Precious- and base-metal districts in Rio Arriba and Sandoval Counties, New Mexico

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in:
San Juan Basin IV, Lucas, S. G.; Kues, B. S.; Williamson, T. E.; Hunt, A. P.; [eds.], New Mexico Geological Society
43rd Annual Fall Field Conference Guidebook, 411 p. https://doi.org/10.56577/FFC-43

This is one of many related papers that were included in the 1992 NMGS Fall Field Conference Guidebook.

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INTRODUCTION

Precious (silver, gold) and base (copper, lead, zinc) metals have been important to the economy of New Mexico since the mid-1880s. These metals occur widely throughout New Mexico in a variety of deposit types (Lindgren et al., 1910; North and McLemore, 1986, 1988). The production of precious and base metals in Rio Arriba and Sandoval Counties has been of lesser importance compared to metal production elsewhere in the state, and especially when compared to production of oil, gas, uranium and coal from these counties. However, a few districts in this area have produced moderate amounts of one or more metals (relative to total New Mexico production). For example, over 7.6 million lbs of copper have been produced from the Nacimiento district; it ranks eleventh as a placer gold district in the state (Johnson, 1972; North and McLemore, 1988). Total production from these two counties is estimated at 8 million lbs of copper, 66,000 oz of gold, 284,000 oz of silver, 41,000 lbs of lead, and 1000 lbs of zinc (Table 1).

This paper provides precious- and base-metal production statistics, mining history, and brief description of the geology and mineral deposits of the metal-mining districts in Rio Arriba and Sandoval Counties.

PRODUCTION

Known and/or estimated production is given by district in Table 1 and each district is located in Fig. 1. Production data is derived from many sources of varying reliability; some of the production records for New Mexico are chaotic at best. Previous publications have incorrectly reported total production for various reasons; these have been resolved as well as possible. Because of the chaotic nature of some records I expect continuing updates and corrections will be necessary as work in specific districts progresses.

DESCRIPTION OF MINERAL DEPOSITS

Five types of precious- and base-metal deposits are found in Rio Arriba and Sandoval Counties (Fig. 1). The deposit types were described by North and McLemore (1986, 1988) and the reader is referred to these publications for more detail. Brief descriptions of types of mineral deposits, and some examples of mining districts in Rio Arriba and Sandoval Counties (Table 1) are presented here.

Placer deposits

Placer gold deposits are found in the Hopewell, Placitas and Chama placer districts (Fig. 1) in Rio Arriba and Sandoval Counties, but very little production is recorded and economic potential is minimal. Most

### TABLE 1. Precious- and base-metal production from districts in Rio Arriba and Sandoval Counties, New Mexico. Values in parentheses are estimated figures.

