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POSSIBLE SOURCE AREAS FOR SANDSTONE COPPER DEPOSITS IN NORTHERN NEW MEXICO

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INTRODUCTION

Sandstone copper deposits in northern New Mexico occur predominantly in rocks of Permian and Triassic age. Chalcocite is the primary ore mineral with malachite and azurite as oxidation products. In the Permian deposits chalcocite occurs as nodules in organic shales and siltstones and as replacement of woody material in small sandstone channels. These beds lie in a fluvial sequence of red muds, red arkosic siltstones, sandstones, and conglomerates. Examples of deposits include the Scholle district with mineralization in the Abo Formation (Phillips, 1960; LaPoint, 1974a,b) and the Coyote district with copper-uranium mineralization in the Pennsylvanian-Permian Sangre de Cristo Formation (Tschanz, and others, 1958). Triassic deposits (Fig. 1) occur in basal sandstones or conglomerates of the Chinle Formation or equivalent strata. Representative deposits include the Nacimiento and Eureka Mines with mineralization in the Agua Zarca Sandstone (Antony, 1972; Woodward and others, 1974) and the Stauber Mine with mineralization in the Santa Rosa Sandstone. The deposits occur in large fluvial sandstone channels. Chalcocite replaces woody debris, and malachite and azurite cement the sandstone.

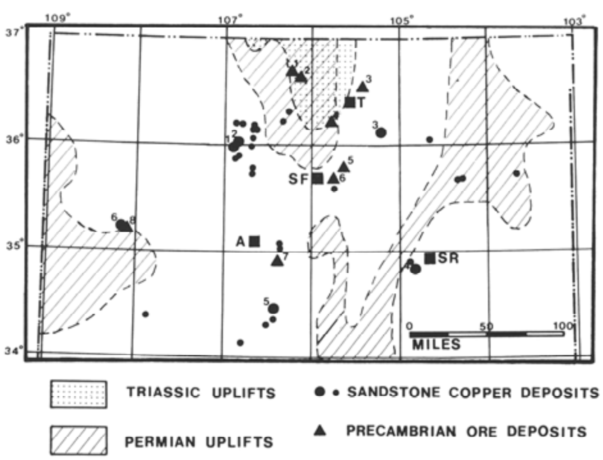

Figure 1. Index map of northern New Mexico showing sandstone copper deposits, Precambrian ore deposits, and approximate extent of Early Permian (adapted from Kottlowski and Stewart, 1970) and Late Triassic (adapted from McKee and others, 1959) landmasses. Precambrian deposits named in text include: 1) Hopewell district; 2) Bromide district, 3) Rio Hondo district; 4) Picuris district; 5) Pecos Mine; 6) Santa Fe district; 7) Tijeras Canyon district; and 8) Zuni Mountains district. Sandstone copper deposits named in text (larger circles) include: 1) Nacimiento Mine; 2) Eureka Mine; 3) Coyote district; 4) Stauber Mine; 5) Scholle district; 6) Zuni Mountains district. Squares on map indicate major towns.

One aspect in a study of these deposits is the question of possible sources of copper. Three general possibilities which will be discussed are:

1) Post-depositional igneous activity.
2). Contemporaneous (late Paleozoic or Mesozoic) igneous activity.
3) Erosion of Precambrian highlands.

RECENT IGNEOUS ACTIVITY

Within the vicinity of most deposits, there is some evidence of post-depositional igneous activity. This includes small dikes south of the Scholle district, the Jemez volcanics east of the Nacimiento and Eureka Mines, and Tertiary intrusives near the Coyote district and Stauber Mine. However, all of the sandstone copper deposits discussed lack mineralized dikes or veins (except a dike south of Scholle), high temperature or complex ore mineralogy, and alteration assemblages. Copper mineralization is confined mainly to beds of Permian and Triassic age with minor occurrences in Pennsylvanian rocks. If young fluids of any type formed these deposits, one would expect other rocks in the section to be mineralized.

