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BASE- AND PRECIOUS-METAL DEPOSITS IN LINCOLN AND OTERO COUNTIES, NEW MEXICO

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Abstract—Base (copper, lead, zinc) and precious (gold, silver) metals have been produced in Lincoln, and to a lesser extent, Otero Counties from the 1880s to the present. Four types of deposits occur in these two counties: (1) placer (late Tertiary to Quaternary), (2) Great Plains margin (GPM, mid-late Tertiary), (3) sedimentary copper (Permian), and (4) veins and replacement in Proterozoic rocks. Three of the deposit types are defined primarily by age of host rock and presumed genesis (placer, sedimentary copper, and veins and replacements in Proterozoic rocks). The GPM deposits are defined by similar tectonic setting, similar age of formation, association of other metals, and form of the deposits. These deposits occur along the tectonic boundary between the stable Great Plains and the active Rocky Mountains or Basin and Range (including the Rio Grande rift). Only the GPM and placer deposits have economic potential in Lincoln and Otero Counties. Low-grade but large-tonnage placer deposits may occur in the Jicarilla district, and smaller deposits may occur in the White Oaks, Nogal and Orogrande districts. GPM deposits typically consist of gold-bearing breccia pipes and quartz veins, copper and/or lead/zinc skarns and iron skarns. Future economic potential of GPM deposits is good if large, low-grade, bulk-minable breccia-pipe deposits, similar to the Ortiz deposits in the Old Placers district in Santa Fe County, can be found in Lincoln and Otero Counties. Breccia pipes occur in the Gallinas, Nogal, Jicarilla and Orogrande districts, but the potential for gold is unknown.

INTRODUCTION

Production of base (copper, lead, zinc) and precious (gold, silver) metals has been important to the economy of Lincoln County and, to a lesser extent, Otero County from the 1880s to the 1940s. Well over $7 million of base and precious metals, iron ore and other minerals have been produced from these two counties (Griswold, 1959; Schmidt and Craddock, 1964). Much of the early settlement of this area can be attributed to mining and exploration activities. Exploration and some minor production continues in a few areas today. The metals are widely distributed in a variety of deposits. The purpose of this paper is to present production data for the mining districts in Lincoln and Otero Counties, describe briefly the different types of deposits, discuss possible genetic relationships, and assess the resource potential of these deposits.

PRODUCTION

Production occurred in many of the mining districts in Lincoln and Otero Counties as early as 1865, although the Spaniards may have produced some ore before the 1860s (Griswold, 1959). Known and/or estimated production of base and precious metals is given by district in Table 1. The location of each district is shown in Fig. 1. The geology of several of the districts is described elsewhere in this guidebook. The production data come from many sources of varying reliability. The best data are from U.S. Geological Survey and U.S. Bureau of Mines mineral yearbooks and are supplemented by various published and unpublished reports and miscellaneous file data, as indicated.

In some cases, previous publications have incorrectly reported total production. Table 1 reflects my best estimates of the correct totals; however, due to the chaotic nature of some records, I expect continuing updates and corrections as work in specific districts continues.

TYPES OF BASE- AND PRECIOUS-METAL DEPOSITS

Four types of deposits occur in Lincoln and Otero Counties: placer, Great Plains margin, sedimentary copper, and veins and replacements in Proterozoic rocks (Table 2). This four-fold classification arises from the work of North and McLemore (1986, 1988), who have grouped mineral deposits in New Mexico on the basis of age of formation, tectonic setting, host rocks, form of the deposit, genetic processes, mineralogy and associated metals. Three types of deposits in this area (placer, sedimentary copper, and veins and replacements in Proterozoic rocks) are distinguished by distinct age of host rock and presumed genesis. The fourth deposit type, the Great Plains margin (GPM), is defined by similar tectonic setting, similar age of formation, association of other metals, and form of the deposits. A brief description of each type of deposit in these two counties follows.

Placer deposits (late Tertiary to Quaternary)

During the mid-1800s, placer gold deposits were an important source of gold in New Mexico (Johnson, 1972). Production from placer deposits has been reported from the Jicarilla, White Oaks and Nogal districts in Lincoln County and from the Orogrande district in Otero County (Johnson, 1972). Typically, the placer gold deposits were found and worked first in these districts. Subsequently, prospectors found and developed the lode deposits. The Jicarilla placers have been the most productive in the area, totaling about 8000 oz (Table 1). The major difficulties in producing these placers have been the lack of water needed for recovery of gold and the small grain size of the gold.