<table>
<thead>
<tr>
<th>District</th>
<th>Years of Production</th>
<th>Ore (short tons)</th>
<th>Copper (pounds)</th>
<th>Gold (troy ozs)</th>
<th>Silver (troy ozs)</th>
<th>Lead (pounds)</th>
<th>Zinc (pounds)</th>
<th>Estimated Value</th>
<th>Type of Deposits¹</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromide district</td>
<td>1881-1940</td>
<td>—</td>
<td>—</td>
<td>(20,000)</td>
<td>(4,500)</td>
<td>—</td>
<td>—</td>
<td>400,000</td>
<td>E,A</td>
<td>Elston(1967)</td>
</tr>
<tr>
<td>Hopewell district</td>
<td>1881-1919</td>
<td>some</td>
<td>(24,000)</td>
<td>(10,000)</td>
<td>some</td>
<td>—</td>
<td>—</td>
<td>400,000</td>
<td>E,A</td>
<td>Elston(1967)</td>
</tr>
<tr>
<td></td>
<td>1933-1940</td>
<td>1,445</td>
<td>400</td>
<td>94</td>
<td>734</td>
<td>7,100</td>
<td>—</td>
<td>—</td>
<td>D</td>
<td>USBM Mineral Yearbooks</td>
</tr>
<tr>
<td>Chama placers</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>A</td>
<td>Johnson (1972)</td>
</tr>
<tr>
<td>Chama Canyon prospects</td>
<td>none</td>
<td>—</td>
<td>—</td>
<td>(&lt;100)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>D</td>
<td>Light (1982, 1983)</td>
</tr>
<tr>
<td>Coyote district²</td>
<td>1956-1957</td>
<td>462,000</td>
<td>—</td>
<td>841</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1,100,000</td>
<td>D,E</td>
<td>Elston(1967)</td>
</tr>
<tr>
<td>Nacimiento district</td>
<td>1880-1964</td>
<td>7,561,567</td>
<td>0.4</td>
<td>75,068</td>
<td>1,783</td>
<td>463</td>
<td>—</td>
<td>1,100,000</td>
<td>D,E</td>
<td>Elston(1967)</td>
</tr>
<tr>
<td></td>
<td>1900-1964</td>
<td>26,786</td>
<td>1,261,567</td>
<td>12,068</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>D,E</td>
<td>Elston(1967)</td>
</tr>
<tr>
<td>Jemez Springs district</td>
<td>1928-1937</td>
<td>233</td>
<td>19,200</td>
<td>1</td>
<td>159</td>
<td>—</td>
<td>—</td>
<td>4,000</td>
<td>D</td>
<td>Elston(1967)</td>
</tr>
<tr>
<td>Chama district</td>
<td>1894-1963</td>
<td>205,000</td>
<td>2,500</td>
<td>42,000</td>
<td>210,000</td>
<td>22,457</td>
<td>—</td>
<td>1,400,000</td>
<td>B</td>
<td>Elston(1967); USBM Mineral Yearbooks, Lindgren et al. (1910)</td>
</tr>
<tr>
<td>Placitas district</td>
<td>1904-1961</td>
<td>39</td>
<td>2,441</td>
<td>49</td>
<td>48</td>
<td>10,357</td>
<td>580</td>
<td>3,000</td>
<td>A,C,D,E</td>
<td>USBM Mineral Yearbooks</td>
</tr>
<tr>
<td>TOTAL ESTIMATED PRODUCTION</td>
<td>1880-1975</td>
<td>8,000,000</td>
<td>66,000</td>
<td>284,000</td>
<td>41,000</td>
<td>1,000</td>
<td>2,900,000</td>
<td>—</td>
<td>These statistics probably reflect conservative totals</td>
<td>—</td>
</tr>
</tbody>
</table>

¹Types of deposits: A = placer gold; B = volcanic-epithermal vein; C = sedimentary-hydrothermal barite-fluorite-galena; D = sedimentary-copper; E = Precambrian vein and replacement deposits. ²Does not include production from confidential and withheld.
of the placer gold deposits were formed by late Tertiary through Recent
depositions that are hosted by volcanic rocks. One of the most economically
attractive exploration targets in Rio Arriba and Sandoval Counties are
volcanic-epithermal veins in the Cochiti district in the Jemez Mountains
(Bundy, 1958). Additional investigation is required.

Cochiti district

The Placitas district in the northern Sandia Mountains (Fig. 1) is the
youngest volcanic epithermal districts in New Mexico.

The mineralized veins in the Cochiti district occur in north-trending,
steeply dipping faults and fractures that cut Miocene andesitic volcanic
and felsic intrusive rocks. Multiple episodes of vein filling, stockwork
zones and brecciation have occurred. Mineralized veins are up to 460
m long and 15 m wide (Bundy, 1958; Stein, 1983) and consist pre-
donently of quartz, with small amounts of sulfides and calcite. Sulfide
minerals are sparse, rarely exceeding a few percent, and consist of
pyrite, sphalerite, chalcopyrite, covellite, galena, argentite and prous-
tite-pyrrhotite. Native gold and electrum also occur in the veins (Wron-
kiewicz et al., 1984). Fluid inclusion data indicates mineral deposition
occurred at or above boiling, at temperatures between 240°C and 315°C,
by low salinity fluids (less than 5 wt% eq. NaCl; Wronkiewicz et al.,
1984). Alteration of the host rock is zoned from regional propylitization
(farthest from veins) to advanced argillic alteration to silicification (near-
est veins; Parkison et al., 1985). Clay minerals are zoned from chlorite-
montmorillonite farthest from the vein to vermiculite-halloysite to illite-
kaolinite to dickite nearest the vein (Bundy, 1958). An epithermal origin
is proposed for these deposits, where episodic boiling of mineralized
solutions resulted in deposition of vein minerals and alteration of the
host rock (Wronkiewicz et al., 1984).

