Geochemical Reconnaissance of the Cortez-Buckhorn Area, Southern Cortez Mountains, Nevada

By JOHN D. WELLS and JAMES E. ELLIOTT

CONTRIBUTIONS TO ECONOMIC GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1312-P

Geochemical data show the distribution of gold, silver, mercury, arsenic, antimony, copper, zinc, molybdenum, and tellurium in carbonate and siliceous sedimentary rocks and granitic and basaltic igneous rocks

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1971

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catalog-card No. 79–609840

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 2040

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By John D. Wells and James E. Elliott

ABSTRACT

The Cortez-Buckhorn area, in the southern Cortez Mountains, contains rocks of various ages and lithologies in a complex structural setting. The area occupies part of the Cortez window, where predominantly carbonate sedimentary rocks are exposed in the lower plate of the Roberts Mountains thrust fault. Upper plate siliceous sedimentary rocks surround the window. The sedimentary strata have been intruded or covered by igneous rocks during four igneous episodes. These rocks range in composition from basaltic andesite to rhyolite. Major igneous masses are the Mill Canyon stock and flows of basaltic andesite. Many high-angle faults are present. Alluvial, lacustrine, and colluvial deposits occur along streams and in intermontane basins.

Total ore production from the Cortez district is estimated at about $14 million. Silver contributed the main dollar value, but significant amounts of gold, copper, lead, and zinc have been produced. The Buckhorn district has produced about $1.1 million in gold and silver ore. Gold ore reserves of the recently developed Cortez mine, located west of the map area, are 3.4 million tons containing 0.29 ounce per ton valued at $34,510,000 (at $35 per oz).

Geochemical maps show the distribution of gold, silver, mercury, arsenic, antimony, copper, zinc, molybdenum, and tellurium determined from analyses of nearly 1,000 samples collected from about 45 square miles.

Arsenic, mercury, and antimony anomalies are closely associated with gold and silver anomalies. The other metals are important as indicators of mineralized zones, although they cannot be used as guides to gold and silver concentrations as reliably as arsenic, mercury, and antimony. Most of the geochemical anomalies occur in or along fracture zones. The stronger anomalies are in carbonate rocks near granitic igneous bodies and in the igneous bodies; some weak anomalies are in the siliceous rocks. The Roberts Mountains thrust fault in this region localized only a few geochemical anomalies, and most of these are in lower Mill Canyon.

Evaluation of a geochemical anomaly to establish an exploration target depends on sound interpretation of the characteristics of the anomaly as well as its geologic setting.

INTRODUCTION

The area discussed in this report is in north-central Nevada, in the southern Cortez Mountains, Lander and Eureka Counties (fig. 1), and is one having diverse mineral deposits and complex geology in the vicinity of the Cortez window in the Roberts Mountains thrust. Nearly 1,000 samples were collected from an area of about 45 square miles, mostly between Cortez on the west and the Buckhorn mine on the east. The old Cortez silver mine is about three-fourths mile northeast of Cortez, and the new Cortez gold mine lies just outside the west boundary of the map area about 4 miles north of Cortez. The purpose of this study was to determine the distribution of trace amounts of selected metals within the area and to relate their distribution to each other, to known mineralized areas, and to the geologic environment. It is hoped that the information and the interpretations presented in this report will provide a basis for future exploration in the area.

The geochemical investigation of the Cortez-Buckhorn area was conducted as part of the Heavy Metals program of the U.S. Geological Survey. Fieldwork was done in 1966 and 1967 with assistance from Robert D. Lupe and Robert P. Moragne.

PREVIOUS GEOCHEMICAL AND GEOLOGIC WORK

Geochemical research related to mineral exploration has been conducted in the Cortez vicinity since 1959 by members of the U.S. Geological Survey. Results have been published of studies of the upper plate rocks west of Cortez (Erickson, Masursky, and others, 1961); the lower plate rocks northwest of Cortez (Erickson, Masursky, and others, 1964; Erickson, Van Sickle, and others, 1966); hydrogeochemistry in Fourmile Canyon (Erickson and Marranzino, 1961); and the rocks in Mill Canyon (Elliott and Wells, 1968). The geology of the southern Cortez Mountains is described by Gilluly and Masursky (1965) in their report on the Cortez quadrangle. The Horse Creek quadrangle, which lies east of the Cortez quadrangle, has been partly mapped by Masursky but the geologic data are not published. Plate 1 shows a generalized map of the Cortez-Buckhorn area based on these maps, with minor modifications resulting from recent detailed mapping by the authors.

