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DISTRIBUTION OF SELECTED METALS IN THE STOCKTON DISTRICT, UTAH*

By

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Abstract

Spectrographic analyses of bedrock and oxidized surficial materials from the Stockton district in northeastern Utah indicate a zonal distribution of metals spatially related to an intrusive center of Tertiary age. Areas of locally high bismuth and molybdenum concentrations define the central zone; copper and lead-zinc-arsenic areas overlap and extend progressively farther from the central zone; locally high boron concentrations in the outer zone extend largely beyond the limits of significant, known mineralization; silver and antimony are erratically distributed in the area studied. The present distribution of metals at Stockton apparently reflects hypogene environmental controls.

Introduction and acknowledgments

The Stockton district lies in the western foothills of the Oquirrh Mountains about 1½ miles east of Stockton and 30 miles southwest of Salt Lake City, Utah. A study of the metal distribution in surficial materials was undertaken to supplement a geologic investigation in the Bingham district, located approximately 12 miles to the northeast.

During the fieldwork at Stockton, E. H. Snyder and I. S. Droubay of the Combined Metals Reduction Co. made available many district maps and reports; this assistance is gratefully acknowledged. The writers

also acknowledge the advice and considerable analytical support provided by A. P. Marranzino, G. B. Gott, and J. H. McCarthy, Jr., of the U.S. Geological Survey. Sahng Yup Kim of the Korean Geological Survey assisted with the magnetic studies.

General geology

The geology and ore deposits of the Stockton district have been studied by Butler and others (1920) and Gilluly (1932). The district is underlain by an interbedded sequence of quartzites and limestones of the Pennsylvanian-Permian Oquirrh Formation; the exposed Oquirrh section in this area ranges from about 4,000 to 9,000 feet above the basal contact with the Manning Canyon Shale of Mississippian-Pennsylvanian age. The limestone layers, rarely more than 50 feet thick, are medium to dark gray, arenaceous, and thin bedded. Dense buff to gray quartzites and cherty, calcareous sandstones separate the limestone beds. The outcrop map (fig. 1), prepared in the course of geochemical sampling, shows the distribution of the most persistent calcareous units in the area. Many of the thin limestones are obscured or concealed by a cover of scrub oak and quartzite slope wash.

The beds form part of the east limb of the northwest-plunging Ophir anticline (Gilluly, 1932, pl. I) and generally strike about N. 70°-80° W. and dip 60°-80° N. Locally the beds are overturned and dip 70° or more south in the northern part of the map area. Minor drag folds are associated with some of the larger faults in the northern and central portions of the district.

Gilluly (1932, p. 88-90) recognized several periods of faulting in the Stockton district. The earliest faults are bedding faults of minor displacement that presumably accompanied folding. These were followed by north-trending faults that dip steeply to the west and may have controlled, in part, the emplacement of quartz monzonitic intrusive rocks. Ore bodies are localized principally along the north-trending and bedding faults. Sheared sulfides occur locally in the underground workings, suggesting continuing postore faulting. The horizontal displacement on the faults rarely exceeds 100 feet; an exception is the Continental fault zone which displaces the beds horizontally about 1,000 feet. Faults of small displacement are not shown in figure 1.

Intrusive rocks ranging in composition from diorite to quartz monzonite cut the Oquirrh Formation. Most of these are dikes of quartz monzonite porphyry. The stocklike bodies shown near the southern limits of the map (fig. 1) include several small masses of quartz diorite. The igneous rocks in the vicinity of Stockton are a part of an intrusive center which includes the large stock and numerous sills exposed 2 miles to the southeast in Soldier Canyon (fig. 1, insert).

A northwest-trending aeromagnetic anomaly, presumably related to intrusive rocks at depth, was found in this area (Mabey and others, 1964, fig. 2, insert). Its presence has been confirmed by additional traverses at the surface over portions of the Stockton district, by means of a portable flux-gate magnetometer. A local magnetic high also occurs northwest of the Calumet mine over the alluviated area surrounded by stocklike intrusives (fig. 2). This suggests the presence of a major extension from the larger, northwest-trending intrusive mass.

