OCCURRENCES OF PRECIOUS METALS AND URANIUM ALONG THE RIO GRANDE RIFT IN NORTHERN NEW MEXICO

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INTRODUCTION

Silver and gold occur in at least minor concentrations (above 1 ppm Au and 14 ppm Ag) in 25 mining districts within and adjacent to the Rio Grande rift in Colfax, Taos, Rio Arriba, Sandoval, Santa Fe, and Torrance Counties in northern New Mexico (Fig. I , Table 1). No platinum or platinum-group metals are known to occur in the area. Uranium occurs in 15 of these districts and in four additional areas (Fig. 1, Table 1). Uranium also occurs in Precambrian pegmatites in the Tusas and Sangre de Cristo Mountains, and in Jurassic and Cretaceous sediments in the eastern San Juan Basin, Chama Basin, and near San Ysidro. These occurrences are not discussed in this report, but they are described elsewhere by Hilpert (1969), Chenoweth (1974a, 1974b, 1979), and McLemore (1983).

Gold, silver, and/or uranium occurrences are found in eight types of deposits (Table 1), many of which are genetically related to the formation of the Rio Grande rift. Gold occurs in late Tertiary to Recent placers in eight districts within basins of the Rio Grande rift and surrounding areas. Gold, silver, and uranium are associated with three types of Tertiary-age deposits: (I) hydrothermal gold—silver vein and breccia deposits, (2) base-metal veins, and (3) replacement deposits in limestones. Silver and rarely gold are found in barite—fluorite—lead vein

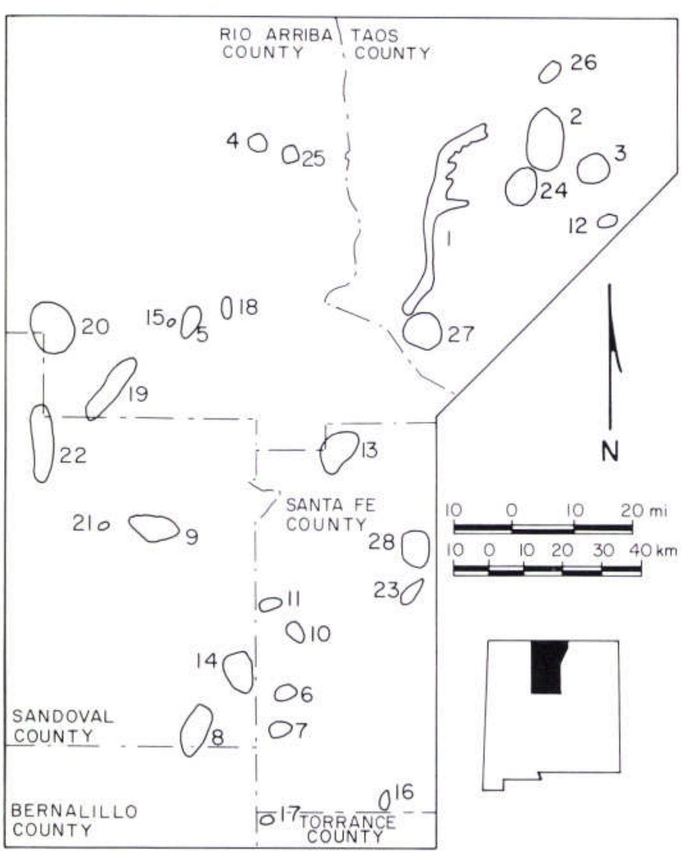

FIGURE 1. Gold, silver, and/or uranium districts or areas in northern New Mexico. Numbers represent localities given in Table 1.

TABLE 1. Precious metals and uranium districts along the Rio Grande rift and vicinity in northern New Mexico. [1]Commodities: Au—gold, Ag—silver, W—wolframite (tungsten), Cu—copper, Pb—lead, Zn—zinc, U—uranium, Ba—barite, Fl—fluorite. [2]Status of district: 1—active and producing presently, 2—inactive with past production, 3—inactive with no precious metal or uranium production. Production is listed in Table 2.