ACKNOWLEDGMENTS

The authors acknowledge the assistance, in chemical and spectrographic analytical work, of G. H. Van Sickle, D. J. Grimes, T. G. Ging, E. L. Mosier, H. G. Neiman, V. D. James, H. D. King, A. J. Toevs, T. A. Roemer, S. K. McDonal, E. E. Martinez, S. I. Hoffmann,

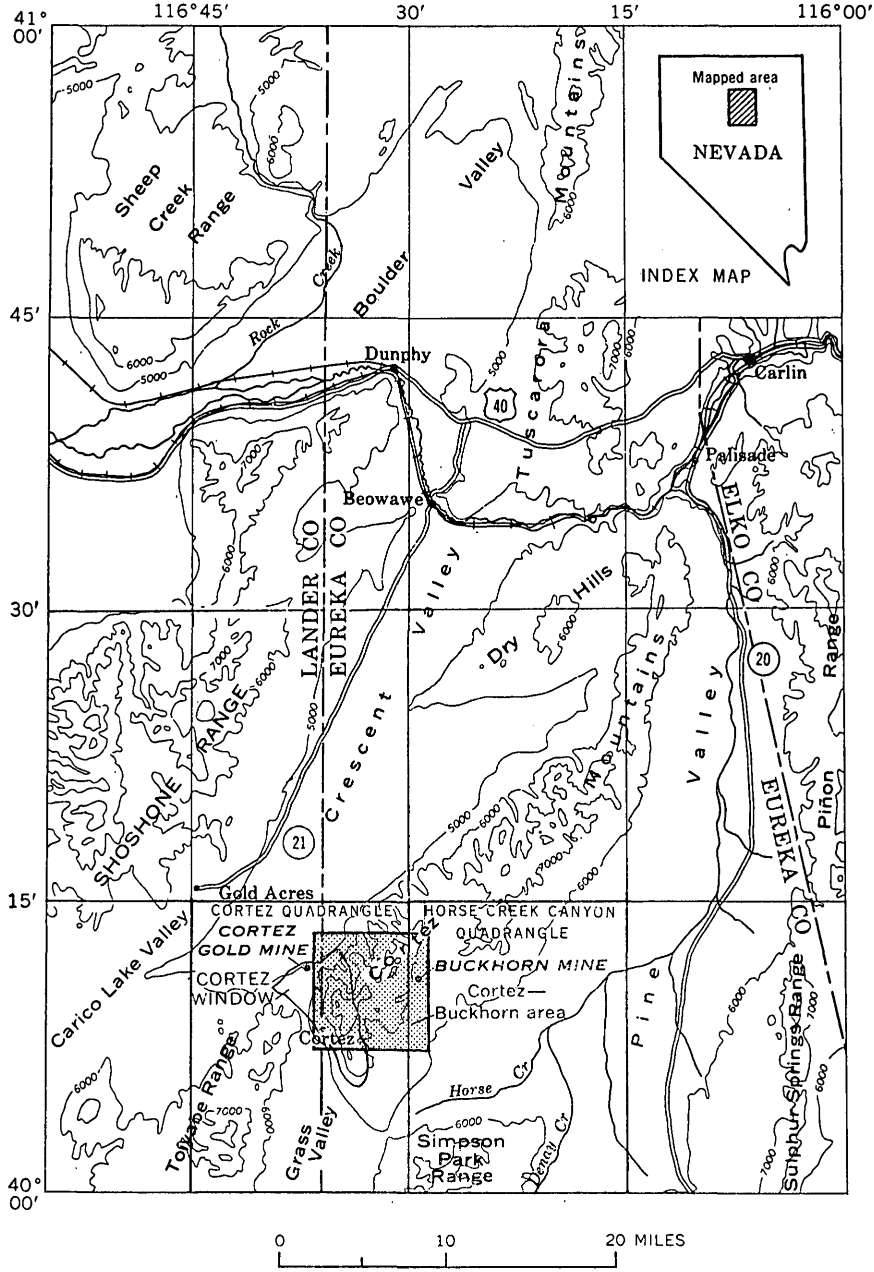

Figure 1.—Map showing location of the Cortez-Buckhorn area, Nevada.

R. L. Marshall, J. M. Matooka, R. L. Turner, C. W. Gale, W. R. Vaughn, R. L. Miller, S. L. Noble, K. C. Watts, and G. W. Dounay, all of the Geological Survey. Also, the authors thank the many mine and claim owners for permitting access to their lands and for generally facilitating the work.

