STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine the mineral values, if any, that may be present. Results of the surveys must be made available to the President and the Congress. This report discusses the results of a geochemical survey of the Sangre de Cristo Wilderness Study Area, Rio Grande and San Isabel National Forests, Fremont, Saguache, Custer, Huerfano, Alamosa, and Costilla Counties, south-central Colorado. The area was designated as a wilderness study area under Public Law 94-560 in 1980.

ABSTRACT

A trace-element geochemical study of the Sangre de Cristo Wilderness Study Area (SCWSA) is based on analyses of 710 heavy-mineral-concentrate samples, 767 minus-80 mesh stream-sediment samples, and 145 rock samples. All samples were analyzed for 31 elements by semiquantitative emission-spectrographic methods, and some stream-sediment and rock samples were also analyzed for selected elements by wet chemical methods.

Several significant geochemical anomalies, including Cu, Pb, Zn, Cd, and As in stream-sediment samples or Cu, Pb, Ba, Mo, W, Sn, Au, Bi, and Zn in heavy-mineral-concentrate samples, outline areas of: (a) quartz-veining and (or) metallization associated with fractured rock throughout much of the study area; (b) porphyry-type mineralization in the Elk Creek area, parts of the Alvarado fault system, and areas in the vicinity of Blanca Peak; (b) porphyry-type mineralization in the vicinity of Cottonwood Peak; (c) redbed-type uranium-copper mineralization associated with upper Paleozoic clastic sedimentary rocks; and (d) possible stratabound metal deposits in Precambrian gneiss in the northern part of the study area.

INTRODUCTION

This package of geochemical maps and interpretations comprises the geochemical contribution to the mineral resource evaluation of the Sangre de Cristo Wilderness Study Area (SCWSA), Colorado (fig. 1). Other parts of the evaluation include a mineral resource potential report by Johnson and others (1986a), a geologic map by Johnson and others (1986b), and a study of known prospects and mines by Ellis and others (1985).

The geochemical investigation consisted of a pilot study, used to determine the most effective sample media for the region, and a follow-up survey. The pilot study of the entire study area, followed by a regional-scale stream drainage sampling program and a rock sampling program at selected mines and prospects. The total number of samples which were collected include 710 heavy-mineral-concentrate samples, 767 minus-80 mesh stream-sediment samples, and 145 rock samples. All samples were analyzed for 31 elements by semiquantitative emission-spectrographic methods, and some rock and stream-sediment samples were also analyzed for selected elements by wet chemical methods.

GEOLOGY

The two most common rock types in the study area are Precambrian crystalline and upper Paleozoic clastic sedimentary rocks. Other rock types which occur in less voluminous amounts include lower Paleozoic sedimentary rocks, including carbonates; Jurassic sedimentary rocks; and Tertiary plutonic, volcanic, and sedimentary rocks. Two major episodes of deformation affected the area. These include a period of compressional tectonics during Laramide time, which produced a series of thrust sheets, and a younger (Oligocene to Recent) period of extensional tectonics, which produced the presently exposed horst-and-graben structure of the Sangre de Cristo Mountains and the San Luis and Wet Mountain valleys.

Recent mapping by members of the U.S. Geological Survey resulted in a regional-scale (1:62,500) map of clusters of dikes, 1984b) from which much of the geologic information presented below was taken. Other geologic studies from within the study area include structural and stratigraphic studies of the Crestone area by Scott (1960), a study of the Goldman (1952) and Linney (1958) and a petrographic and petrologic study of the Rito Alto stock by Toulmin (1955).

PRECAMBRIAN ROCKS

Precambrian metamorphic rocks are divided into two groups on the geologic map, corresponding to rocks whose original volcanic texture is still identifiable (Xvs) and gneisses whose original texture is not identifiable (Xgn). The metamorphic rocks are confined to the northern part of the study area whereas the gneisses occur in the northern, central, and southeastern parts of the area.

There are three dominant ages of Precambrian intrusive rocks in the study area (R. R. Taylor, personal communication). The oldest intrusive rocks are of the same approximate age as the gneiss prezolith and occur in the northern part of the area as granodiorite and diorite, and in the upper part of Sand Creek as granodiorite.

Intrusive rocks of the next younger age group include biotite granite and metadiorite in the southern part of the study area and a granodioritic mass exposed along Rito Alto Creek in the central part of the study area. A body of quartz monzonite east of Crestone is the youngest Precambrian intrusive rock in the study area, apparently belonging to the 1.43-b.y.-age group.

PALEOZOIC SEDIMENTARY ROCKS

Lower Paleozoic sedimentary rocks, totaling less than 400 feet in thickness, occur in scattered places in the northern part of the study area (Gallagher, 1985). These rocks include the Lower Cambrian Sawatch Quartzite, Ordovician Harding Sandstone, and Upper Ordovician Fremont Dolomite, the Manitou(?) to Upper Devonian Chaffee Group; and the Lower Mississippian Leadville Limestone.