Map no. in Fig. 1	District	Commodities present[1]	Status of district[2]
	PLACER DEPOSITS		
1	Rio Grande valley	Au	2
2	Red River	Au	2
3	Elizabethtown-Baldy	Au	2
4	Hopewell	Au	2
5	Chama Placers	Au	2
6	Old Placers	Au	2
7	New Placers	Au	1
8	Placitas	Au	2
	HYDROTHERMAL Au-Ag VEIN AND BRECCIA DEPOSITS		
2	Red River	Cu, Pb, Zn, Au, Ag, Mo, U	2
3	Elizabethtown-Baldy	Au, Ag, W	2
6	Old Placers	Ag, Cu, Pb, W, Au	1
7	New Placers	Cu, Pb, Zn, Ag, Au	2
9	Cochiti	Au, Ag, Cu, Pb, Zn, U	2
	BASE-METAL VEIN DEPOSITS WITH GOLD AND/OR SILVER		
8	Placitas	Cu, Pb, Ag	2
10	Cerrillos	Cu, Pb, Zn, Au, Ag, U	2
11	La Bajada	Cu, U, Ag, Zn	2
	REPLACEMENT DEPOSITS IN LIMESTONES		
3	Elizabethtown-Baldy	Au, Ag, W	2
6	Old Placers		
7	New Placers	Cu, Pb, Zn, Ag, Au, W	2
12	Cimmaroncito	Au, Ag, Cu	2
	URANIUM DEPOSITS IN SEDIMENTARY ROCKS		
13	San Jose	(Tesuque Formation)	2
14	Hagan Basin	(Galisteo Formation)	2
15	Box Canyon	(Todilto Formation)	2
	BARITE-FLUORITE-LEAD (ZINC, COPPER, SILVER) VEIN DEPOSITS		
8	Placitas	Ba, Fl, Pb, Cu, Ag	2
16	Crow Butte	Ba, Fl, Pb, Ag	3
17	Edgewood	Ba, Fl, Pb, Ag	3
	STRATABOUND COPPER DEPOSITS (RED BEDS)		
18	Abiquiu	Cu, U, Ag	3
19	Coyote	U, Cu, Ag	3
20	Gallinas	Cu, U, Ag	3
21	Jemez Springs	Cu, Pb, Ag, Au, U	2
22	Nacimiento	Cu, Pb, U, Ag	2
23	Glorieta	Cu, Ag, U	3
	DEPOSITS IN PRECAMBRIAN ROCKS		
2	Red River	Cu, Pb, Zn, Au, Ag, U	2
3	Hopewell	Cu, Pb, Au, Ag	2
8	Placitas	Cu, Ag, Au	3
24	Twining	Cu, Ag, Au	2
25	Bromide #2	Cu, Au, Ag, U	2
22	Nacimiento	Cu, Au, Ag, U	3
26	Costilla Massif	U	3
27	Picuris	Cu, Ag, Au, W, U	2
28	Santa Fe	Cu, Pb, Zn, Ag, Au	3

TABLE 2. Reported gold, silver, uranium, and vanadium production from deposits in northern Rio Grande rift and adjacent areas. From North and McLemore (1984), Johnson (1972), Anderson (1957), Wells and Wootton (1940), U.S. Atomic Energy Commission ore production reports (1950–1970), and NMBMMR files. [a]—Estimated; [b]—Type of deposit: 1—placer gold deposit, 2—Au–Ag vein deposit, 3—base-metal vein deposit, 4—replacement deposit, 5—uranium deposit in sedimentary rocks, 6—stratabound copper deposit, 7—Ba–F–Pb (Zn, Cu, Ag) deposit, 8—deposit in Precambrian rocks.

Map No.	District	Au oz	Ag oz	U_3O_8 lbs	V_2O_5 lbs	Type of deposit[b]
	RIO ARRIBA					
18	Abiquiu	--	--	7	43	6
19	Coyote	--	--	182	206	6
25	Bromide #2	300[a]	4,500[a]	12	10	8
4	Hopewell	24,000[a]	10,000[a]	--	--	1, 8
15	Box Canyon	--	--	253	212	5
5	Chama placers	100[a]	--	--	--	1
	SANDOVAL					
20	Gallinas	--	--	12	24	6
21	Jemez Springs	1.0	159	--	--	6
22	Nacimiento	--	75,068	--	--	6
9	Cochiti	41,016	203,895[a]	--	--	2
8	Placitas	49	48	--	--	1, 3
	SANTA FE					
10	Cerrillos	930.68	27,864	--	--	3
11	La Bajada	--	52	27,116	42	3
7	New Placers	117,000[a]	304,625	--	--	1, 2, 4
6	Old Placers	200,000[a]	311	--	--	1, 2, 4
13	San Jose	--	--	12	--	5
	TAOS					
27	Picuris	14.75	1,351	--	--	8
2	Red River	364.89	8,051	3	--	2, 8
1	Rio Grande Valley	<1,000[a]	--	--	--	1
24	Twining	80[a]	1,000[a]	--	--	8
	COLFAX					
3	Elizabethtown-Baldy	471,400[a]	--	--	--	1, 2, 4
12	Cimmaroncito	100[a]	1,000[a]	--	--	4