GENERAL GEOLOGY

The Cortez-Buckhorn area contains Paleozoic sedimentary rocks, intrusive and extrusive rocks emplaced at four times during the Mesozoic and Tertiary, Tertiary gravel, and Quaternary alluvial, colluvial, terrace, pediment, and landslide deposits (pl. 1). The Paleozoic sedimentary rocks consist of two distinctive sequences of equivalent age that are separated by the Roberts Mountains regional overthrust.

The dominantly carbonate sequence in the lower plate consists of the Hamburg Dolomite of Cambrian age, the Eureka Quartzite and Hanson Creek Formation (limestone and dolomite) of Ordovician age, the Roberts Mountains Limestone of Silurian age, and the Wenban Limestone of Devonian age.

The siliceous sequence in the upper plate consists of several formations, only two of which are exposed in the Cortez-Buckhorn area. These are the Vinini Formation of Ordovician age and the Fourmile Canyon Formation of Silurian age; both formations are made up of chert, sandstone, shale, and small amounts of carbonate.

The Mill Canyon stock of Jurassic age was intruded during the first of the four periods of igneous activity. The stock, a composite body consisting of quartz monzonite, granodiorite, and alaskite porphyry, occupies a central position in the Cortez window and extends eastward across the Roberts Mountains thrust fault. The Oligocene(?) Caetano Tuff (not exposed in the Cortez-Buckhorn area) and Oligocene quartz porphyry dikes represent the second period. Only a few of the quartz porphyry dikes crop out in the area (pl. 1).

In the eastern part of the area, upper Tertiary extrusive basaltic andesite that represents the third igneous episode overlies Tertiary gravels and forms a cuesta that dips gently to the southeast. At least eight flows with an aggregate thickness of 350 feet were extruded in a structural depression; the number of flows and the thickness diminish toward the margins of the depression. Northwest-trending dolerite dikes east of Fourmile Canyon are generally believed to be feeders to the flows of basaltic andesite. Near Horse Canyon and

Willow Creek the basaltic andesite is intruded and overlain by rhyolite porphyry, which is the youngest igneous rock in the area.

Tertiary gravels are present west of, and beneath, the andesitic basalt; their maximum thickness is about 750 feet, judged from exposures in the northeastern part of the region (pl. 1). The gravel is unconsolidated, except in exposures near the Buckhorn mine where the gravel is cemented with silica. Bedded chert is present in this unit near the Buckhorn mine.

Quaternary deposits consist of alluvium deposited along streams and on pediments and of colluvium and landslide deposits on mountainsides.

The principal structural feature in the area are the Roberts Mountains thrust fault and high-angle faults with large displacements that bound the mountain ranges. The upper plate siliceous rocks are generally believed to have been displaced eastward from their original site of deposition along the Roberts Mountains thrust (Merriam and Anderson, 1942; Roberts and others, 1958) so that they now lie in fault contact above the lower plate carbonate rocks. The Crescent fault with about 10,000 feet of vertical displacement forms the northwest side of the Cortez Mountains, and the Cortez fault with 3,000 feet of vertical displacement marks the southwestern limit of the range. Faults with displacements of generally less than a few hundred feet are common elsewhere in the area. In the eastern part of the mapped area (pl. 1) faults trend about N. 10° W., cut the basaltic andesite, and in the vicinity of the Buckhorn mine are mineralized.

ORE DEPOSITS

The Cortez mining district at the southern end of the Coretz Mountains has produced about $14 million in ore since the discovery of the Cortez silver mine in 1863 (Gilluly and Masursky, 1965). Values have been primarily from silver, but significant amounts of gold, copper, lead, and zinc have been produced. Most of this production has been from the Cortez silver mine and the mines in Mill Canyon (pl. 1). The Buckhorn district has produced about $1.1 million worth of gold and silver ore (Roberts and others, 1967). According to Wells, Stoiser, and Elliott (1969), the recently developed Cortez gold mine (0.4 mile west of the area shown on pl. 1) has a reserve of 3.4 million tons averaging 0.29 ounce per ton valued at $34,510,000 (at $35 per oz).

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CURRENT GEOCHEMICAL WORK

The four major distinctive lithologic units—carbonate sedimentary rocks, cherty siliceous sedimentary rocks, granitic igneous rocks of the Mill Canyon stock, and the sequence of basaltic andesite flows—described above and shown on plate 1, form the framework for the geological and geochemical comparisons made in this report.