LATE PALEOZOIC OR MESOZOIC IGNEOUS SOURCES

Evidence of igneous activity during Permian and Triassic times in western Nevada, California, and southeastern Arizona consists of intrusives and associated volcanic rocks. Volcanic ash and ash-flow tuff may have covered large areas, creating potential source beds for copper, as suggested by Phillips (1960). Volcanic rock fragments are found in the Triassic Agua Zarca Sandstone; however, major source areas for the sandstone are Precambrian rocks in the Triassic Uncompahgre Highlands to the northeast of the Nacimiento Mine. Also, volcanic detritus thins to the north, away from the volcanism in the Mogollon Highlands during Chinle deposition (Stewart and others, 1972). Volcanic rock fragments have not yet been reported from either the Santa Rosa Sandstone or the Permian Abo Formation. The sources for both of these formations are also uplifts of Precambrian rocks (Fig. 1).

Regardless of the fact that the main source of sand detritus was from Precambrian rocks, volcanic ash may still be a source if it covers wide areas and can be leached of metals during diagenesis (Harshman, 1972). Chemical data for Cenozoic rhyolite ash-flow tuffs (Fig. 2) indicate a low copper content that decreases with increasing silica content. Similar Mesozoic volcanic rocks from southeast Arizona (Fig. 2; Table 1), the most likely source of volcanic material from the Chinle Forma-

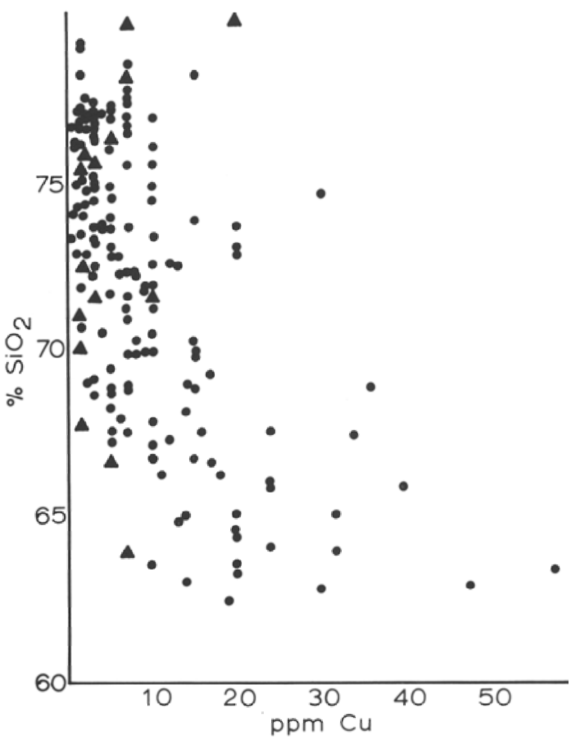

Figure 2. Copper content in rhyolitic ash-flow tuffs as coi pared to silica content. Circles represent recent volcanic c posits from the San Juan Mountains (Ratté and Steven, 196 Lipman, unpublished data, 1973) and the Nevada test si (Lipman and others, 1966; Lipman, unpublished data, 197: Triangles represent analyses of Mesozoic volcanic rocks frc southeast Arizona (Drewes, 1971; Simons, 1972).

Table 1. Chemical analyses of rhyolitic ash-flow tuffs. Sources are: Lipman (unpublished data, 1973), Lipman and others (1966), Ratté and Steven (1967), Greene (1973), Lindsey and others (1973), Sheppard and Gude (1973), Drewes (1971), and Simons (1972).

RECENT ASH-FLOW TUFFS		
San Juan Mountains (66 samples):---------------	18ppm Cu	---68.2% SiO_2
Nevada test site (127 samples):---------------	5.5ppm Cu	--74.0% SiO_2
TOTAL (including samples from Spor Mt., Utah; southeast Oregon; Mohave county, Arizona. (254 samples):-----------------	10ppm Cu	---68.9% SiO_2
MESOZOIC ASH-FLOW TUFFS		
TOTAL - southeast Arizona (14 samples):--------	5ppm Cu	---74.1% SiO_2

tion, also have low copper values. Based on average copper content (Table 1), minor leaching of copper may have occurred, especially in the less silicic volcanic rocks of Mesozoic age.

To form an orebody the size of the Stauber Mine with 7.5 million pounds of copper, 2.7 x 10^4 cubic meters (9.6 x 10^5 cubic feet) of volcanic rock would have to be leached of 5 ppm copper per cubic meter. If the volcanic bed were one meter thick, its area would cover 2.7 x 10^4 square meters (2.95 x 10^5 square feet). These figures assume maximum leaching of the copper based on chemical data from Table 1 and complete precipitation of the copper at the sedimentary deposit. However, there is no evidence of large volcanic beds associated with the sandstone channels. In addition, the volcanic ash would have to travel at least 200 miles. This material would represent the more explosive, silicic, and copper-poor fraction of an eruption.