Placer deposits commonly consist of free gold with minor silver and are associated with grains of quartz, feldspar, garnet, magnetite, hematite, pyrite, zircon and other heavy minerals. Small high-grade pay streaks occur locally in overlying weathered basement rock or in clay or caliche lenses within the gravel deposits. In the Jicarilla district, placer gold occurs in weathered zones of the Tertiary monzonite/diorite stocks or laccoliths (Segerstrom and Ryberg, 1974). In the Orogrande (Jarilla) district, placer gold locally occurs in the caliche-cemented gravels immediately above bedrock (Schmidt and Craddock, 1964). However, most placer deposits occur as zones or layers of disseminated fine-grained gold in Quaternary stream deposits or alluvial-fan deposits. Gold-bearing gravels are typically thin and less than 164 m beneath the surface. Weathering, oxidation and locally steep topographic gradients are necessary for development of placer gold deposits. The placers were derived from nearby vein deposits or gold-enriched intrusives in these districts.

The economic potential of placer deposits in Lincoln and Otero Counties is largely speculative. Segerstrom and Ryberg (1974) estimated gold reserves at Jicarilla to be about 5.4 million yd^3 with an average grade of 0.043 oz Au per yd^3. Additional deposits probably occur in the Jicarilla, White Oaks, Nogal and Orogrande districts; prospective areas would be near weathered and oxidized vein deposits and igneous intrusives. The lack of water and the fine grain size of the gold in all of these districts will continue to be major problems for production.

Great Plains margin deposits (mid-late Tertiary, ~40–5 Ma)

Several mining districts in New Mexico lie along or near the border

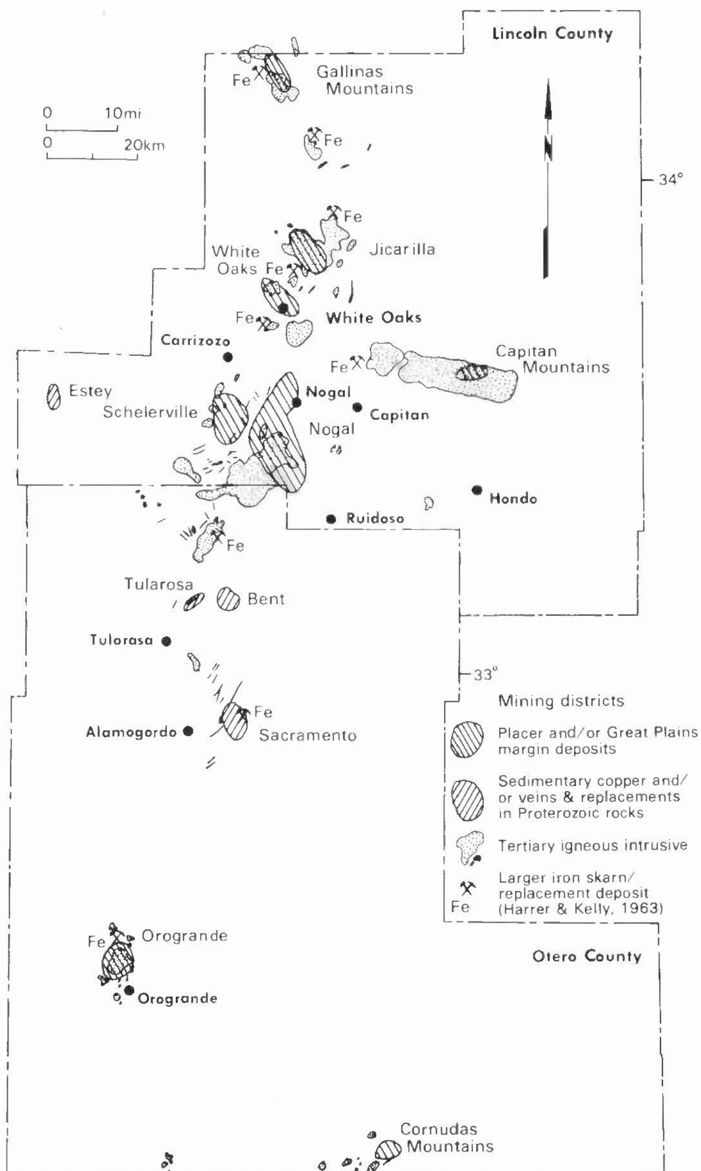

FIGURE 1. Mining districts, iron skarn deposits, and major Tertiary igneous intrusives in Lincoln and Otero Counties, New Mexico.

