DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geochemical Prospecting for Carlin-Type Gold Deposits

by

S. P. Marsh

Open-File 76-335

1976

GEOCHEMICAL PROSPECTING FOR CARLIN-TYPE GOLD DEPOSITS

by S. P. Marsh

ABSTRACT

Disseminated, Carlin-type, gold deposits are associated with a volatile suite of elements consisting of Hg, As, Sb, W, and sometimes, but not always, Au. Geochemical exploration for this type of disseminated deposit depends upon recognizing the significance of this volatile suite and interpreting it in light of other geologic and geophysical data. One way of estimating the significance of the volatile suite is to determine enrichment factors. The enrichment factor is defined as abundance divided by crustal abundance or abundance divided by the local Clarke. Enrichment factors for the volatile suite in specific areas of the Edna Mountain quadrangle, Humboldt County, Nevada, interpreted with other geologic and geophysical factors, indicate that a potential for disseminated gold mineralization exists. Although most known disseminated gold deposits are exposed at the surface, the potential for finding additional buried or concealed deposits in north-central Nevada is high. Future geochemical exploration programs should be geared toward finding these buried or concealed deposits, which may be indicated at the surface by leakage halos of the volatile suite.

INTRODUCTION

Geochemical exploration for disseminated or "Carlin-type" gold deposits has been ongoing for almost a decade now, and most exploration geochemists recognize the existence of a suite of elements associated with this type of deposit. This suite is often called the volatile or Carlin suite and is characterized by the elements Hg, As, Sb, W, and sometimes, but not always, Au. Many authors, including Erickson, Radtke, Gott, White, Weisberg, and Roberts, have reported on the existence of this geochemical suite in association with the gold deposits of north-central Nevada. (See "Selected References.") Indeed, this volatile suite was used by Erickson in the discovery of the Cortez gold deposit.

Where we see it today, the association of this volatile suite with gold is often related to young volcanics; and, in some areas of the world, such as New Zealand, Japan, and Russia, gold is currently being deposited by thermal springs. This method of ore emplacement, related to volcanics and thermal-spring activity, has probably occurred throughout geologic time.

Exploration for this type of disseminated deposit is contingent upon finding and recognizing the volatile suite and interpreting the geochemical results in relation to geologic and geophysical data. To the present time, extensive exploration programs have resulted in the discovery of several disseminated gold deposits exposed at the surface. Future exploration programs must apply techniques and expertise toward finding the less obvious, concealed deposits.

GEOCHEMICAL EXPLORATION PROGRAM

Choosing a sample media is one of the first priorities in starting a geochemical exploration program. The two most commonly used media are stream sediments and rocks. The semi-arid basin-and-range environment of north-central Nevada is particularly suited to exploration using these media, and both have been used successfully. Standard -80 mesh stream sediments are most useful in delineating potential areas of interest within broad areas and have been used successfully in the Wilderness programs and in resource-appraisal programs. Once areas of interest have been defined, rock samples can be used for detailed studies of specific areas. In the Edna Mountain project, Humboldt County, Nevada, rocks were chosen as the sample media because the area was well prospected and areas of interest had already been defined. The rock sampling program had two main goals: (1) establishing a trace-element fingerprint or signature of the units in the area for determining a local Clarke value and (2) determining mineralized or potentially mineralized blocks of ground. These data, combined with detailed geologic mapping and geophysical information, lead to a definition of target areas for potential ore deposits. Rock samples of mineralized, apparently mineralized, and altered material can indicate plumbing systems by which mineralizing solutions travel, and type of mineralization involved, and, as in the case for disseminated gold exploration, the elemental suite. Recently, both stream-sediment and rock sampling have been used successfully in delineating a potential target area in northern Nevada. In this area the volatile suite of Hg, As, Sb, W, and some Au has been found as leakage halos through young volcanic rocks in a structurally favorable area.

ANALYSES

In any geochemical program it is important to obtain as much information as possible from the samples. Standard 30-element spectrographic analyses give a broad base of geochemical information and give excellent sensitivity for most elements. In addition to spectrographic information, chemical analyses for specific elements are often desired. In the case of the volatile suite, spectrographic sensitivities are high, generally 100 to 200 ppm, and chemical analyses are often desired. Mercury must be analyzed by instrumentation. This represents a considerable investment in analyses, but this expense is more than offset when compared to the cost of collecting the samples and the increased interpretative capabilities.

GEOCHEMICAL INTERPRETATION

Gold deposits in north-central Nevada generally fall into three main types: (1) disseminated, which are characterized by the volatile suite, are generally impoverished in the base-metal suite (Cu, Pg, Zn, and Ag), and have very high gold-silver ratios; (2) vein type, characterized by the base-metal suite; and (3) replacement, characterized by the base-metal suite and low gold-silver ratios.

In geochemical exploration for the disseminated-type gold deposits, recognition and interpretation of the volatile suite are sometimes difficult. Some elements of the volatile suite may be present but may not be indicative of disseminated gold mineralization. One method of evaluating the significance of the values obtained for the volatile elements is to determine the enrichment factor for each element. Basically, the enrichment factor is the abundance (ppm) divided by crustal abundance (ppm) or, when sufficient data are available, abundance (ppm) divided by the local Clarke (ppm). In the course of the Edna Mountain project, several areas showing an enrichment of the volatile suite were discovered. In the Ordovician block on the east side of Edna Mountain, enrichment factors were calculated using all the samples collected in the project for background. The samples in the Ordovician block were further divided into mineralized versus nonmineralized data sets. A sample was considered mineralized if it showed any mineralization, if it was gossan or had abundant iron staining, or if it exhibited fractures with fracture fillings. Enrichment factors of from 3.5 to 7.1 for the volatile suite were obtained from the Ordovician block samples, and, when only the mineralized samples were used, enrichment factors of from 4.3 to 13.3 were obtained. Tunsten, although it was present, was not used because most of the reported values were from the mineralized Ordovician-block samples. Tungsten was not detected in the rest of the Edna Mountain samples, with the exception of samples from the Golconda tungsten mine (another area high in the volatile suite). Generally speaking, the base-metal suite is absent in the disseminated-type gold deposits, with the exception of possible local highs.