Limestones near intrusive contacts are commonly bleached and recrystallized; recrystallized limestone is common within the area defined approximately by the 600-gamma contour line in figure 2. Small bodies of lime silicate minerals including diopside, epidote, andradite, idocrase, and wollastonite are found in this area but also occur locally in narrow zones along dikes and fissures throughout the district. The more siliceous clastic rocks in the southern portion of the district have been metamorphosed to spotted or layered hornfelses. Gilluly (1932, p. 94) reported that the calcareous cement in these rocks is partially replaced by diopside, epidote, orthoclase, and garnet.

Propylitization is the dominant type of the intrusive rocks at Stockton (Gilluly, 1932, p. 93). Weathering has obscured the effects of this process at the surface but several dikes have a matrix composed, in part, of a soft, pale-green material, presumably chlorite. Sericitic alteration is common in gouge zones and in the plagioclase phenocrysts of the intrusive rocks.

Ore deposits

Ore deposits were first discovered in the Stockton district in 1864 and have since yielded metals valued at more than $30 million from about 1,200,000 short tons of ore (E. H. Snyder, written communication, 1965). Production values are divided among the following metals: lead, 75 percent; silver, 16 percent; zinc, 5 percent; gold, 3 percent; and copper, 1 percent. The major properties have been owned by the Combined Metals Reduction Co. since 1924. At the present time the underground workings are inaccessible.

The major ore deposits are pipelike or blanketlike replacement bodies that plunge steeply to the north; they are chiefly localized at the intersection of north-trending fault and breccia zones with favorable limestone units. The strike length of the ore shoots seldom exceeds 100 feet, although several have been followed downplunge from the surface for over 1,800 feet (Gilluly, 1932, p. 162). Weak mineralization was observed along some north-trending fissures cutting quartzite beds and along the brecciated margins of quartz monzonite dikes.

Hypogene ore minerals include galena and argentite with minor amounts of sphalerite and chalcopyrite in a gangue composed of pyrite, calcite, and quartz. Oxidation of the ore bodies is essentially complete to depths of 600 to 800 feet (Gilluly, 1932, p. 160). Cerussite, plumbo-jarosite, and anglesite are the major ore minerals in the zone of oxidation; minor amounts of cerargyrite, pyromorphite, smithsonite, hemimorphite, and malachite are also present in some ores. Gangue minerals in the oxidized zone are generally quartz and hydrated iron oxides and locally, manganese oxides, barite, and gypsum.

Geochemical studies

About 1,000 bedrock samples were collected for semiquantitative spectrographic analysis within the areas outlined by heavy dashed lines in figure 3. The southern and western boundaries of the sample area approximate the outcrop limits of the Oquirrh Formation; boundaries on the north and east were selected along or near prominent drainage divides. Nearly 70 percent of the samples were taken from gossans or breccia zones that showed variable amounts of iron staining; the remainder represent "background" sample sites where no mineralization was visible.

The sample distribution is shown in the insert map, figure 3. No attempt was made to sample at regular intervals on a grid system, as the ore metals are chiefly concentrated along north-trending fissures and fractures.

All analytical work was done by G. C. Curtin, A. P. Marranzino, and Uteana Oda of the Branch of Exploration Research, U.S. Geological Survey. Each sample was analyzed for Ca, Mg, Fe, and 27 minor elements.

The generalized distribution of locally high concentration areas for bismuth (Bi), molybdenum (Mo), copper (Cu), lead (Pb), zinc (Zn), arsenic (As), antimony (Sb), silver (Ag), and boron (B) is shown in figure 3; these areas contain 70 to 90 percent of the samples that exceed the indicated minimum concentration for a given element. Minimum concentration values were arbitrarily chosen after scanning analyses for the visibly unmineralized samples; these values are greater than local background by at least a factor of five for all elements except Bi and B. Background concentrations of the latter two are less than or similar to the 10-ppm lower-sensitivity limit of the spectrographic method employed. The directional trend of individual areas is not significant, since most areas contain many diversely oriented fissures; however, their aggregate distribution may be significant.