Nearly 1,000 rock samples were collected from these units in an area of about 45 square miles. Most samples were taken from outcrops, but some came from mine dumps, open pits, float, and underground workings. The material selected appeared to be mineralized—that is, the rocks showed bleaching, oxidation, brecciation, or other evidence of possible hydrothermal activity. Identifiable ore minerals, such as pyrite, galena, and chalcopyrite, were present in some of the samples. However, many samples that showed only slight or questionable evidence of hydrothermal activity were collected. Samples of fresh rock believed by the authors to be unmineralized were collected so that a background metal content could be determined. At some localities, materials of a variety of mineralogic and lithologic types were sampled to establish a range of metal values, but only the highest values obtained from each locality are shown on the distribution maps (pls. 1–3).

The samples were analyzed for 31 elements by spectrographic, atomic absorption, mercury detector, and wet chemical methods. Nine elements (gold, silver, mercury, arsenic, antimony, copper, zinc, molybdenum, tellurium) were selected to show distribution patterns. The reasons for selecting the elements are (1) gold and silver are of primary interest in the Heavy Metals program; (2) arsenic, mercury, and antimony constitute a suite of metals that is recognized as a guide in exploration for gold deposits of the Carlin, Nev., type (Erickson, Marranzino, and others, 1964; Erickson, Van Sickle, and others, 1966); (3) copper and zinc commonly constitute ore in the region; and (4) tellurium and molybdenum are associated with precious- and base-metal deposits, and their distribution may assist in detecting a likely exploration target. Other elements that might have been included because they are associated with ore deposits elsewhere, such as tungsten, lead, and cadmium, were mostly below detection limits or showed no geologically significant variation.

A summary of the analytical data (table 1) shows the range of values and median values of the geochemical samples. For all nine elements the minimum value corresponds to the lower limit of sensitivity for that element. For five of the nine elements the maximum value is not resolved by the analytical method and corresponds to the upper limit of sensitivity. For truncated sets of data such as these, in which some samples show values greater than or less than the detection limit of the analytical method, the median value seems to be the best measure of central tendency ("average").

GEOCHEMICAL ANOMALIES

Geochemical anomalies are generally defined as unusually high and meaningful concentrations of designated elements in surface materials. Recognition of anomalies requires a knowledge of the usual (background) and the unusual (anomalous) amounts of the elements. A general background may be obtained from published values for the average crustal abundance of elements in given rock types such as those compiled by Krauskopf (1967, p. 639). These figures are not sufficiently discriminating nor specific to allow comparisons within small areas such as that covered by this report. To determine background values for rocks in the Cortez-Buckhorn area, samples were taken in 1966 and 1967 from all geologic units at locations distant from known mineralized rocks. Table 2 summarizes the analytical results from these samples, as well as 97 samples collected in 1960—51 samples of upper plate rocks collected by R. L. Erickson, Harold Masursky, and A. P. Marranzino and analyzed by E. F. Cooley, and 46 samples of lower plate rocks collected by R. L. Erickson and Harold Masursky and analyzed by Uteana Oda. No determinations for gold and mercury are available for the samples collected in 1960. No data are available for tellurium. Values of the maximum, minimum, median, and 90 percentile (90 percent of the values are equal to or less than the value) are given for each of the elements in table 2. Values equal to or greater than the 90 percentile values for the unmineralized rocks are considered to be anomalous because the maximum values may be erratic and represent some mineralization. In situations where the values for the 90 percentile fall below the limit of sensitivity of the analytical method, the limit of sensitivity is given as the lower limit for anomalous values (table 3). The lower limit for anomalous tellurium values has been estimated from all the data from the area.

TABLE 1.—*Range of values and median values for selected metals, in parts per million, of geochemical samples collected from the Cortez-Buckhorn area*

Element	Minimum	Maximum	Median	Number of samples
Au	<0.1	160	<0.1	911
Ag	<.5	5,000	.5	911
Hg	<.01	>10	.5	715
As	<200	>10,000	<200	911
Sb	<100	>10,000	<100	911
Cu	<2	>5,000	30	911
Zn	<200	>10,000	<200	911
Mo	<2	1,000	5	911
Te	<.1	62	.1	817

GEOCHEMICAL MAPS

Maps have been prepared for nine elements showing distribution of samples and amount of metal found at each site. Data for gold, silver, mercury, arsenic, antimony, copper, zinc, molybdenum, and tellurium are shown on plates 1–3.

These maps reveal that areas showing anomalies in several elements are coincident and that few areas show anomalies in all elements. In order to describe these variations in a geographic and geologic context, the map area has been divided into the following 11 tracts based on the major lithologic units described previously:

- Lower plate carbonate facies:
  - I, Lower Mill Canyon
  - II, Upper Mill Canyon
  - III, Mount Tenabo
  - IV, South ridge
- Upper plate siliceous facies:
  - V, Lower Fourmile Canyon
  - VI, Upper Fourmile Canyon
  - VII, Willow Creek area
  - VIII, Horse Canyon
- Granitic igneous rocks:
  - IX, Mill Canyon stock
- Basaltic andesite:
  - X, Buckhorn
  - XI, Southwest basaltic andesite

The upper Tertiary rhyolite shows no evidence of mineralization and is not included in any of the tracts.