As with most exploration programs, complications can arise and a situation in which several types of mineralization and elemental suites overlap often occurs. In the Ordovician block, it was discovered that several suites of metals invaded the same block of structurally prepared ground and geochemically overprinted each other. The volatile suite was present but masked by a base-metal suite and a vanadium deposit.

Through detailed mapping, chemical analyses, geophysics, and isotopic studies, a complete picture of the Ordovician block began to emerge. The mineral suites appeared to be related to three periods of mineralization. In the first period of mineralization, a stratabound vanadium deposit associated with an elemental suite containing Be, Cr, Ni, Hg, and W was formed. Next came a period of base-metal mineralization in which a suite containing Cu, Mo, and Bi and satellite deposits of Pb and Zn were formed. A third episode of mineralization, probably late Tertiary, is characterized by the volatile suite associated with the Carlin-type gold deposits and was probably emplaced by thermal-spring activity. This type of overprinting of geochemical suites is not uncommon, and only complete chemical and geologic data can unravel the complex nature of some areas.

Zoning patterns of the volatile suite around a disseminated gold deposit may be vertical or horizontal. Mercury tends to be restricted to the central part of the anomaly, while arsenic and antimony are peripheral. This is in direct contrast to base-metal anomalies, where mercury is in the outer zone, farthest from the center of the anomaly.

ENVIRONMENTS FOR DISSEMINATED GOLD DEPOSITS

The ideal environment for emplacement of disseminated gold may be considered in three parts: (1) structure, (2) host rocks, and (3) heat source. Favorable structure may consist of blocks of prepared ground that have been thrust, faulted, or fractured or that may be favorable contact zones. In the Edna Mountain quadrangle, the Ordovician block has been structurally prepared by having been thrust into its present position (possibly on the Roberts Mountain thrust) and then normal-faulted and intruded during several periods of igneous activity.

Most of the known occurrences of disseminated gold deposits are in favorable host rocks, usually carbonaceous limestones and laminated limey siltstones. These may be exposed as windows in thrust faults, may be vertically faulted into position, or may be buried beneath less favorable cover. The Ordovician block in the Edna Mountain quadrangle does not consist of exceptionally favorable host rock, being mostly Vinini cherts and quartzites. However, anomalous metal values from these somewhat poor host rocks give rise to speculation that more favorable ground may be underneath.

Heat sources seem to be requisite for emplacement of disseminated gold deposits. Most areas of interest show signs of thermal activity, and many currently active thermal springs are anomalous in the volatile suite. Although the Ordovician block has no active thermal springs, evidence of past thermal activity is abundant. The volatile suite is also present in other areas of the Edna Mountain quadrangle where current thermal-spring activity exists.

In considering potential target areas for disseminated gold deposits, attention is immediately drawn toward the north-central region of Nevada. The area is one of structural complexity; the many periods of thrusting and faulting have resulted in may areas of structurally favorable ground. Favorable host rocks are exposed in many areas and others may be found under less favorable cover. Thermal activity is common and large areas of young volcanics provide potential heat sources.

Future exploration programs should be geared toward the discovery of concealed deposits. Fortunately, the elements in the suite associated with the disseminated gold deposits have high mobility in vapor phases. Providing a proper sample media, either the vapor phase itself or a natural trap for the elements of interest at ~~the surface~~, these deposits should be detectable through great thickness of cover. The potential for a major breakthrough from research now in progress is great.

SELECTED REFERENCES

Erickson, R. L., Marranzino, A P., Oda, Uteana, and Janes, W. W., 1964, Geochemical exploration near the Getchell Mine, Humboldt County, Nevada: U.S. Geol. Survey Bull. 1198-A, 26 p.

Erickson, R. L., Van Sickle, G. H., Nakagawa, H. M., McCarthy, J. H., Jr., and Leong, K. W., 1966, Gold geochemical anomaly in the Cortez district, Nevada: U.S. Geol. Survey Circ. 534, 2 p.

Gott, G. B., and Zablocki, C. J., 1968, Geochemical and geophysical anomalies in the western part of the Sheep Creek Range, Lander County, Nevada: U.S. Geol. Survey Circ. 595, 17 p.

Radtke, A. S., and Scheiner, B. J., 1970, Carlin Gold Deposit, Nevada--The role of carbonaceous materials in gold deposition <u>in</u> Studies of hydrothermal gold deposition (I): Econ. Geology, v. 65, no. 2, p. 87-102.

Roberts, R. J., Radtke, A. S., and Coats, R. R., 1971, Gold-bearing deposits in north-central Nevada and southwestern Idaho: Econ. Geology, v. 66, p. 14-33.

Stewart, J. H., and McKee, E. H., 1968, Favorable areas for prospecting adjacent to the Roberts Mountains thrust in southern Lander County, Nevada: U.S. Geol. Survey Circ. 563, 13 p.