In the sample area north of the Calumet mine, locally high concentrations of Bi and Mo are clustered in gossan samples near the Tip Top shaft (fig. 3A); several narrow dikes have been mapped in this area (fig. 2). The first dike east of the Tip Top mine is locally termed the "Raddatz" porphyry and, according to Gilluly, "widens considerably at depth and where cut on the 1,200-foot level of the Honerine mine is 300 feet wide" (1932, p. 52).

Concentrations of Cu greater than 50 ppm occur in a broad area that overlaps and extends beyond the Bi-Mo zone. Figure 3B shows that the area of locally high Pb, Zn, and As concentrations generally coincides with the limits of the Cu zone but extends beyond these limits at the northern and eastern margins of the district. Ag and Sb are erratically distributed within the Pb-Zn-As zone. B concentrations of greater than 20 ppm occur largely beyond the limits of significant known mineralization.

Many features of the metal distribution in the main mining area are repeated on a smaller scale in the vicinity of the Calumet mine (fig. 3). It is possible that two separate centers of mineralization are involved; however, both are spatially coincident with extensions from the large intrusive mass suggested, in part, by magnetic data in figure 2.

The hypogene minerals which supplied certain metals now found in the gossan samples at Stockton are largely a matter of speculation. Galena, sphalerite, chalcopyrite, and argentite are likely sources for the Pb, Zn, Cu, and Ag; small amounts of tetrahedrite and arsenopyrite reported by Butler and others (1920, p. 372) may account for the presence of Sb and As. Hypogene tourmaline occurs in the metamorphosed limestones of the Ophir and Mercur districts southeast of Stockton (Gilluly, 1932, p. 129) but no minerals having B as an essential constituent were identified in the Stockton area itself. Similarly, hypogene Mo and Bi minerals remain unknown; Mo may be present as the trace mineral molybdenite, whereas Bi may occur as microscopic inclusions of bismuthinite or matildite in galena (Fleischer, 1955, p. 979-980).

The distribution of metals at Stockton appears to reflect hypogene environmental controls. Areas of "high" Bi-Mo concentrations, consistently associated with stocklike intrusive bodies of quartz monzonite porphyry, are inferred to have formed in relatively high-temperature zones during the early stages of mineralization (Goldschmidt, 1954, p. 483; Erickson and others, 1961, p. D317). The intermediate Cu and Pb-Zn-As zones would indicate lower temperatures of sulfide deposition.

High concentrations of manganese in mineralized areas have been related to environments distant from the source of metal-bearing solutions (Erickson and others, 1961, p. 317; Hewett, 1964). In the present study no systematic distribution of manganese was observed. Boron occurs in the fringe areas of mineralization; this occurrence is consistent with the known mobility of the element (Rankama and Sahama, 1950, p. 487-489) and is considered to be a characteristic feature of the low temperature, hydrothermal environment at Stockton.

Exploration possibilities

Geochemical studies in the areas of known mineralization at Stockton have indicated a distribution of metals characterized by a central Bi-Mo, a medial Cu-Pb-Zn-As, and an outer B zone. The western and southwestern portions of the district are covered by alluvium and have been only partly explored; based on a zonal and crudely concentric distribution of metals, further exploration is suggested in these areas. Geophysical methods and geochemical analysis may isolate target areas in the alluvium-covered limestones marginal to the intrusive center shown in figure 2. Recent work (Erickson and Marranzino, 1960, p. B98; Erickson and others, 1964, p. 17) suggests that copper and possibly silver are concentrated in caliche coatings on alluvial sediments overlying buried ore deposits; a reconnaissance study of caliche and soil samples based on traverses extended from the bedrock control areas may be worthwhile.

Geophysical anomalies have been reported in Rush Valley south of Stockton (anonymous oral communication, 1965); these anomalies have been confirmed by the writers. This area lies along the projected axial zone of the Ophir anticline--the locus of ore bodies in the Ophir district (Gilluly, 1932, pl. I)--and may be a favorable area for the additional geophysical and geochemical exploration.

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