Crucés Basin prospects

Very little is known concerning the deposits in the Crucés Basin in
northern Rio Arriba County (Fig. 1). Silver concentrations as high as
0.9 oz/ton (31 ppm) are reported and are associated with manganese
mineralization along fractures and faults in the Conejos quartz latite
(Tertiary) and underlying Precambrian gneiss and pegmatites (Hanni-
gan, 1984). Additional investigation is required.

Sedimentary-hydrothermal barite-fluorite-galena deposits

The Placitas district in the northern Sandia Mountains (Fig. 1) is the
only district known to contain sedimentary-hydrothermal barite-fluorite-
galena deposits in Rio Arriba and Sandoval Counties. The lack of
obvious magmatic activity in the Placitas district suggests these deposits
were formed by sedimentary-hydrothermal processes. Sedimentary-
hydrothermal deposits are common throughout the Rio Grande rift (Beane,
1974; Allmendinger, 1975, 1974; Putnam et al., 1983; McLemore and
Barker, 1985). Water is trapped within basin sediments during depo-
sition and after burial by dehydration of minerals, chemical reactions,
migmatism and downward percolation of meteoric waters. These formation waters are heated by compression and compaction during burial and further warmed by convection from deeper sources, radiogenetic heat from the Sandia granite, and high heat flow associated with the Rio Grande rift. The heated formation waters leached metals and other ions from Precambrian rocks and Paleozoic sedimentary rocks. Precipitation occurred by cooling of hydrothermal waters, degassing and/or mixing of waters.

**Placitas mining district**

Little is known about the mining history of the Placitas district. A group of mines along the Cuchillo de San Francisco were mined for copper ores; potsherds found in one of these mines were dated at 1500–1550 A.D. (Warren and Weber, 1979). Metal mining did not begin until the arrival of the railroad in 1880. Production prior to 1904 is unknown, and production after 1904 is minor and amounts to less than $3000 (Table 3).

Numerous small deposits, only a few of which have been developed, occur throughout the district and include placer gold, sedimentary-hydrothermal barite-fluorite-galena, sedimentary copper, and base- and precious-metal veins and replacements in Precambrian rocks (Kelley and Northrop, 1975; McLemore et al., 1984). The most important deposits are sedimentary-hydrothermal deposits. Most of the veins in the Placitas district occur along or near faults in Pennsylvanian and Mississippian sedimentary units and in the Precambrian Sandia Granite. Typically the base- and precious-metal veins, with or without accessory barite and fluorite, occur in the vicinity of the sedimentary-hydrothermal barite-fluorite-galena veins. Base-metal veins consist of copper, lead and zinc minerals with minor silver, whereas precious-metal veins consist of silver and gold with minor copper and lead minerals. The barite-fluorite-galena veins consist primarily of barite with accessory fluorite and argentiferous galena. The veins are 0.6–0.9 m wide and up to several thousand meters long. The depth and age of the veins are unknown.

Chemical analyses from four barite-fluorite-galena deposits range from 0.10 to 0.46 oz/ton (3–16 ppm) silver, 0.19 to 4.99% lead, 0.001 to 0.65% zinc, and 0.001 to 0.12% copper (McLemore et al., 1984). Hedlund et al. (1984) reported 0.43 oz/ton (14 ppm) silver from the La Luz base-metal mine and Hendzel et al. (1983) reported 6 oz/ton (200 ppm) silver from a strip mine in sec. 1, T12N, R4E and >20,000 ppm Pb from the La Luz mine. Many of the prospects and mines have been reclaimed by the U.S. Forest Service.