PRECAMBRIAN SOURCES

Precambrian rocks that were exposed in the Permian and Triassic uplifts are an attractive source for the copper found in the northern New Mexico sediments. Lindgren (1908) cited the close association of Precambrian ore deposits and red-bed copper deposits near Cotopaxi, Colorado. Others (Phillips, 1960) have related copper mineralization in Precambrian rocks in the Zuni Mountains with sandstone copper found in conglomerates of the Abo Formation which flanks the uplift. However, the question arises, is it necessary to have preexisting ore deposits to form sandstone copper deposits?

Precambrian ore deposits are found throughout north-central New Mexico (Fig. 1). Known deposits include the Pecos Mine (Krieger, 1932), the Hopewell and Bromide districts (Barker, 1958; Bingler, 1968; McLeroy, 1970), the Champion Mine in the Picuris district (Montgomery, 1953; Schilling, 1960), the Rio Hondo district (Schilling, 1960; Clark and Read, 1972), the Santa Fe district (Lindgren and others, 1910), and Tijeras Canyon district (Reiche, 1949). In general, mineralization consists of sulfides or oxides of copper, lead, and zinc with silver and gold. Veins or pods of mineralization may parallel the foliation within zones of phyllites, schists, or gneisses. Surrounding rocks may be amphibolites, chlorite schists, sericitic schists, metarhyolites, banded iron formations, and quartz-eye schists or gneisses. Many of these ore bodies represent massive sulfide deposits (Sangster, 1972) within a Precambrian metavolcanic terrain similar to the massive sulfide deposits in central Arizona (Anderson, 1968; Anderson and Nash, 1972), and they may, in fact, be part of the same trend.

Precambrian ore deposits form an excellent source, similar to porphyry copper deposits, that erode to produce copper-bearing gravels (Newburg, 1967). Gabelman and Brown (1955) report a chalcocite placer within the Agua Zarca Sandstone, and Hey! and Bozion (1973) report a fossil gold placer in Pennsylvanian sandstones overlying the Precambrian near the Pecos Mine. However, it is felt that the concept of a source consisting only of preexisting mineral deposits is too restrictive, considering the large number of small occurrences of sandstone copper (Fig. 1). In contrast, Precambrian rocks as a whole are too broad a source. Instead, it is proposed that the Precambrian metavolcanic rocks, possibly supplemented by massive sulfide horizons, form the most likely source for the New Mexico deposits.

Analyses of igneous rocks show that copper is enriched in mafic rocks, with an average of 100 ppm copper in basalts (Vinogradov, 1962). Copper may be found as sulfides, replacement of Fe and Mg in silicates, or as an ion absorbed by various minerals (Rabinovich and Badalov, 1971). Therefore, high copper concentrations can occur in rocks containing hornblende, biotite, chlorite, sulfides, and iron oxides. Plagioclase may also be important due to its abundance, particularly if copper is concentrated along crystal lattice discontinuities (Goni and Guillemin, 1964).

Data from the Eagle Nest quadrangle near Taos illustrates that mafic metamorphic rocks in New Mexico do contain high copper values (Table 2). Mafic gneiss averages twice as much copper as quartzites and granitic rocks and comprises the only Precambrian rock defined as anomalous in copper by Misaqi (1968). The Rio Hondo district lies within this area and consists of copper sulfides with quartz in chlorite schist; gold and silver are also reported. From mining company reports and Clark and Read's (1972) rock descriptions, it appears that metavolcanic rocks, termed mafic gneiss, occur within the area.

Table 2. Precambrian rock analyses from Eagle Nest quadrangle. Data is from Misaqi (1968).

MAFIC GNEISS: (35 samples)	72ppm Cu average
	20 - 345ppm Cu range
6 anomalous samples: 95, 100, 110, 150, 160, 345 ppm Cu.	
QUARTZITE: (20 samples)	36ppm Cu average
	20 - 70ppm Cu range
no anomalous samples	
GRANITE: (40 samples)	34ppm Cu average
	10 - 60ppm Cu range
no anomalous samples	

Sulfides remain an attractive source because copper and other metals are easily mobilized during weathering. However, most of the metal will precipitate a short distance from its origin as the acidic waters regain equilibrium with the silicate sediments (Newburg, 1967). If sulfides are considered as a source for the present copper deposits in sandstones, the copper must have been remobilized by groundwaters passing through copper-rich alluvial sediments.