deposits in three areas along or near the Rio Grande rift in northern New Mexico. Silver, uranium, vanadium, and rarely gold also occur in stratabound sedimentary copper deposits and probably formed prior to the Rio Grande rift. Mineral deposits in Precambrian rocks also contain gold, silver, and/or uranium mineralization and are occasionally associated with younger mineralization.

Production of gold and silver from placer deposits, deposits of Tertiary age, and deposits in Precambrian rocks has been moderate (Table 2). Except for La Bajada mine, uranium and vanadium production has been insignificant (Table 2).

PLACER-GOLD DEPOSITS

Placer gold is reported from eight localities in the vicinity of the northern Rio Grande rift. Most are adjacent to known lode-gold producing areas, where the eroded gold has been concentrated in Tertiary and Quaternary gravels formed by erosion of the Rio Grande valley.

Rio Grande Valley

Less than 1,000 oz (31,100 g) of placer gold (Table 2; Johnson, 1972) have been produced from the Rio Grande valley between Red River and Embudo (#1, Fig. I) since Spanish Colonial times (Schilling, 1960). Early reports on the extent and grade of the gold-bearing gravels and sand bars of the present Rio Grande channel and Pliocene Servilleta Formation predicted great success for dredging operations (Silliman, 1880; Payne, unpubl. report 1932). Although large-scale operations were unsuccessful due to the presence of large basalt boulders in the gravels (Schilling, 1960), the area remains a favorite of recreational gold panners. The gold is fine- to medium-grained, averaging about pinhead size (Schilling, 1960), and is estimated to occur in deposits containing from 0.012 (Silliman, 1880) to 0.082 oz per cubic yard (Payne, unpubl. report 1932) running about 900 fine. The gold was probably derived from Precambrian and Tertiary lode deposits of the Taos Range to the east.

Red River

Less than 500 oz (15,550 g) of gold (Table 2; Johnson, 1972) have been produced from placer-gold deposits in the Red River district (#2, Fig. 1) in Bitter, Gold, Spring, and Placer Creeks (Johnson, 1972). These deposits were probably worked originally by Spanish miners and later in the 1800's by miners attracted to the rich Elizabethtown—Baldy placers (#3, Fig. I). The Red River placers are predominantly in Quaternary gravels, although Tertiary gravel terraces have been prospected and possibly some gold was produced (Park and McKinlay, 1948). The gold was derived mainly from local Oligocene skarn and vein deposits and to a lesser extent from Precambrian vein deposits.

Elizabethtown—Baldy

The largest producing placer-gold district in the state was Elizabethtown—Baldy (#3, Fig. I) where placer gold was found in nearly all the gulches draining the Baldy Mountain. Total placer production is estimated at 250,000 oz (7,775,000 g) of gold (Table 2; Anderson, 1957). Gold was discovered in 1866 in Willow Creek, and by 1868 several thousand people inhabited Elizabethtown (Clark and Read, 1972). Work declined in the 1870's but probably continued on a small scale well into the 20th century (Clark and Read, 1972). Placer gold, occasionally containing some fairly coarse nuggets, was mined extensively from Quaternary gravels in Willow, Ute, and South Ponil Creeks, Grouse and Hamburg Gulches, and the Moreno River. The placers were derived from the Oligocene vein and skarn deposits of the Baldy Mountain.

Hopewell District

Placer gold was discovered in the Hopewell district (#4, Fig. I) in the 1880's, and $175,000 worth of gold was produced within only three years (Lindgren and others, 1910). Production slowed considerably as the high-grade Fairview placer was worked out by the late 1880's and work almost ceased by 1900 (Johnson, 1972). Nuggets up to 2 oz (62 g) were found during this period (Little, unpubl. report 1947). Total placer production is estimated as 16,000 oz (497,600 g; Table 2; Johnson, 1972). The placer deposits in the district are of two ages. The richest placer, the Fairview, is in Tertiary gravels exhumed by Placer Creek, whereas the lower-grade placers in Placer Creek are Quaternary (Bingler, 1968). The gold was derived from the Precambrian vein deposits of the district.