The magnitude or strength of the anomalies for each element in each of the tracts has been evaluated empirically as strong, moderate,

TABLE 2.—*Range of values, median values, and ninety percentile values for selected metals, in parts per million, in samples of various unmineralized rocks collected to determine background in the Cortez-Buckhorn area*

Element	Minimum	Maximum	Median	Ninety percentile	No. of samples
Lower plate carbonate—facies rocks					
Au	<0.02	0.1	<0.02	0.03	35
Ag	<.5	3	<.5	<.5	78
Hg	<.05	.7	.04	.2	34
As	<200	200	<200	<200	81
Sb	<50	300	<50	<100	81
Cu	<2	70	3	20	81
Zn	<100	700	<100	<200	81
Mo	<2	20	<2	<2	81
Upper plate siliceous—facies rocks					
Au	<0.02	0.06	<0.02	<0.1	20
Ag	<.5	5	<1	1.5	71
Hg	<.01	.95	.15	.7	19
As	<200	<1,000	<200	<200	71
Sb	<50	200	<200	<200	71
Cu	3	300	70	100	71
Zn	<200	1,000	<200	300	71
Mo	<2	50	<10	15	71
Granitic igneous rocks					
Au	<0.02	0.43	<0.02	0.04	30
Ag	<.5	50	<.5	.5	29
Hg	<.01	.9	0.12	.45	30
As	<200	500	<200	<500	30
Sb	<100	150	<100	<100	29
Cu	<5	100	10	70	29
Zn	<200	300	<200	<200	29
Mo	<2	3	<2	2	30
Basaltic andesite					
Au	<0.02	<0.1	<0.02	<0.02	7
Ag	<.5	.7	<.5	.7	7
Hg	<.05	.4	.1	.4	7
As	<500	<500	<500	<500	7
Sb	<100	<100	<100	<100	7
Cu	5	70	30	70	7
Zn	<200	<200	<200	<200	7
Mo	<2	2	<2	2	7

or weak, based upon the judgment of the authors. However, the evaluations take into consideration the different levels of background given in table 3, the number of anomalous sample localities, and the values indicated by the symbols at each locality. The results of this evaluation are given in table 4.

TABLE 3.—*Lowest values, in parts per million, considered to represent anomalous concentrations of metals*

Element	Carbonate facies (lower plate)	Siliceous facies (upper plate)	Granitic igneous rocks	Basaltic andesite
Au	0.1	0.1	0.1	0.1
Ag	.5	1.5	.5	.7
Hg	.2	.7	.5	.4
As	200	200	200	200
Sb	100	100	100	100
Cu	20	100	70	70
Zn	200	300	200	200
Mo	2	15	2	2
Te	.1	.1	.1	.1

Tract I, Lower Mill Canyon.—The rocks in the lower Mill Canyon tract (pl. 1) consist of the Wenban Limestone of the lower plate and undifferentiated Paleozoic rocks in the Roberts Mountains thrust zone. The area is adjacent to the Mill Canyon stock and contains mines that have produced gold, silver, lead, zinc, and copper (Elliott and Wells, 1968; Emmons, 1910). The ore deposits consist of quartzose veins and replacement bodies in the limestone and occur along a zone of mineralization that extends southeastward across the Mill Canyon stock (tract IX) into upper Mill Canyon (tract II).

The geochemical maps show strongly anomalous concentrations of all nine metals (table 4), except mercury which is only moderately anomalous. Localities with high values are concentrated along veins and in the lower part of the Roberts Mountains thrust zone. Most of the elements, particularly zinc, antimony, arsenic, and mercury, are present in generally lesser amounts along the thrust zone than in the veins.

Tract II, Upper Mill Canyon.—This tract is similar to lower Mill Canyon (tract I), excluding the thrust zone, in that the rocks are virtually the same units and are bounded in part by the Mill Canyon stock. Their eastern boundary is the Roberts Mountains thrust (pl. 1). Gold and minor amounts of other metals have been produced from tract II.

The two areas are similar geochemically; all selected metals except tellurium occur in strongly anomalous concentrations in tract II (table 4). The localities with the highest values are along veins in the fault that trends northwestward.