In addition to the sulfides, a second reservoir of copper is contained within the mafic silicate minerals and feldspars. During diagenesis and the reddening of alluvial sediments (Walker, 1967), copper along with iron and other metals can be released with the breakdown of ferromagnesian minerals and alteration of plagioclase to clay minerals. An alkaline, oxidizing groundwater will develop, which can carry copper as carbonate complexes. The groundwater migrates downdip in the sandstone channels; precipitation of copper as chalcocite occurs in reducing micro-environments in organic shales and around organic material in the channels. This model, at present, seems to explain the Triassic deposits.

Mineralization in the Permian deposits occurs in organic shales and siltstones and in channel sandstones. It is possible that copper-rich montmorillonite clays and/or copper-organic complexes were eroded from weathered, copper-rich metavolcanic rocks. Streams carried the clays and/or organics to a quiet water environment where they were deposited. Dewatering during compaction of the sediment would lead to remobilization of the copper. Chalcocite nodules could form in the organic shales and siltstones along with replacement of woody material in adjacent sandstone channels.

In summary, although the relative importance of the various transportation and depositional processes cannot yet be determined, there is good evidence that the primary source for northern New Mexico copper was Precambrian metavolcanic terrains north of the present deposits.

REFERENCES

Anderson, C. A., 1968, Arizona and adjacent New Mexico, *in* Ridge, J. D. (ed.), Ore deposits in the United States 1933/1967: Graton-Sales Volume 2, Am. Institute of Mining Engineers, New York, p. 1163-1190.

Anderson, C. A., and Nash, J. T., 1972, Geology of the massive sulfide deposits at Jerome, Arizona-a reinterpretation: Econ. Geol., v. 67, p. 845-863.

Antony, J. J., 1972, Geology and copper deposits of the Nacimiento Mine-Eureka Mesa area, Sandoval and Rio Arriba counties, New Mexico: Unpublished M.S. thesis, Colo. School of Mines, 63 p.

Barker, F., 1958, Precambrian and Tertiary geology of Las Tablas quadrangle, New Mexico: New Mexico Bur. Mines and Min. Res. Bull. 45, 104 p.

Bingler, E. C., 1968, Geology and mineral resources of Rio Arriba County, New Mexico: New Mexico Bur. Mines and Min. Res. Bull. 91, 158 p.

Clark, K. F., and Read, C. B., 1972, Geology and ore deposits of Eagle Nest area, New Mexico: New Mexico Bur. Mines and Min. Res. Bull. 94, 149 p.

Drewes, H., 1971, Mesozoic stratigraphy of the Santa Rita Mountains, southeast of Tucson, Arizona: U.S. Geol. Surv. Prof. Paper 658-C, 81 P.

Gabelman, J. W., and Brown, H. G., III, 1955, Possible Triassic chalcocite placer, Rio Arriba County, New Mexico (abs.): Geol. Soc. Am. Bull., v. 66, p. 1674.

Goni, S., and Guillemin, C., 1964, Sites of trace elements in minerals and rocks: Geochem. Internat., no. 5, p. 1025-1034.

Greene, R. C., 1973, Petrology of the welded tuff of Devine Canyon, southeastern Oregon: U.S. Geol. Surv. Prof. Paper 797, 26 p.

Harshman, E. N., 1972, Geology and uranium deposits, Shirley Basin, Wyoming: U.S. Geol. Surv. Prof. Paper 745, 82 p.

Heyl, A. V., and Bozion, C. N., 1973, Fossil gold placer in New Mexico, *in* Geological Survey Research 1973: U.S. Geol. Surv. Prof. Paper 850, p. 48.

Holmquist, R. J., 1947, Stauber copper mine, Guadalupe County, New Mexico: U.S. Bur. Mines Rept. Invest. 4026, 7 p.

Kottlowski, F. E., and Stewart, W. J., 1970, The Wolfcampian Joyita Uplift in central New Mexico, Part I: New Mex. Bur. Mines and Min. Res. Mem. 23, 82 p.

Krieger, P., 1932, Geology of the zinc-lead deposit at Pecos, New Mexico: Econ. Geol., v. 27, p. 344-364, 450-470.

LaPoint, D. J., 1974a, A comparison of selected sandstone-type copper deposits in New Mexico (abs.): Geol. Soc. Am. Abst. w/Prog., v. 5, p. 112.