Chama Placers

Gold was found prior to 1848 in the sand and gravel deposits of the Chama River near the intersection of Canones Creek west of Abiquiu (#5, Fig. 1). Since then there has periodically been considerable interest in these placers, most recently in the late 1930's. Total production is unknown; Johnson (1972) estimated less than 100 oz (3,110 g), whereas Mitchell (unpubl. report 1938) claims $300,000 worth of production in only a few months. This appears exaggerated, but the district has probably produced more than 100 oz (3,110 g). We estimate the production of this district to be less than 1,000 oz (31,100 g).

According to Johnson (1972), the gold was derived from Precambrian rocks along the deep canyons of the Chama River; however, the Chama River does not cut Precambrian rocks north of Abiquiu; it cuts mainly Mesozoic sedimentary rocks (Bingler, 1968, pl. lb). Another possible source of the gold is from Tertiary volcanic rocks to the south, drained by the Canones Creek, but no ore deposits are known to occur in these rocks. Currently much of the area is inundated by the Abiquiu reservoir.

Old Placers

Placer gold was discovered in the Old Placers district (#6, Fig. 1) in 1828 and was mined actively prior to 1900 and intermittently since that time. Total placer production is estimated to be greater than 100,000 oz (3,110,000 g; Table 2; Johnson, 1972). Gold occurs in both Quaternary and Tertiary gravels in the Dolores and Cunningham Gulches, and lower-grade material is found in the Lucas Canyon (Anderson, 1957). The richest gravels were mined from the upper part of a mesa-forming (Tertiary?) alluvial fan at the mouth of the Cunningham Gulch (Koschmann and Bergendal, 1968). The placers were derived from Oligocene vein and breccia deposits in the area.

New Placers

The New Placers district (#7, Fig. 1) was discovered in 1839 (Atkinson, 1961) and has produced until recently, although since 1900 on a small scale. The district is estimated to have produced about 97,000 oz (3,016,700 g) prior to 1900; since 1900 the production has been about 3,000 oz (93,300 g; Table 2; Johnson, 1972). The area is currently exploited on a small scale for the coarser material (>1 mm) that is sold chiefly as mineral specimens.

Gold was produced from unconsolidated Quaternary gravels surrounding the San Pedro Mountains and the best material was found in the Old Timer and San Lazarus Gulches. The cemented gravels (Tertiary?) in the vicinity of Golden contain gold, but all attempts to mine them have failed (Wells and Wootten, 1940). The placers were derived from the copper-silver-gold skarn and vein deposits of the San Pedro Mountains.

Placitas District

About 49 oz (1,520 g) of gold were produced from cemented gravels in the Placitas district at the north end of the Sandia Mountains (#8, Fig. 1; U.S. Bureau of Mines Mineral Yearbooks). Little is known about the history and total production of these placers, but apparently they were worked in the early part of this century when up to $3 worth (about 0.15 oz) of gold a day was recovered by dry-washing methods (Heikes, 1913).

HYDROTHERMAL GOLD-SILVER VEIN AND BRECCIA DEPOSITS

Hydrothermal vein and breccia deposits containing dominantly gold and silver and minor base metals occur in three districts in north-central New Mexico. The value of precious-metal production exceeds the value of base-metal production. These Oligocene-age deposits are associated with a period of igneous activity beginning around 33 m.y. and continuing until about 25 m.y. B.P., roughly coinciding with the earliest Tertiary rifting in the area (Chapin, 1979).

Red River District

This is a large district (#2, Fig. 1) which includes Red River, Cabresto Creek, lower Red River, Black Copper Canyon, and the Anchor-Midnight areas. Although many prospects and small mines occur in the district, reported production is small (Table 2).

Veins occur along fissures and shear zones in and adjacent to Miocene(?) soda granite and associated volcanic rocks, and in some places Precambrian rocks are mineralized (Schilling, 1960). The mineralogy of the veins is variable, but they generally contain auriferous pyrite or limonite pseudomorphs after pyrite. Some veins in the area were prospected for molybdenite (Schilling, 1960) and uranium (McLemore, 1983). The quartz-vein deposits have been dated from 21.0 3.0 to 23.5 ± 0.8 m.y. B.P. (Ishihara, 1967; K-Ar on biotite) and hence are contemporaneous with rifting.