Tract III, Mount Tenabo.—The Mount Tenabo tract contains all the lower plate formational units that crop out in the region. The tract is bounded on the east by the Roberts Mountains thrust, on the west by the Cortez fault, and on the north by the intrusive contact of the Mill

TABLE 4.—*Magnitude of geochemical anomalies rated as strong (S), moderate (M), or weak (W), for each element and each tract*

[--, no data]

	Carbonate facies (lower plate)				Siliceous facies (upper plate)				Granitic igneous rocks	Basaltic andesite	
	Lower Mill Canyon	Upper Mill Canyon	Mount Tenabo	South Ridge	Lower Fourmile Canyon	Upper Fourmile Canyon	Willow Creek	Horse Canyon	Mill Canyon stock	Buckhorn	Southwest basaltic andesite
Tract	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Element											
Au	S	S	W	W	W	W	W	W	S	S	W
Ag	S	S	W	M	W	W	W	W	S	W	W
Hg	M	S	M	M	W	W	W	S	W	S	W
As	S	S	W	W	W	M	M	S	S	M	W
Sb	S	S	M	M	W	W	M	M	S	W	W
Cu	S	S	M	M	M	M	M	M	S	M	W
Zn	S	S	M	M	M	W	W	W	S	W	W
Mo	S	S	W	W	W	S	W	W	W	M	W
Te	S	M	M	M	M	S	W	W	M	W	--

Canyon stock (pl. 1). Many minor faults, some of which are mineralized, are in the area. Masses of jasperoid replace the Wenban Limestone in the southeastern part of the area. The approximate outlines of two of the larger of these are shown on the geologic map; other smaller masses are present in the area.

The tract is not strongly anomalous in any of the nine selected elements; mercury, antimony, copper, zinc, and tellurium show moderate anomalies, and gold, silver, arsenic, and molybdenum are weakly anomalous (table 4). Most of the sample localities with high metal values are near the top of Mount Tenabo. Relatively high mercury values are present in the jasperoid area east of Mount Tenabo.

Tract IV, South ridge.—The south ridge tract contains the units of the lower plate carbonate facies and is bounded on the east by the Roberts Mountains thrust and on the west by the Cortez fault; it is cut by many faults with small displacement (pl. 1). The Cortez silver mine is in this area.

The tract is not strongly anomalous in any of the selected elements; gold, arsenic, and molybdenum are weakly anomalous, and silver, mercury, antimony, copper, zinc, and tellurium are moderately anomalous (table 4). Most of the sample localities showing high metal values are from the vicinity of the Cortez silver mine, although relatively high copper and mercury values are widespread.

Tract V, Lower Fourmile Canyon.—The rocks in this tract (pl. 1) consist mostly of the Fourmile Canyon Formation, a unit of the upper plate siliceous facies. Quartz porphyry and dolerite dikes cut the sedimentary beds, and small masses of the basaltic andesite and younger rhyolite flows are present. Prebasaltic andesite Tertiary gravel lies along the eastern side of the tract. Quaternary alluvium and colluvium occur. No mines and only a few prospects are known.

Most of the metals show concentrations that are only weakly anomaous; tellurium, zinc, and copper are moderately anomalous, and no strong anomalies are present (table 4). The sample localities showing relatively high values are scattered and have no obvious relationship to geologic features.

Tract VI, Upper Fourmile Canyon.—This tract includes the Fourmile Canyon Formation of the upper plate siliceous facies and is adjacent to the east end of the Mill Canyon stock. A subsidiary thrust fault that branches to the east from the Roberts Mountains thrust lies in the area (pl. 1). Several small igneous bodies of alaskite porphyry satellite to the Mill Canyon stock, Tertiary gravel, and Quaternary alluvium and colluvium are present. Several prospects are known in the area.

Strong anomalies in molybdenum and tellurium and moderate anomalies in copper and arsenic occur (table 4). Most of the sample localities showing high molybdenum, tellurium, and arsenic values are in or near the large satellite alaskite body north of the Mill Canyon stock. The copper anomalies are scattered. A few localities show relatively high gold and mercury values.

Tract VII, Willow Creek area.—The rocks underlying the Willow Creek tract (pl. 1) are mostly of the Vinini Formation, upper plate siliceous rocks, that are intruded by small igneous bodies satellite to the Mill Canyon stock. A small amount of Tertiary gravel and Quaternary alluvium occurs. Prospects are few.

Arsenic, antimony, and copper are moderately anomalous, and the other elements are weakly anomalous.