between the Great Plains and the Southern Rocky Mountains or Basin and Range provinces (Fig. 2). These deposits have enough similar characteristics that, given their common tectonic setting, they define a class of ore deposits called the Great Plains margin deposits (GPM; North and McLemore, 1986, 1988). The most economically important metal deposits in Lincoln and Otero Counties are GPM (Table 1). GPM deposits contain both base and precious metals (Table 3). GPM deposits are spatially associated with deposits of iron, molybdenum (Nogal), rare-earth elements (Gallinas), fluorite, tungsten (White Oaks) and niobium.

The association of mineralization with alkalic rocks in these districts is unclear. Alkalic rocks (commonly porphyritic) are found in most districts and are genetically related to porphyritic silica-saturated (monzonite) or silica-oversaturated (quartz monzonite) rocks. Mineralization is usually spatially associated with silica-saturated or silica-oversaturated rocks. Alkalic rocks coincide with the margin between the Great Plains and Rocky Mountains–Basin and Range from Mexico northward into Canada. One of the problems in Lincoln County is the lack of detailed studies of the petrology and petrogenesis of the igneous intrusives. Recent work by Allen and Foord (1991) will aid in our understanding of the relationship of these deposits and associated igneous intrusives.

These deposits usually consist of three associated deposit types: (1) gold-bearing breccia pipes and quartz veins, (2) copper and/or lead/zinc skarns, and (3) iron skarns. Placer gold deposits are found near many of these deposits.

The intrusive breccia-pipe deposits are important producers of gold in the Ortiz area of the Old Placers district, Santa Fe County, as well as in the Nogal and White Oaks district, Lincoln County (Fig. 2, nos. 6, 13). Quartz veins and breccia pipes cutting both intrusive rocks and enclosing sedimentary rocks have been important producers of precious metals at the White Oaks and Elizabethtown-Baldy districts (Fig. 2, nos. 11, 1), and have probably contributed significantly to the placer deposits in those districts. Breccia pipes also occur at Jicarilla, New Placers and Nogal (Fig. 2, nos. 10, 7, 13). Breccia fragments range as large as 0.3 m in diameter and have been altered to clay minerals (Griswold, 1959). Most breccia fragments are altered beyond recognition. The vein and breccia deposits contain gold and silver, typically associated with pyrite, with quartz and a variety of other gangue minerals. The veins have high gold/base metal ratios and typically low silver/gold ratios compared to other gold/silver deposits in New Mexico (North and McLemore, 1988). Intrusive breccia pipes in the Gallinas Mountains may also contain similar precious metals deposits (Perhac, 1970). Lead, zinc, copper, fluorite, silver and rare earths have been produced from vein deposits in the Gallinas district (Fig. 2, no. 9), which may be another variation of this type.

Copper skarn deposits are common in deposits of this type, and smaller lead-zinc skarns occur at the Orogrande district (Fig. 2, no. 15). Primary copper mineralization consists of chalcopyrite in a gangue of quartz, garnet, epidote, diopside, other calc-silicates, hematite and calcite. Cretaceous carbonaceous shale and Paleozoic limestone host the skarn mineralization.

The relationship of iron skarns to other metal mineralization is uncertain. Districts with reported iron skarns include Elizabethtown-Baldy, Old Placers, New Placers, Gallinas, White Oaks, Jicarilla and Orogrande (Kelley, 1949). Numerous additional iron skarns occur in the Lincoln County area (Fig. 1). Anomalous gold (>0.6 ppm) and silver (>15 ppm) have been found in samples from the Capitan Mountains iron skarn deposits in Lincoln County (North and McLemore, 1986; McLemore and Phillips, 1991). These iron deposits do not contain recoverable gold or silver, but their occurrence in close proximity to the copper skarn and gold-silver vein deposits in these districts in this region is interesting. The iron skarns are in host rocks similar to the copper skarns, and contain predominantly magnetite and specular hematite with garnet, epidote, diopside and other calc-silicates.