Upper Paleozoic sedimentary rocks in the study area are composed of Upper Paleozoic units, including the Fountain and Pennsylvanian Sangre de Cristo, Middle Pennsylvanian Minturn, and Middle and Lower Pennsylvanian Belden Formations. These rocks are composed principally of arkose, sandstone, or shale and total some 12,000 feet in thickness (Johnson and others, 1986a). Parts of the Sangre de Cristo Formation, which is the youngest unit in the study area, are believed to be derived from a large, unroaded Cambrian(?) alkaline intrusive complex located somewhere west or southwest of the study area (R. R. Taylor, personal communication).

Younger sedimentary rocks do not comprise a significant proportion of the study area, but do crop out along the boundaries and outside the area.

TERTIARY IGNEOUS ROCKS

Tertiary plutonic rocks comprise two small stocks of Tertiary age, the Rito Alto and Slide Rock Mountain stocks, which occur in the north-central part of the area. Both stocks are near-surface features, and several andesitic to rhyolitic dikes in the area are apparently related to these or similar unexposed stocks (Toulmin, 1955).

STRUCTURAL SETTING

The major structural features of the study area are Laramide thrusts and late Oligocene to Holocene normal faults (Hartig, 1983; Koch, 1983; Linney, 1958; Bolting, 1970; Scott and Taylor, 1974). The Laramide faulting produced a series of northeast-trending structures with mostly west-dipping surfaces.

The Oligocene to Holocene time produced the present day Sangre de Cristo Mountains and the San Luis and Wet Mountain valleys. The Sangre de Cristo Mountains in the study area are bounded by two large normal faults, the Sangre de Cristo fault along much of the west side of the range and the Crestone fault in the Crestone area on the east side of the range, related to the present period of extensional tectonics. Faulting is still active in the San Luis valley (Scott, 1979) but may have ceased in the Wet Mountain valley.

METALLIC MINERAL DEPOSITS

WITHIN THE STUDY AREA

Few reports have been published regarding metallic mineral deposits within the study area. Sagg (1968) described copper deposits in sandstone near Rito Alto Peak. Goldman (1952) defined a mineral belt in south-central Colorado which includes the Precambrian rocks in the study area. Deposits in the study area, and Tooladi (1953) described molybdenum mineralization associated with the Rito Alto stock.

Metallic mineral deposits which have been studied in recent years in the study area include: (a) redbed-type copper from redbed-type occurrences, molybdenum from the Rito Alto stock, and copper and gold from vein deposits. There are no mines with significant mineral production within the study area (Johnson and others, 1986a).

OUTSIDE THE STUDY AREA

Metallic mineral deposits which occur adjacent to or within a few miles of the study area include iron from the replacement of lower Paleozoic sedimentary rocks at the Orient mine (Stone, 1934; Bolting, 1970), Precambrian stratabound Cu-Pb-Zn-Au-Ag deposits such as those that occur near Zeilsha, Colorado, tungsten-bearing veins such as those in the Ute Pass area, and Tertiary base-metal vein systems related to Tertiary igneous activity such as at Silvercliffe, Colorado. Other deposit types which occur in nearby areas include similar to those found in the study area include porphyry-metal deposits and Pb-Zn-Ag replacement deposits of lower Paleozoic sedimentary rocks.

GEOCHEMISTRY

Samples collected for trace-element analysis involved two studies, a pilot study and a regional-scale study. The pilot study, conducted during May and June 1982, 30 minus-80 mesh (0.180 mm) stream sediment, heavy-mineral-concentrate, and rocks. The sampling, preparation, analytical methods, and data for the pilot study samples are discussed in Zimbelman and others (1983). After selection of optimum sample media in the pilot study a regional-scale trace-element geochemical survey was performed during July 1982.

Composite stream-sediment samples were collected within or adjacent to the study area at sites that are usually also the location of stream-sediment samples. The heavy-mineral-concentrate samples were panned in the field, shortened to approximately 25 pounds (11 kg) concentrate. The slightly magnetic material was removed by a magnet and the nonmagnetic material was reserved by a sieve. The nonmagnetic material was removed by allowing the heavier fraction to settle through bromoform (specific gravity 2.82). The heavy-mineral fraction was then separated into a magnetic and nonmagnetic fraction by the Frantz Isodynamic Separator at a setting of 0.4 ampere, with 15° forward and 15° side settings. The nonmagnetic fraction was pulverized in an agate mortar before analysis. The heavy-mineral-concentrate samples were analyzed for 31 elements by the same spectrographic methods described above.

Rock samples were collected from within or adjacent to the study area. Most rock samples were taken from the most unusual rock types not characteristic of the most voluminous rock in any particular area such as dikes, veins, or visibly stained rocks. Rock samples were taken from unweathered outcrops wherever possible, ground to minus-200 mesh with a vertical pulverizer, and analyzed for 31 elements using the six-step semiquantitative spectrographic method described above.