Tract VIII, Horse Canyon.—The rocks in this tract (pl. 1) consist of gray to black siliceous rocks of the upper plate Vinini Formation that have been locally bleached to light gray and stained by iron oxides, probably as an effect of the rhyolite plug to the northeast. In the highly altered areas the rock disintegrates to small fragments upon weathering, and locally the hills are noticeably rounded and barren of vegetation. Cinnabar can be panned from mercury prospects.

Mercury, expectably, and arsenic are strongly anomalous. All the other elements are weakly anomalous, except antimony and copper which are moderately anomalous (table 4). Most of the sample localities with high values are found in rocks that are altered.

Tract IX, Mill Canyon stock.—This area encompasses the Mill Canyon stock (pl. 1), which is mostly quartz monzonite but ranges in composition from alaskite to granodiorite. The tract contains several prospects along narrow quartzose fissure veins similar to those in lower Mill Canyon (tract I). Some ore, primarily silver, has been mined.

Most metals are strongly anomalous. Tellurium is moderately anomalous, and mercury and molybdenum are weakly anomalous (table 4). Most of the sample localities with high values are along the southeast-trending mineralized zone in Mill Canyon.

Tract X, Buckhorn.—The rocks in the Buckhorn tract are a series of Pliocene basaltic andesite flows and a few small patches of consolidated Tertiary gravel (pl. 1). The rocks are displaced along a series of northwest-trending mineralized faults. These zones were sites of intense clay alteration. The Tertiary sedimentary rocks which underlie the basaltic andesite are exposed in several small areas in a horst formed by the northwest-trending faults. The Buckhorn mine has produced gold and silver from one of these faults and from the adjacent lower part of the basaltic andesite.

Gold and mercury are strongly anomalous, and arsenic, copper, and molybdenum are moderately anomalous (table 4). The localities with high values are in the faults and altered basaltic andesite.

Tract XI, Southwest basaltic andesite.—This tract is characterized generally by the same rocks as in the Buckhorn tract, although the rocks exposed are the upper part of the basaltic andesite flows. The Tertiary gravel is nowhere exposed, and wallrock alteration is much less intense along the northwest-trending faults.

Metals in the area are weakly anomalous and generally restricted to the faults. No data on tellurium are available from this area.

SUMMARY OF GEOCHEMICAL ANOMALIES

Gold is strongly anomalous along the mineralized zone in Mill Canyon which extends southeastward from lower Mill Canyon (tract I) through the central part of the Mill Canyon stock (tract IX) to upper Mill Canyon (tract II). The Buckhorn area (tract X) also has a zone of high gold values trending along the faults. Other high values are scattered throughout the area but are fairly common in upper Fourmile Canyon (tract VI).

High silver values are present near the Cortez silver mine, and silver anomalies generally coincide with gold anomalies elsewhere. The zone of enrichment of silver along Mill Canyon is wider in the Mill Canyon stock than in the adjacent limestone.

Mercury and arsenic are strongly anomalous in much the same pattern as gold and silver along the mineralized zone in Mill Canyon (tracts I, II, IX) and near the Buckhorn mine (tract X). Horse Canyon (tract VIII), adjacent parts of the Roberts Mountains thrust, and the jasperoid near Mount Tenabo (tract III) contain high concentrations of mercury and arsenic. Individual high values are scattered in other areas but are fairly common in upper Fourmile Canyon (tract VI). Antimony anomalies are distributed much like the mercury and arsenic but are of lower intensity, except in the Buckhorn mine area (tract X) where antimony values are generally below the detection limit.

Most of the sample localities with high copper values are along the mineralized zone in Mill Canyon (tracts I, II, IX), but other individual high values are widely scattered throughout the area.

Zinc is strongly anomalous in lower Mill Canyon (tract I), and individual high values occur near the Cortez silver mine (tract IV).

Along the mineralized zone in Mill Canyon, molybdenum anomalies are strong in carbonate rocks in upper and lower Mill Canyon (tracts I, II) but are weak in the Mill Canyon stock (tract IX). Individual high values are abundant in the cherts in upper Fourmile Canyon (tract VI) and in nearby igneous rocks. High molybdenum values are present at localities near the Buckhorn mine (tract X), and values are generally high relative to the other elements at localities in the southwest basaltic andesite (tract XI).

Strong tellurium anomalies are concentrated in lower Mill Canyon (tract I) and in upper Fourmile Canyon (tract VI). Individual high values are scattered over the region. Tellurium values are low in the Buckhorn area (tract X) despite high content of other metals.

The relationships described above show that strong arsenic, mercury, and antimony anomalies are closely associated with the strong gold and silver anomalies. The other elements are not everywhere present with the gold and silver, and even though they may be important indicators of mineralization, they should not be used as reliable guides to gold and silver occurrences.