The close proximity of GPM deposits with other mineral deposits probably has some relationship to the origin and genesis of the GPM deposits. Molybdenum deposits occur in the Nogal district (Giles and Thompson, 1972; Thompson, 1973) and anomalously high concentrations of molybdenum are present at the Vera Cruz mine (Vera Cruz Minerals Corp., news release, 12 January 1989; Ryberg, 1991, this guidebook). About 120,000 pounds of tungsten have been produced from quartz veins and breccia deposits in Lincoln County, mostly from the White Oaks district (Griswold, 1959). Rare-earth elements occur in anomalously high concentrations in the Gallinas Mountains (Perhac, 1970), Capitan Mountains (McLemore and Phillips, 1991) and Cornudas Mountains (McLemore et al., 1988a, b). Fluorite occurs in the Capitan Mountains, Gallinas, Jicarilla, Nogal, Schelerville and Orogrande districts (Griswold, 1959). Anomalously high concentrations of niobium occur in the Capitan Mountains (McLemore and Phillips, 1991) and Cornudas Mountains (V. T. McLemore, unpublished data).

The origin and genesis of the GPM and associated deposits are not clear. They coincide with a belt of alkalic igneous rocks and crustal thickening (Bird, 1984) in New Mexico, which follows the tectonic boundary from Texas to Colorado between the tectonically stable Great Plains and tectonically active Rocky Mountains and Basin and Range. For simplification, in this paper the Rio Grande rift is defined as part

TABLE 1. Base and precious metal production from mining districts in Lincoln and Otero Counties, New Mexico. Estimated production data by the author are in parentheses. GPM—Great Plains margin deposits. W—Figures withheld to protect company confidentiality. *Production from the Bent district may be lower than actual production.

District	Period of production	Ore (short tons)	Copper (pounds)	Gold (troy ounces)	Silver (troy ounces)	Lead (pounds)	Zinc (pounds)	Type of Deposit	References
Lincoln County									
Estey	1900-1910	234	42,265 (444,000)	---	124	---	---	Sedimentary copper	Soulé (1956), Jones (1965)
Capitan Mountains	none	---	---	---	---	---	---	GPM	North and McLemore (1986)
Gallinas	1909-1955	5,367	385,418	6.58	23,723	1,726,738	17,344	GPM, sedimentary copper	NMBMMR files, USBM Mineral Yearbooks, Perhac (1964, 1970)
Jicarilla	1912-1957	53,307	4,201,474	7,347 (lode) 8,000 (placer)	37,531	2,665	---	GPM, placer	USBM files, Johnson (1972), USBM Mineral Yearbooks
Nogal	1865-1941 1868-1942	59,883 ---	W ---	7,725 (15,000) 200 (placer)	18,193 (20,000)	W ---	W ---	GPM, placer	USBM files, Johnson (1972, North and McLemore (1986)
Schelerville		---	W	minor	W	W	---	GPM	North and McLemore (1986)
White Oaks	1850-1942	---	W	(163,500) 1,000 (placer)	(1,000)	W	---		
	1933-1951	2,679	450	1,432	1,044	12,200	---	GPM, placer	USBM Mineral Yearbooks, Johnson (1972), North and McLemore (1986)
Otero County									
Bent (Tularosa)*	1906-1957	14,260	2,400	---	1,189	---	---	Sedimentary copper, Proterozoic	USBM Mineral Yearbooks
Cornudas Mountains	none	---	---	---	---	---	---	GPM	North and McLemore (1986)
Orogrande (Jarilla)	1904-1966 1879-1966	136,813 ---	5,695,066 ---	15,089 (16,500) 2,000 (placer)	45,477 (50,000)	157,661 ---	--- ---	GPM, placer	USBM Mineral Yearbooks, Johnson (1972), North and McLemore (1986)
Sacramento (High Rolls)	1913-1957 1908-1962	5,253 ---	106,193 260,570	3.82 ---	891 ---	309,500 1,915,500	--- ---	Sedimentary copper, Proterozoic	Lasky and Wootton (1933), USBM Mineral Yearbooks
Tularosa	none	---	---	---	---	---	---	Sedimentary copper	North and McLemore (1986)

TABLE 2. Age and tectonic setting of base and precious metal deposits in Lincoln and Otero Counties (modified from North and McLemore, 1988).