LaPoint, D. J., 1974b, Genesis of sandstone-type copper deposits at the Scholle district, Central New Mexico (abs.): Geol. Soc. Am. Abst. w/Prog., v. 5, p. 451-452.

Lindgren, W., 1908, Notes on copper deposits in Chaffee, Fremont, and Jefferson counties, Colorado: U.S. Geol. Surv. Bull. 340, p. 157-174.

Lindgren, W. and others, 1910, The ore deposits of New Mexico: U.S. Geol. Surv. Prof. Paper 68, 361 p.

Lindsey, D. A., and others, 1973, Hydrothermal alteration associated with beryllium deposits at Spor Mountain, Utah: U.S. Geol. Surv. Prof. Paper 818-A, 20 p.

Lipman, P. W., and others, 1966, A compositionally zoned ash-flow sheet in southern Nevada: U.S. Geol. Surv. Prof. Paper 524-F, 47 p.

Marvin, R. F., and others, 1973, Radiometric ages of igneous rocks from Pima, Santa Cruz, and Cochise counties, southeastern Arizona: U.S. Geol. Surv. Bull. 1379, 27 p.

McKee, E. D., and others, 1959, Paleotectonic maps, Triassic System: U.S. Geol. Surv. Misc. Inv. Map 1-300.

McLeroy, D. F., 1970, Genesis of Precambrian banded iron deposits, Rio Arriba County, New Mexico: Econ. Geol., v. 65, p. 195-205.

Misaqi, F. L., 1968, Geochemical and biogeochemical studies in the Eagle Nest quadrangle, New Mexico: New Mexico Bur. Mines and Min. Res. Circ. 94, 24 p.

Montgomery, A., 1953, Pre-Cambrian geology of the Picuris Range, north-central New Mexico: New Mexico Bur. Mines and Min. Res. Bull. 30, 89 p.

Newberg, D. W., 1967, Geochemical implications of chryscolla-bearing alluvial gravels: Econ. Geol., v. 62, p. 932-956.

Phillips, J. S., 1960, Sandstone-type copper deposits of the western United States: Unpublished Ph.D. Dissertation, Harvard University, 320 p.

Rabinovich, A. V., and Badalov, S. T., 1971, Geochemistry copper in some intrusives of Karamazar and West Uzbekistan: Geochem. I nternat., v. 8, p. 146-150.

Ratté , J. C., and Steven, T. A., 1967, Ash flows and related volcanic rocks associated with the Creede Caldera, San Juan Mountains, Colorado: U.S. Geol. Surv. Prof. Paper 524-H, 58 p.

Reiche, P., 1949, Geology of the Manzanita and North Manzano Mountains, New Mexico: Geol. Soc. Am. Bull., v. 60, p. 1183-1212.

Sangster, D. F., 1972, Precambrian volcanogenic massive sulphide deposits in Canada: a review: Geol. Surv. Canada Paper 72-22, 44 p.

Schilling, J. H., 1960, Mineral resources of Taos County, New Mexico: New Mexico Bur. Mines and Min. Res. Bull. 71, 124 p.

Simons, F. S., 1972, Mesozoic stratigraphy of the Patagonia Mountains and adjoining areas, Santa Cruz County, Arizona: U.S. Geol. Surv. Prof. Paper 658-E, 23 p.

Sheppard, R. A., and Gude, A. J., 3rd, 1973, Zeolites and associated authigenic silicate minerals in tuffaceous rocks of the Big Sandy Formation, Mohave County, Arizona: U.S. Geol. Surv. Prof. Paper 830, 36 p.

Stewart, J. H., and others, 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geol. Surv. Prof. Paper 690, 336 p.

Tschanz, and others, 1958, Copper and uranium deposits of the Coyote district, Mora County, New Mexico: U.S. Geol. Surv. Bull. 1030-L, p. 343-398.

Vinogradov, A. P., 1962, Average contents of chemical elements in the principle types of igneous rocks of the earth's crust: Geochemistry, no. 7, p. 641-664.

Walker, T. R., 1967, Formation of red beds in modern and ancient deserts: Geol. Soc. Am. Bull., v. 78, p. 353-368.

Woodward, L. A., and others, 1974, Strata-bound copper deposits in Triassic sandstone of Sierra Nacimiento, New Mexico: Econ. Geol., v. 69, p. 108-120.