SUMMARY OF GEOLOGIC ASSOCIATIONS

The geochemical anomalies just described are consistently associated with specific geologic features. Strong and moderate metal anomalies are more frequent, in both number and variety, in the tracts with predominantly carbonate sedimentary rocks than in the tracts containing predominantly siliceous rocks. Strong anomalies in both siliceous and carbonate sedimentary rocks are near major granitic igneous intrusive bodies (tracts I, III, VI, VIII).

Some strong geochemical anomalies are present in tracts that consist of igneous rocks. In the Mill Canyon stock all the metals are strongly anomalous except for mercury and molybdenum. Most of the localities in the stock that show high values are restricted to the mineralized zone along Mill Canyon. It is notable that, although values in molybdenum are generally low throughout the stock, high values are found at localities near the margins of the stock in both carbonate and siliceous host rocks.

A few metals are strongly anomalous in the fault zones and the altered basaltic andesite near the Buckhorn mine, but most elements are of moderate to weak concentrations in the basaltic andesite elsewhere. No mineralization is evident in the upper Tertiary rhyolite.

The Roberts Mountains thrust fault in this area contains only a few individual localities that are geochemical anomalies, and most of these anomalies are in lower Mill Canyon.

In summary, most of the strong geochemical anomalies occur in or along fracture zones in carbonate rocks near igneous bodies and in the Jurassic Mill Canyon stock. Some strong anomalies occur along fractures in the basaltic andesite. Relatively few strong anomalies are in the siliceous facies of the sedimentary rocks.

GEOCHEMICAL ANOMALIES AND EXPLORATION TARGETS

This geochemical study outlines the known mining areas and prospects in the Cortez-Buckhorn area. The Cortez gold mine was discovered through geochemical methods (Erickson, Masursky, and others, 1961; Erickson, Van Sickle, and others, 1966; Wells and others, 1968, 1969). These facts indicate the applicability of geochemical sampling to mineral exploration. Because available analytical methods can detect trace amounts of many elements, geochemical anomalies can be recognized in areas where ore-grade material is not known. Some of the anomalies may be related to ore-grade material which exists elsewhere on the surface or at depth. It thus becomes critical to distinguish between anomalies that are likely to be related to ore and those that are not.

Two tracts (VIII, XI) have been selected as examples to show how we have interpreted the geochemical and geological data to infer possible exploration targets. One tract contains strong and moderate anomalies in some elements, and the other contains only weak anomalies.

In the Horse Canyon tract (VIII) strong mercury and arsenic anomalies and moderate antimony and copper anomalies are present. Scattered sample localities show high gold and silver values. The surface rocks are upper plate siliceous rocks that show effects of some alteration possibly associated with rhyolitic igneous rocks nearby. The Roberts Mountains thrust dips under the area, and the lower plate carbonate rocks are within reasonable drilling depth. If one assumes that the rocks are fractured at depth and that an igneous intrusive also is present, an exploration target beneath the surface anomalies in the carbonate rocks seems probable. The likelihood of a target in the Roberts Mountains thrust zone is small, and a target in the shallow upper plate siliceous rocks, though possible, is not likely because neither gold nor silver has been mined from upper plate siliceous rocks in this area.

In the southwest basaltic andesite tract (XI) the metals are only weakly anomalous. The mercury-arsenic-antimony suite is present but only weakly developed. Moderate amounts of copper and molybdenum occur only at scattered localities. A small amount of gold is detected at a few localities, and silver is virtually absent. The metals were introduced, and some wallrock alteration occurred, along fractures in the upper part of the sequence of basaltic andesite flows. The gold and silver at Buckhorn was mined from the lower part of the flows, and therefore similar ore bodies may also exist at depth here, even though weak anomalies at the surface seem to indicate that no drilling target is present. Tertiary gravels are present below the basaltic andesite flows. At greater depths upper plate siliceous rocks and lower plate carbonate rocks are probably present, and intrusive rocks may be present. A favorable site for deposition of gold or silver from hydrothermal solutions may exist at depth in this area.

A third possible exploration target in Mill Canyon was described in detail previously by Elliott and Wells (1968). In Mill Canyon, veins probably intersect a favorable ore formation, the Roberts Mountains Limestone, near the Mill Canyon stock at depth, and this intersection may have localized ore.

The foregoing examples show that geological and geochemical conditions must be determined and evaluated together for each potential exploration site. Exploration of only weakly anomalous areas may be justified if the geologic setting is favorable.

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