Age	Tectonic Setting	Type of Deposit	Major Metals
Late Tertiary to Quaternary	Areas of uplift with typically steep gradients and high amount of weathering and oxidation	Placer gold	Au
Mid-Late Tertiary (~40-5 Ma)	At the margin of stable tectonic environment (Great Plains) with tectonically active terranes (Rocky Mountains, Basin and Range, Rio Grande rift)	Great Plains margin (GPM)	Au, Ag, Cu, Pb, Zn, Fe, REE, Mo, W, fluorite (±U, Th)
Permian(?)	Stable continental platform with clastic sedimentation	Sedimentary copper (red-bed copper)	Cu, Ag, U (±Pb)
Proterozoic(?)	Largely unknown	Veins and replacement	Au, Ag, Cu

of the Basin and Range tectonic province (Fig. 2). This belt of alkalic rocks continues northward into Canada and southward into Mexico (Clark et al., 1982), and some of the ore deposits in other areas along this trend (e.g., Cripple Creek, Colorado and Golden Sunlight, Montana) are geologically similar. In Lincoln County, this alkalic belt intersects the Capitan lineament, a major west-northwest-trending zone which transverses central New Mexico (see Day 3 road log). It is characterized by the alignment of various igneous and structural features (Kelley and Thompson, 1964; Chapin et al., 1978) and periodically has leaked magma since about 33 Ma. The diversity of associated igneous rocks and mineral deposit types suggests that the boundary of the Great Plains with the Rocky Mountains and Basin and Range is a region of highly fractionated and differentiated magmas, perhaps involving upper mantle and lower crustal sources.

It has not yet been proven that these ore deposits are genetically related to the igneous rocks. However, supporting evidence for a magmatic origin includes: (1) fluid inclusion and isotopic evidence from the Capitan quartz veins (Phillips, 1990; Phillips et al., 1991), (2) nature of stockwork molybdenum deposits at Sierra Blanca (Giles and Thompson, 1972), (3) close spatial association with igneous rocks, (4) presence of skarn deposits along the contacts of the igneous rocks, and (5) similarity to other deposits at Cripple Creek, Colorado and Ortiz, New Mexico, where a magmatic origin is favored (Thompson et al., 1985; Maynard et al., 1990). It is likely that the co-occurrence of gold, copper, iron, molybdenum, fluorite, tungsten, and possibly rare earths, thorium, uranium and niobium is the result of several different complex magmatic fractionation and differentiation events and tectonic subenvironments which overlap near the Great Plains margin, perhaps as a complex zoned system, as suggested by Rice et al. (1985) for Mo-Au-fluorite mineralization at Central City, Colorado (also along this trend). Additional petrographic, geochemical and isotopic studies are required in this area to completely understand the origin and genesis of the GPM deposits.

Future exploration along the Great Plains margin will doubtless concentrate on the large, low-grade, bulk-minable breccia-pipe deposits similar to the Ortiz deposits in the Old Placers district. Similar breccias in the Gallinas, Nogal, Jicarilla and Orogrande districts should be examined for possible gold potential. Copper skarn deposits may possibly be exploited on a smaller scale.