Elizabethtown-Baldy District

Lode deposits in the Elizabethtown-Baldy district (#3, Fig. 1) were discovered in 1866 and mined continuously until 1940. Since 1900 most mining has been on a small scale, except for operations of the Maxwell Land Grant Co. from 1910 to 1940 (Pettit, 1946). Total lode-gold production from the district is estimated at 221,400 oz (6,885,500 g; Koschmann and Bergendahl, 1968), most of which came from the vein deposits. The district also produced silver, copper, and small amounts of lead.

Mineralization fills fissures and major and minor fault zones that cut sills of quartz-diorite porphyry and Cretaceous Pierre Shale (Pettit, 1946; Clark and Read, 1972), and occurs along the unconformable contact between the Pierre Shale and the overlying Tertiary Raton Formation (Lee, 1916). The veins contain dominantly quartz and pyrite with minor calcite, chalcopyrite, pyrrhotite, and in places magnetite and molybdenite (Clark and Read, 1972). These deposits are thought to be the result of a hydrothermal system associated with the quartz-diorite porphyry (Lindgren and others, 1910). Similar sills in the Ute Park-Cimmaron Canyon Palisades have been dated at 33.8 m.y. B.P. (Armstrong, 1969; K-Ar on biotite) and mineralization at Elizabethtown-Baldy is probably of similar age.

Old Placers District

Vein and breccia deposits occur in a horst block northwest of the Tijeras fault zone in the Old Placers district (#6, Fig. 1). Mining began prior to 1850 (Jones, 1904) and continued intermittently until about 1930. Lode mining in the district was inactive until early 1980 when Gold Fields Mining Corp. opened a 3,000 short ton a day open-pit mine (Wright, 1983; Fig. 2). The ore averages 0.053 oz/ton (1.82 ppm) and is processed by cyanide heap-leaching methods (Hickson, 1982). The earliest mining was confined to quartz veins containing free gold, specular hematite, magnetite, pyrite, chalcopyrite, and, in the Live Oak vein, molybdenite (Lindgren and others, 1910). A breccia pipe composed of clasts of Cretaceous Mesaverde Group and intrusive quartz-latite porphyry is currently being mined (Wright, 1983).

The dominant igneous rock in the district is the nepheline-bearing augite-monzonite Ortiz stock which intruded the Cretaceous Mesaverde Group and was subsequently intruded by latite and quartz-latite dikes, sills, and laccoliths and overlain by an ash-flow tuff (Wright, 1983). The quartz veins cut the latite stock (Lindgren and others, 1910), indicating that mineralization occurred after emplacement of the latite. The breccia deposits contain only latite and Mesaverde clasts but border the ash-flow tuff (Wright, 1983), suggesting that mineralization occurred before the deposition of the tuff. A latite sill on the west side of the Ortiz intrusive complex has been dated at 34.0 ± 2.2 m.y. B.P. (Bachman and Mehnert, 1978; K-Ar on hornblende).

New Placers District

FIGURE 2. The open-pit Ortiz mine of Gold Fields Operating Co.–Ortiz, Old Placers district (#6, Fig. 1). Gold Fields mines about 3,000 tons of ore a day running about 0.05 oz/ton (1.8 ppm), making this the tenth largest gold producing mine in the U.S. in 1982. Photo by Susan Beattie. Published with permission and through the courtesy of Gold Fields Operating Co.–Ortiz.

Gold-bearing veins in the New Placers district (#7, Fig. 1) cut metasedimentary and intrusive igneous rocks around the margins of stocks in the San Pedro Mountains (Atkinson, 1961). Although production from these veins has been minor compared to the replacement (skarn) and placer deposits, they may represent an important source for the placer gold. Lead and zinc vein deposits occur at the Carnahan mine in the southern part of the district (Atkinson, 1961) and contain argentite (acanthite?), native silver, and chlorargyrite (Northrup, 1959). Precious-metal production from these veins is small.

Cochiti District

Early prospecting in the Cochiti district in the Jemez Mountains (#9, Fig. 1) began around 1880, but serious mining was prevented because of claims of Mexican land-grant owners. Federal Courts subsequently declared the lands open to location and by the 1890's the district was the site of considerable activity (Bundy, 1958). The most productive period was 1894-1904 when the Albemarle deposit was mined, with later flurries of activity in 1914-16 and 1932-40 (Koschmann and Bergendahl, 1968). Prospecting and possibly a small amount of production are currently underway.