The data and the sampling, preparation, and analytical methods for each of these media are discussed in Adrian and others (1986).

DETERMINATION OF THRESHOLD AND ANOMALOUS LEVELS

Throughout this report the term anomalous is used to refer to samples which contain a greater abundance of an element than its threshold value. The threshold value for each element was defined after visual inspection of the frequency distributions (which are included with the element discussions presented below) and after the geochemical discussion presented below interprets many of the trace-element anomalies in terms of two metallic mineral deposit types that have either not been recognized in the study area (Precambrian stratabound deposits) or are poorly understood at this time (metallization along fractured rock). A brief introduction to these occurrence types is provided below.

Precambrian stratabound deposits

Precambrian rocks in the mountain province of Colorado, northern New Mexico, and southern Wyoming have long been known to contain anomalous concentrations of copper, lead, zinc, silver, gold, and tungsten (e.g., Tweto, 1960; Tweto, 1968; Gilbert, 1968; Sheridan and Raymond, 1977; Sheridan, Raymond, 1980; Drobeck, 1979; Heinrich, 1981; and Sheridan and Raymond, 1984). Many of these anomalous metal occurrences are found associated with calc-silicate rocks, less frequently, amphibolite lenses or pods within gneiss of the 1.7-to.7 -age group (Tweto, 1960; Sheridan and Raymond, 1977). The stratabound deposits are distributed regionally, and include deposits of widely varying size, grade, and type, and those of limited economic importance. However, it is believed that this type of deposit may be important in terms of explaining trace-element anomaly patterns such as those described in this paper.

The scientific study and understanding of Precambrian stratabound deposits in this area is relatively limited because most of the deposits are small, low grade, and often very small and of limited economic importance. The deposits are usually discontinuous and thus hard to study, and the deposits are often inconspicuous and thus hard to recognize. Studies of these deposits that have included trace-element data include Tweto (1960), who found anomalous amounts of V, Mn, Co, Zn, Mo, Pb, Y, Yb, and Cu and Sn from stratabound deposits in Colorado and northern Wyoming and Sheridan and others (1981), who reported anomalous amounts of Zn, Cu, Ag, and Pb with less frequent but anomalous amounts of Au, Ag, Mo, and Sn from stratabound occurrences in the Dumbleton region, Colorado.

In summary, Precambrian stratabound deposits occur in rocks of the mountain province of Colorado, northern and parts of Wyoming and New Mexico. The study area includes rocks of similar lithologic composition, age, and metamorphic grade as those hosting this type of deposit in surrounding areas. However, this type of deposit has not been identified in the study area, possibly because of the inconspicuous nature of this deposit type and its ore minerals.

Metallization along fractured rock

Found throughout the study area are geochemical anomalies associated with fractured rock. These anomalies are commonly found in quartz veins and in hydrothermally altered, fractured rock. The zones of fractured rock contain significant geochemical anomalies that are hard to explain geologically. Tweto and others (1978) attribute similar features in the Gore Range, Colorado, to "metallization along fractures." Tweto and others (1978) also quantities from quartz-vein deposits."

Much of the central part of the study area contains stream-sediment anomalies which could be the result of sedimentary rocks. The geochemical anomalies in rock and stream-sediment samples from the Gore Range, Colorado, included the elements copper, lead, zinc, gold, silver, molybdenum, arsenic, antimony, and tungsten, and tin (Tweto and others, 1978). Another example of anomalous trace-element abundances in fractured rock, with no other apparent mineralizing features present, is a study of the Pegasus Mountains, Nevada (Erickson and others, 1965). These rocks contain anomalously high values of zinc, lead, mercury, and silver in oxidized iron-rich fracture filling and small geosan pods.

ARRANGEMENT OF THE GEOCHEMICAL DISCUSSIONS

Throughout this report, the discussions of the trace-element geochemistry of the study area in the introductory paragraph explains all of the interpreted geologic controls and their locations for any particular element followed by a more detailed definition and discussion of clusters of anomalous samples for each particular element. The clusters of anomalous samples are outlined in figures 2 through 4 for stream-sediment samples and in figures 7 through 12 for heavy-mineral-concentrate samples.

STREAM-SEDIMENT GEOCHEMISTRY

In general, the trace-element stream-sediment data are best interpreted in terms of background lithogeochemistry most applicable to petrogenetic, structural, or geologic mapping investigations (R. B. Taylor, personal communication) and lower Paleozoic sedimentary rocks, including carbonates. The anomalous zinc could be related to either the stratabound metal occurrences, quartz-veining and (or) redbed-type mineralization along fractured rock, or possible replacement deposits in the lower Paleozoic sedimentary rocks.

Anomalous zinc is commonly found in stream sediments and is commonly found in stream sediments and is commonly found in stream sediments and