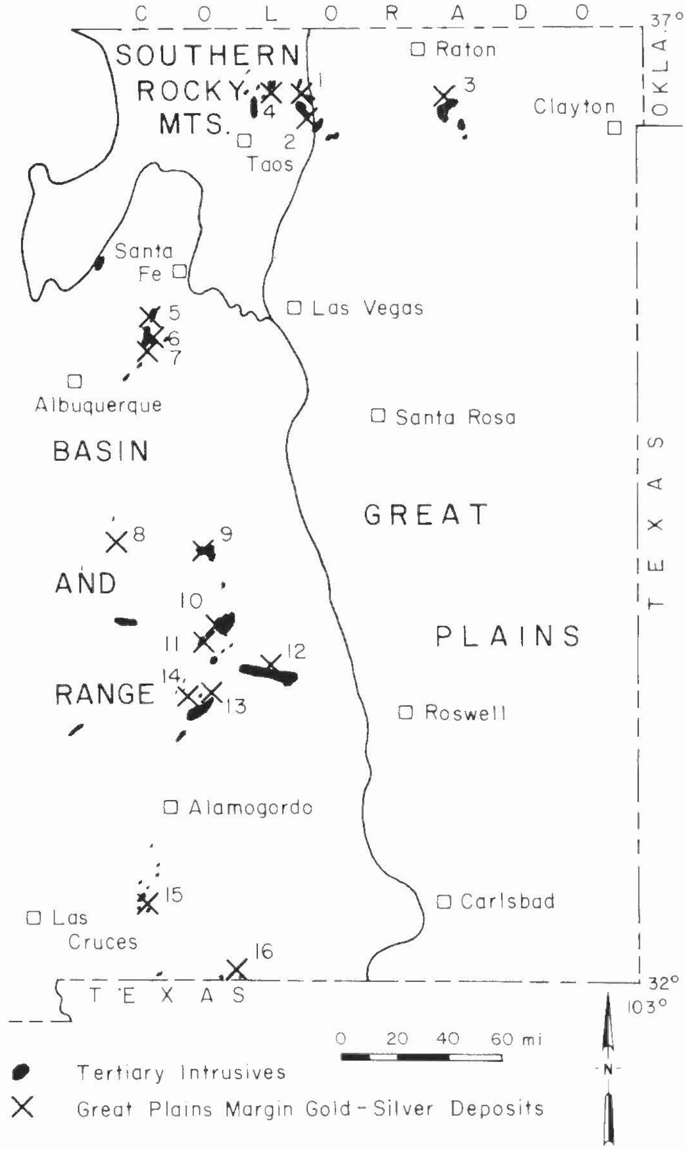

FIGURE 2. Great Plains margin gold-silver deposits in New Mexico (North and McLemore, 1988, 1986). Physiographic provinces and Tertiary igneous intrusives from New Mexico Geological Society (1982). 1—Elizabethtown-Baldy; 2—Cimarroncito; 3—Laughlin Peak area; 4—Red River; 5—Cerrillos; 6—Old Placers; 7—New Placers; 8–Chupadera; 9—Gallinas; 10—Jicarilla; 11—White Oaks; 12—Capitan; 13—Nogal; 14—Schelerville; 15—Orogrande; 16—Cornudas Mountains.

Stratabound, sedimentary-copper deposits (Permian)

Local high concentrations of copper and silver occur in stratabound, sedimentary-copper deposits in red-bed sequences deposited within tectonically stable intracratonic basins, many without any known associated igneous activity. These deposits have been called "sandstone" or "red-bed" copper deposits (Soulé, 1956; Phillips, 1960) even though mineralization is not restricted to sandstones and may also occur in bleached gray, green or tan sandstones, shales, siltstones and limestones within the red-bed sequences. In Lincoln and Otero Counties, production generally has been insignificant (Table 1).

This type of stratabound mineralization typically occurs in Pennsylvanian through Triassic formations in New Mexico. Deposits in Lincoln and Otero Counties occur only in Permian rocks as disseminations or cement within host rocks, along fractures, bedding planes and contact zones, and as replacements of wood or other organic material. The distribution of most ore deposits is controlled by sedimentary features

TABLE 3. Grade from selected Great Plains margin deposits in New Mexico. (1) U.S. Bureau of Mines mineral yearbooks supplemented by U.S. Bureau of Mines files; (2) New Mexico Bureau of Mines and Mineral Resources files; and (3) Gold Fields Ltd. Annual Reports, 1982–1985. Number refers to Fig. 2.

District (period of production)	Au (oz/ton)	Grade Ag (oz/ton)	Cu %	Pb %	Source
15 Orogrande (1904-1966)	0.11	0.33	2.1	0.05	1
13 Nogal (1902-1953)	0.13	0.30	---	---	1
10 Jicarilla (1912-1957)	0.14	0.70	3.9	---	1
01 Elizabethtown-Baldy (1904-1936)	0.86	0.17	---	---	1
11 White Oaks (1933-1951)	0.52	0.39	0.008	0.2	1
07 New Placers (1909-1938)	0.05	1.19	2.4	---	1,3
09 Gallinas (1909-1935)	0.001	5.56	4.6	20.11	2

such as bedding and crossbedding, paleochannels and intraformational slumping, although local structures, such as folds and fractures, appear to control mineralization in some areas (McLemore and North, 1985). This apparent control by sedimentary features suggests that this mineralization occurred during deposition of the sediment or during early diagenesis. Ore bodies in Lincoln and Otero Counties range in size from small occurrences containing less than one ton of ore to medium-sized deposits of several thousand tons of ore. In general, these deposits are low grade (less than 1% copper), although some small high-grade (greater than 1% copper) deposits may occur locally. Some deposits in the Sacramento and Bent districts contain minor concentrations of uranium (<0.20% U_3O_8; McLemore and Chenoweth, 1989). Deposits in the Sacramento district are unlike most sedimentary copper deposits in New Mexico in that they are spatially associated with Tertiary andesite sills and dikes. However, no associated alteration of the dikes is evident. However, the lead-rich bodies tend to occur nearest these dikes and sills and the copper-rich bodies are downdip of the intrusives.