The ore deposits are in veins filling faults in Tertiary andesite, volcanic breccia, and quartz diorite. The early vein filling was calcite which was subsequently replaced by quartz-sulfide mineralization. Sulfides present include pyrite, chalcopyrite, sphalerite, and argentite (Bundy, 1958). The gold is associated with pyrite and argentite. Uranium minerals are reported to occur at a few localities (Chenoweth, 1974a; Lindgren and others, 1910). Veins vary from a few millimeters to about 15 m at the surface and are reported to be as wide as 45 m at depth (Bundy, 1958).

The deposits of the district are best classified as epithermal deposits despite their replacement character, because they have many of the characteristics of epithermal deposits as discussed by Buchanan (1981). Fluid-inclusion data by Parkison and others (1984) indicate temperatures of mineralizing fluids of 240-315°C (see Wronkiewicz and others, this guidebook). The age of these deposits is given by Parkison and others as between 6.5 and 1.5 m.y. B.F., hut no analytical data are given. Radiometric-age determinations in this geographic area must be subjected to close scrutiny due to possible resetting, or partial resetting, of radiometric ages by Pleistocene volcanic activity.

BASE-METAL VEIN DEPOSITS

Precious metals have been produced as byproducts of base-metal mining from vein deposits in three districts in north-central New Mexico. In all cases, silver is the most important byproduct, with subordinate gold and uranium.

Placitas District

Only one of the many base-metal veins in the Placitas district (#8, Fig. I) has produced. The Montezuma mine produced 48 oz (1,493 g) of silver, and some copper and lead, in 1920 and 1926 (Elston, 1967). Numerous small fissure veins containing base-metal with silver and traces of gold occur in the vicinity of barite—fluorite and fluorite veins throughout the district (Kelley and Northrop, 1975; Hedlund and Kness, 1984).

Cerrillos District

Mining in the Cerrillos District began with prehistoric turquoise mining and continued with exploitation of lead oxides for glaze paint used on pottery (Warren and Weber, 1979). Metal mining for lead and possibly silver was initiated during the Spanish Colonial period prior to the Pueblo Revolt in 1680 (Warren and Weber, 1979). Very little mining activity is known to occur until around 1880; afterwards, activity was fairly continuous until 1960 (Elston, 1967). The district has been essentially idle since that time, with the exception of intensive exploration for copper mineralization in porphyry (Akright, 1979).

The important vein deposits of the district cut Oligocene augite-biotite-monzonite porphyry and hornblende-monzonite porphyry. Less important veins cut Oligocene Espinaso volcanics and underlying Eocene Galisteo Formation (Disbrow and Stoll, 1957). The veins are dominantly lead—zinc with minor copper, silver, uranium, and gold, and are probably related to the intrusion of the augite—biotite-monzonite porphyry. Primary ore minerals include sphalerite, galena, chalcopyrite, and pyrite, with silver associated with galena and gold with chalcopyrite (Disbrow and Stoll, 1957). An intrusive thought to be correlative wit the augite—biotite-monzonite porphyry has been dated at 30.2 ± 0. m.y. B.P. (Baldridge and others, 1980; K—Ar on biotite), which i probably close to the age of mineralization in the district.

La Bajada Deposit

La Bajada (Lone Star) deposit is a unique, low-temperature, base metal vein deposit that formed during the Oligocene or Miocene (Hil pert, 1969; Haji-Vassiliou and Kerr, 1972). Thin veins of uraniur mineralization and base-metal sulfides occur along the footwall of limburgite dike which was emplaced along a north-trending fault in th Oligocene Espinaso Formation. The uniqueness of the deposit is du to the presence of ore-controlling carbonaceous material (Haji-Vassilio and Kerr, 1972) in volcanic rocks including intrusive limburgite tIu are intensely altered by hydrothermal solutions. The organic materh is thought to have been derived from the underlying Cretaceous sedi ments (Haji-Vassiliou and Kerr, 1972). Hydrothermal alteration an mineralization probably occurred during the Oligocene or Miocene (Hi. pert, 1969).

Lustig (1957) described 23 minerals from this deposit, including (i order of decreasing abundance) pyrite, sphalerite, marcasite, colusite ($Cu_3(As,Sn,V,Fe)S_4$), chalcopyrite, and bornite. In addition, uraniurr cobalt, nickel, molybdenum, germanium, and gold occur in appreciabl amounts (Hilpert, 1969). Due to the complex association of uraniur and carbonaceous material, specific uranium minerals have not bee identified. One select sample assayed 0.09% U,0„, 1.51% Cu, 19 ppr Th, 0.06% Pb, 0.03% Zn, 0.54 oz/ton (19 ppm) Ag, and no gold.

