggesting that hypogene mineral assemblages have not been notably affected by supergene alteration. Supergene veinlets of halloysite, kaolinite, alunite, and chalcedonic quartz occur locally; we avoided these in our sampling.

Hydrothermal alteration effects are grossly similar in all the pre-alteration stratigraphic units, but differences in original lithology do produce some variations in sizes, shapes, and mineralogy of the alteration zones. Alteration zones, for instance, tend to broaden and locally follow bedding where conduit fractures cut clastic rocks such as coarse tuffs or conglomerates. Alunite, although it may be present or absent regardless of lithology, is most abundant locally in rhyolitic rocks, which are the most potassium-rich rocks in the area.

Immediately outside the Goldfield altered area many of the rock units described above show various types of diagenetic or deuteric alteration that must have existed before hydrothermal activity began in what is now the altered area. The quartz monzonite locally shows mild propylitic or sericitic alteration. All the rhyolitic units are locally opalized. The latite flow underwent strong deuteric oxidation which converted the mafic minerals to hematite and magnetite. In the tuffs included with the latite, glass was converted to nontronite. Various flows in the Milltown Andesite have been propylitized; some contain calcite and others contain zeolites. These diagenetic and deuteric alterations are recognized by being restricted to certain flows or tuff beds. Diagenetically and deuterically altered rocks are included with unaltered rocks, and in fact make up a large porportion of the samples in some of the unaltered rock data subsets. In most cases such rocks probably have not undergone drastic chemical changes relative to the original truly fresh rock.

Sampling scheme and method of collecting samples

We collected a total of 1,954 geochemical samples from the Goldfield altered area at the intersection points of a grid with 500-foot spacing. This sampling was done between July and September 1966. We assumed that metal anomalies might appear in any of the hydrothermally altered rocks regardless of intensity of alteration. The grid-sampling program was intended as a reconnaissance; it showed scattered anomalous values, but the sample spacing in most cases was too large to provide much information about the size and nature of the anomalies that gave rise to these values. Meanwhile, we received chemical analyses for a suite of samples collected from the main productive part of district (reported on by Ashley and Albers, 1969, 1973). Results of the latter sampling indicated that only the most highly altered rocks, the silicified zones forming scattered rugged exposures throughout the altered area, are likely to produce anomalous gold, silver, and lead values associated with new deposits. It became clear then that the grid sampling was not the best sampling scheme