Copper, silver and associated minerals probably were transported in low-temperature solutions through permeable sediments and along bedding planes, fractures and contact zones. Although the geochemistry of the mineralizing fluids is not precisely known, soluble chloride, carbonate, bicarbonate and organic complexes could transport these metals in low-temperature solutions, such as ground water. Precipitation occurs at favorable oxidation-reduction interfaces, typically in the presence of organic materials or H_2S-brines, although precipitation could occur with any change in Eh or pH conditions. The ore metals probably were derived from ordinary trace amounts present in rock-forming minerals in Proterozoic rocks in the highlands near the deposits or in clay minerals within the host rocks. Intrusives in the Sacramento district may have remobilized the deposits there; however, detailed geologic and geochemical work is necessary to test this hypothesis.

The economic potential for copper, silver, gold and other associated elements in stratabound, sedimentary-copper deposits in Lincoln and Otero Counties and elsewhere in New Mexico is considered poor due to low grade, small tonnage and poor accessibility to existing mills.

Veins and replacements in Proterozoic rocks

A few copper veins and replacements along shear zones, with some gold and silver, occur in Proterozoic rocks in the Bent and Sacramento districts in Otero County (Table 1, Fig. 1). In general, these vein deposits are small, low grade and of minor importance. The age of these deposits is uncertain and sometimes they are assigned a Proterozoic age because they appear to be restricted to Proterozoic rocks. They may represent potential source areas for younger deposits. They are of minor economic importance due to their small size and low grade.

SUMMARY

The most economically important mineralization in Lincoln and Otero Counties is of Tertiary to late Quaternary age. Late Tertiary to Quaternary placer gold deposits occur in several districts. Low-grade but large-tonnage placers may occur in the Jicarilla district, and smaller deposits may occur in the White Oaks, Nogal and Orogrande districts. GPM deposits in this area are mid-late Tertiary and are also economically important. Breccia pipes and quartz veins in Lincoln and other counties have potential for large, low-grade bulk-minable deposits similar to the Ortiz deposits in Santa Fe County. Copper skarn deposits may possibly be exploited on a smaller scale. The age, origin and genesis of the GPM deposits are uncertain. Additional detailed geologic mapping and geochemical, petrologic and geophysical studies are required to refine our understanding of the mineralization processes in this region.

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REFERENCES

Allen, M. and Foord, E., 1991, Geochemical and isotopic characteristics of the Lincoln County porphyry belt, New Mexico: implications for regional tectonics and mineral deposits: New Mexico Geological Society, Guidebook 42.

Bird, P., 1984, Laramide crustal thickening event in the Rocky Mountain foreland and Great Plains: Tectonics, v. 3, p. 741–758.

Chapin, C. E., Chamberlin, R. M., Osburn, G. R., White, P. W. and Sanford, A. R., 1978, Exploration framework of the Socorro geothermal area, New Mexico: New Mexico Geological Society, Special Publication No. 7, p. 115–129.

Clark, K. F., Foster, C. T. and Damon, P. E., 1982, Cenozoic mineral deposits and subduction-related magmatic arcs in Mexico: Geological Society of America Bulletin, v. 93, p. 533–544.

Giles, D. L. and Thompson, T. B., 1972, Petrology and mineralization of a molybdenum-bearing alkalic stock, Sierra Blanca, New Mexico: Geological Society of America Bulletin, v. 83, p. 2129–2148.

Griswold, G. B., 1959, Mineral deposits of Lincoln County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 67, 117 p.

Johnson, M. G., 1972, Placer gold deposits of New Mexico: U.S. Geological Survey, Bulletin 1348, 46 p.

Jones, W. R., 1965, Copper; *in* Mineral and water resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 87, p. 160–176.

Kelley, V. C., 1949, Geology and economics of New Mexico iron ore deposits: University of New Mexico, Publications in Geology, no. 2, 246 p.