The origin of mineralization in the Precambrian rocks in the Placitas district is unknown. The mineralization may be related to the base-metal and barite-fluorite-galena veins in Paleozoic sediments. However, a Precambrian age is also possible. Several periods of mineralization may have occurred, and very few data exist concerning these deposits.

**Sedimentary-copper deposits**

Stratabound sedimentary-copper deposits containing copper, silver, and locally gold, lead, zinc, uranium, vanadium and molybdenum occur throughout the Nacimiento and Jemez Mountains in Rio Arriba and Sandoval Counties (Fig. 1). These deposits are similar and are discussed in Table 3.

<table>
<thead>
<tr>
<th>Year</th>
<th>Ore (short tons)</th>
<th>Copper (lbs)</th>
<th>Gold (oz)</th>
<th>Silver (oz)</th>
<th>Lead (lbs)</th>
<th>Zinc (lbs)</th>
<th>Total Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904</td>
<td>24,411</td>
<td>39</td>
<td>49</td>
<td>48</td>
<td>10,357</td>
<td>580</td>
<td>2,329</td>
</tr>
</tbody>
</table>

**Precambrian vein and replacement deposits**

Vein and replacement deposits containing precious and base metals occur sporadically through most of the Precambrian terranes in New Mexico, including those in Rio Arriba and Sandoval Counties. The two major districts are the Hopewell and Bromide in the Tusas Mountains (Fig. 1), although small veins also occur in the Nacimiento Mountains and Placitas district. The Hopewell and Bromide districts were once part of a single district, the Headstone mining district, but were sep-
arated in the late 1800s (Lindgren et al., 1910). The age of mineralization is uncertain in these districts, but data suggest a Precambrian age. The deposits are structurally controlled by schistosity or shear zones of Precambrian age and therefore are post-tectonic but probably synmetamorphic.

Most of the precious-metal vein and replacement deposits in Precambrian terranes are small and low-grade, although high assays for silver and gold occur sporadically. Some of the world’s largest gold deposits occur in Precambrian greenstone terranes; similar areas in New Mexico should be examined for their silver and gold potential.

**Hopewell mining district**

Placer gold was discovered in the Hopewell district in the 1870s (Lindgren et al., 1910). Total production from the Fairview area in Placer Creek is estimated at $300,000 (Lindgren et al., 1910), with an estimated $175,000 of that in just three years (Bingler, 1968, 1974). By 1881, lode gold deposits were found in the Proterozoic rocks. Gold, silver, copper and lead were mined from the upper oxidized zone, but the amount of this early production is not known (Table 1). By 1890, mining was significantly diminished as the oxidized deposits were depleted. In 1903, a hydraulic operation was set up in Placer Creek to recover placer gold, but the operation was unsuccessful and lasted only a year (Bingler, 1968, 1974). Sporadic exploration and minor production have occurred since the early 1900s (Table 1), but with little success.

In 1935, the Amarillo Gold Co. acquired the Mineral Point claim and constructed a 30-ton mill. About 3500 tons of ore were processed; grades were reportedly 0.15 oz/t Au (5 ppm), 1–1.5 oz/t Ag (34–51 ppm), 0.5% Pb, 0.15% Cu and 0.5% Zn (Benjovsky, 1945). This operation also proved unsuccessful and closed in 1937.

Placer gold deposits occur along Placer Creek west of Hopewell Lake, where free gold is found in the alluvial stream gravels. The gold is probably derived from erosion of lode deposits in the Proterozoic rocks (Bingler, 1968, 1974).

The lode deposits in the Hopewell district consist of structurally controlled hydrothermal sulfide veins and replacement deposits, and quartz and quartz-carbonate veins in phyllite and schist of the Proterozoic Moppin metavolcanic series (Wobus and Manley, 1982; Robertson et al., 1986; Boadi, 1986). The replacement deposits consist of tabular stringer and veinlet zones within sheared, sericitic zones less than a meter thick in the Proterozoic rocks. The minerals include pyrite, chalcopyrite, galena, sphalerite, specular hematite and fluorite. Minor amounts of arsenopyrite and stibnite also occur (Boadi, 1986). Gold is associated with pyrite and chalcopyrite (Bingler, 1968, 1974; Boadi, 1986).