Copper mineralization was first discovered in 1915 or 1916. L Bajada Mining Co. was formed in 1923 and by 1928 the America Smelting and Refining Co. controlled the deposit. In 1928 and 192 the American Smelting and Refining Co. produced 5,345 lbs (2,42 kg) of copper and 52 oz (1,617 g) of silver (Table 3). The deposit wa mined through two shafts. Uranium was discovered in 1950, and fror 1956 to 1966 27,116 lbs (12,300 kg) of U_30, and 42 lbs (19 kg) c V30, were produced (Table 2). In 1957 the underground workings wer found to be unsafe and further development was by open pit (Cher oweth, 1979). The pit has since filled with water because the rim i only several feet above the river level.

In the late 1970's Bokum Resources and Union Carbide Corp. drille exploratory holes in the vicinity of La Bajada mine, but their result are unknown. In 1979 the Lone Star Mining Co. lost the lease to th deposit for failure to submit an approved mining plan to the Bureau c Land Management. Reserves are probably present at the mine, Ix environmental problems will hamper future development. One addi tional uranium occurrence, the Hiser Moore #I, is known in the are (Hilnert. 1969).

TABLE 3. Production from La Bajada mine, Santa Fe County From Lustig (1957), U.S. Atomic Energy Commission ore production reports (1956–1966), and NMBMMR files (1979).

Year	Tons ore	Ag oz	Cu lbs	U_3O_8 lbs	V_2O_5 lbs	
1928	8	24	2,423	—	--	American Smelting and Refining Co.
1929	9	28	2,922	—	--	American Smelting and Refining Co.
1930-1955	no production					
1956	46	--	--	166	--	Lone Star Mining Co.
1957	51	--	--	204	42	Lone Star Mining Co.
1962	1,617	--	--	5,277	--	Lone Star Mining Co.
1963	5,465	--	--	14,482	--	Lone Star Mining Co.
1964	2,106	--	--	5,882	--	Lone Star Mining Co.
1966	364	--	--	1,105	--	Lone Star Mining Co.
TOTAL	--	52	5,345	27,116	42	

REPLACEMENT AND SKARN DEPOSITS

Skam deposits account for the major production of the New Placers (#7, Fig. 1) and Cimmaroncito (#12, Fig. 1) districts. Small replacement and skarn bodies also occur in the Elizabethtown—Baldy and Old Placers districts.

New Placers District

The important lode deposits of the New Placers district are skarn deposits replacing limestone beds in the upper Madera Formation (Pennsylvanian) adjacent to an Oligocene monzonite-porphyry laccolith. The ore deposits are as much as 15 m from the contact of the laccolith with the Madera Formation and are localized by an overlying rhyolite sill (Atkinson, 1961). At the San Pedro mine, ore minerals were deposited in two stages in garnet tactite as a late phase of contact metasomatism. The first stage filled small cavities in the tactite and consists of chalcopyrite, bornite, pyrite, pyrrhotite, calcite, specular hematite, quartz, and chlorite. The second stage filled larger cavities in the tactite with quartz, pyrite, chalcopyrite, calcite, and minor siderite and scheelite (Atkinson, 1961). Gold and silver are associated with copper minerals in both stages. At the Carnahan mine, gold and silver occur with the lead-zinc deposits that have replaced favorable limestone beds (Atkinson, 1961). No age data are available for intrusive rocks in the New Placers district; however, based on geologic relations and on other dated rocks in the "porphyry belt," an Oligocene age is reasonable.

Cimmaroncito District

The ore deposits of the Cimmaroncito district (# 12, Fig. I) arc confined to skarns in calcareous beds in the Pennsylvanian-Permian Sangre de Cristo Formation adjacent to quartz-monzonite-porphyry sills (Robinson and others, 1964). The deposits contain chalcopyrite, galena, and gold in a gangue of pyrite, quartz, garnet, epidote, calcite, magnetite, and specular hematite (Pettit, 1946). Small pockets of high-grade ore were mined and reported to assay as high as 0.5 oz/ton (17 ppm) gold, 4 oz/ton (137 ppm) silver, and 8-10% copper (Lindgren and others, 1910); however, total production has been small (Table 2). The ore deposits are related to the quartz-monzonite sills, which have been dated in the area at 33.8 m.y. B.P. (Armstrong, 1969; K-Ar on biotite).