Kelley, V. C. and Thompson, T. B., 1964, Tectonics and general geology of the Ruidoso-Carrizozo region, central New Mexico: New Mexico Geological Society, Guidebook 15, p. 110–121.

Lasky, S. G. and Wootton, T. P., 1933, The metal resources of New Mexico and their economic features: New Mexico Bureau of Mines and Mineral Resources, Bulletin 7, 178 p.

Maynard, S. R., Nelson, C. J., Martin, K. W. and Schultz, J. L., 1990, Geology and gold mineralization of the Ortiz Mountains, Santa Fe County, New Mexico: Mining Engineering, August, p. 1007–1011.

McLemore, V. T. and Chenoweth, W. L., 1989, Uranium resources in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Map 18, 36 p.

McLemore, V. T. and North, R. M., 1985, Copper and uranium mineralization in east-central New Mexico: New Mexico Geological Society, Guidebook 36, p. 289–299.

McLemore, V. T., North, R. M. and Leppert, S., 1988a, Rare-earth elements (REE) in New Mexico: New Mexico Geology, v. 10, p. 33–38.

McLemore, V. T., North, R. M. and Leppert, S., 1988b, Rare-earth elements (REE), niobium and thorium districts and occurrences in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 324, 28 p.

McLemore, V. T. and Phillips, R., 1991, Geology of mineralization and associated alteration in the Capitan Mountains, Lincoln County, New Mexico: New Mexico Geological Society, Guidebook 42.

New Mexico Geological Society, 1982, Geologic highway map of New Mexico: New Mexico Geological Society, scale 1:1,000,000.

North, R. M. and McLemore, V. T., 1986, Silver and gold occurrences in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Map 15, 32 p., scale 1:1,000,000.

North, R. M. and McLemore, V. T., 1988, A classification of the precious metal deposits of New Mexico; *in* Bulk minable precious metal deposits of the western United States symposium volume: Geological Society of Nevada, Reno, p. 625–660.

Perhac, R. M., 1964, Notes on the mineral deposits of the Gallinas Mountains, New Mexico: New Mexico Geological Society, Guidebook 15, p. 152–154.

Perhac, R. M., 1970, Geology and mineral deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 95, 51 p.

Phillips, J. S., 1960, Sandstone-type copper deposits of the western United States [Ph.D. dissertation]: Cambridge, Harvard University, 320 p.

Phillips, R. S., 1990, Geochemistry of the hydrothermal Th-U-REE quartz/fluorite veins from the Capitan Pluton [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 202 p.

Phillips, R. S., Campbell, A. R. and McLemore, V. T., Th-U-REE quartz/fluorite veins, Capitan pluton, New Mexico: evidence for a magmatic/hydrothermal origin: New Mexico Geological Society, Guidebook 42.

Rice, C. M., Harmon, R. S. and Shepherd, T. J., 1985, Central City, Colorado: the upper part of an alkaline porphyry molybdenum system: Economic Geology, v. 80, p. 1769–1785.

Schmidt, P. G. and Craddock, C., 1964, The geology of the Jarilla Mountains, Otero County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 82, 55 p.

Segerstrom, K. and Ryberg, G. E., 1974, Geology and placer-gold deposits of the Jicarilla Mountains, Lincoln County, New Mexico: U.S. Geological Survey, Bulletin 1308, 25 p.

Soulé, J. H., 1956, Reconnaissance of the "red bed" copper deposits in southeastern Colorado and New Mexico: U.S. Bureau of Mines, Information Circular 7740, 74 p.

Thompson, T. B., 1973, Mineral deposits of Nogal and Bonito mining districts, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 123, 30 p.

Thompson, T. B., Trippel, A. D. and Dwelley, P. C., 1985, Mineralized veins and breccias of the Cripple Creek district, Colorado: Economic Geology, v. 80, p. 1669–1685.

The American Placer Company installed this cantilever-type placering machine and attempted to work the gold placers along Ancho Gulch in the Jicarilla district during 1903–4. Manufactured by W. M. Johnston & Co. of Chicago, the machine was not a dredge, as often stated, because it did not float on water. The machine weighed nearly 200 tons and was doubtless difficult to maneuver. That fact, coupled with too much overburden and too little water, led to its failure. Photo by Fayette A. Jones, 1904; courtesy of Museum of New Mexico.