Hydrothermal veins up to a meter thick are associated with the replacement deposits and are mainly concordant to the foliations in the Proterozoic rocks. The veins consist of massive quartz, siderite, li-monite after pyrite, native gold and tourmaline. Sixteen samples from the Croesus mine ranged as high as 2 oz/t Au (68 ppm) and 2 oz/t Ag (68 ppm) (Bingler, 1968). Seventy-three samples from throughout the district ranged as high as 33.8 oz/t Au (1160 ppm) and 0.4 oz/t Ag (13.7 ppm) (Boadi, 1986). Gold is strongly correlated with silver (Pearson correlation coefficient of 0.88), copper (0.95), and arsenic (1.00) (Boadi, 1986).

The age of these deposits is probably Precambrian (Bingler, 1968). Field observations, petrography, fluid inclusion data and isotopic geochemistry led Boadi (1986) to infer the age of mineralization to be 1467 Ma. The presence of tourmaline in the veins suggests mesothermal temperatures. However, fluid inclusion data indicate that gold depo­sition took place at temperatures ranging from 250° to 330°C and at pressures of approximately 1.5 kb. The fluids were rich in CO₂ (Boadi, 1986). The source of the fluid could have been magmatic hydrothermal or metamorphic (Boadi, 1986).

**Bromide mining district**

The first report of mining activity in the Bromide district was in 1884, with the location of the Bromide claim. The oxidized ore zones were mined until about 1910, but total production was small (Table 1). In 1977, U.S. Borax Inc. drilled seven holes in the district, the deepest of which was 293 m. Although zones containing magnetite and chal­copyrite were encountered, no significant precious-metal deposit was announced.

The mineral deposits in the Bromide district are grossly similar to those in the Hopewell district and consist of structurally controlled sulfide replacement deposits and thin pyrite-quartz veins in shear zones in the phyllite and schist of the Proterozoic Moppin series (Wobus and Manley, 1982; Robertson et al., 1986). The deposits in the Bromide district consist of chalcopyrite, pyrite, tetrahedrite, fluorite, molybdenite and tourmaline (Lindgren et al., 1910; Bingler, 1968). In 1957, a two-ton ore shipment from the Bromide mine to ASARCO, El Paso, contained 25.9 oz/t Ag (886 ppm) and 2.05% Cu (Bingler, 1968). There has been no subsequent production...

The age and origin of the deposits in the Bromide district are speculative. The gross similarity in mineralogy and emplacement of the deposits in both districts suggests a similar origin, but further work is needed.

**POTENTIAL**

The best exploration targets in Rio Arriba and Sandoval Counties are volcanic-epithermal veins in the Cochiti district and in situ leaching of sedimentary-copper deposits in the Nacimiento district. Possible additional targets are Precambrian precious-metal vein deposits in the Bromide and Hopewell districts in the Tusas Mountains. Environmental concerns will likely hinder development of these and other deposits in New Mexico in the near future. The deposits in the Cochiti, Nacimiento and Tusas Mountains occur in or near national forest lands administered by the U.S. Forest Service. Solution (or in situ leach) and other mining requires numerous permits; in addition, mining plans must be approved by several state and federal government agencies. Even if environmental problems are solved, grade and tonnage may be insufficient to develop and produce in these areas.

**ACKNOWLEDGMENTS**

This report is part of an ongoing study of precious- and base-metal deposits in New Mexico. Many people have assisted over the years and their help is greatly appreciated. Robert M. North, Shawn Leppert and Darren Dresser assisted in compiling production statistics. I would especially thank Robert Eveleth for his comments, advice and assistance over the years. Robert Eveleth and James Robertson reviewed this manuscript. Lynne McNeil typed various drafts of this manuscript and Kathy Campbell drafted the figure.

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Kathy Campbell drafted the figure.