URANIUM DEPOSITS IN SEDIMENTARY ROCKS

Uranium deposits occur in the Tesuque Formation (Tertiary) near San Jose, the Galisteo Formation (Eocene) in the Hagan Basin, and the Todilto Formation (Jurassic) at Box Canyon (Fig. 1). Small amounts of uranium and vanadium have been produced from the Tesuque and Todilto deposits (Table 2). All of these deposits are small, low-grade, and uneconomic, although the Galisteo deposits may have a potential should the uranium market improve.

Small and scattered uranium and vanadium occurrences are present in sandstones and conglomerates of the Tesuque Formation. The sediments of the Tesuque Formation were derived from Precambrian rocks in the Sangre de Cristo Mountains and volcanic rocks in the Jemez Mountains during later stages of rifting (Hilpert, 1969). Uranium typically occurs as coatings around opal and chert grains, with organic debris, and in clay zones, and probably represents accumulations of uraniferous ground waters. Uranium may have been derived from the Sangre de Cristo Mountains, the Jemez volcanics, or alteration of detritus in the host rocks. It is unlikely that any large, economic ore deposits could occur in these sediments because (1) past production was small and low-grade (Table 2), (2) known occurrences are low-grade (Hilpert, 1969), (3) organic material needed to trap uranium is not abundant in the Tesuque Formation, and (4) not enough time has elapsed to form economic deposits.

Uranium mineralization occurs in high-energy, braided-stream sediments of a complex alluvial-fan sequence in the Galisteo Formation in the Hagan Basin, which is a structural basin within the Rio Grande rift (Moore, 1979). The Galisteo Formation consists of fluvial-lacustrine sandstones, siltstones, conglomerates, and volcanic tuffs and rests unconformably on the Cretaceous Mancos Shale. It is overlain by the Espinaso Formation volcanics and intruded by uranium-bearing latite dikes and sills (McLemore, 1983; Hilpert, 1969). Uranium was probably derived from these latite dikes and the Espinaso volcanics, and was redistributed as uraninite and coffinite in roll-type ore deposits (Moore, 1979). One of these orebodies, the Diamond Tail, is estimated to contain 0.9 million lbs (0.4 million kg) of U_3O_8 at an average grade of 0.09% U_3O_8, at depths of 3-122 m. High production costs, low-grade ore, environmental constraints, and a declining uranium market forced Union Carbide Corp. to abandon development of uranium mineralization in this area.

A small uranium deposit occurs in the Todilto Limestone at Box Canyon (Hilpert, 1969; Chenoweth, 1974b). Uranium and vanadium are associated with intraformational folds in the limestones, and the deposit is similar to other limestone deposits in the Grants district (McLemore, 1983; Rawson, 1980). These deposits probably formed during the Jurassic and are not genetically related to the Rio Grande rift.

BARITE-FLUORITE-GALENA VEIN DEPOSITS

Silver has been produced as a byproduct from barite-fluorite-galena veins elsewhere in New Mexico (North, 1983; North and McLemore, 1984), but not from deposits along the northern Rio Grande rift. Barite-fluorite-galena and fluorite-galena veins occur in three districts or areas in northern New Mexico (Fig. 1) and silver ranges up to 0.46 oz/ton (16 ppm) in these veins (Table 4).

These deposits occur as veins and minor replacement bodies along fault zones primarily in Pennsylvanian and Permian limestones and rarely in sandstones and siltstones. Silver tends to occur with galena and an increase in lead concentration is accompanied by an increase in silver (Table 4). One variety of mineralization contains dominantly barite and minor amounts of fluorite, lead, zinc, copper, and calcite, whereas another variety contains dominantly fluorite with minor galena, zinc, and copper (Table 4). Uranium is rarely present in these deposits, although one deposit, the Shakespeare in Bernalillo County (not described in this report), contains 0.005% U_3O_8.

Most of the barite and fluorite deposits in New Mexico occur along, or in the vicinity of, the Rio Grande rift. However, no significant barite deposits occur north of the Placitas district in the Sandia Mountains. The barite and fluorite deposits were formed by basin brines (sedimentary hydrothermal) during the early stages of the Rio Grande rift.

STRATABOUND SEDIMENTARY COPPER DEPOSITS

TABLE 4. Chemical analyses of selected samples of barite–fluorite (± galena, silver) and fluorite (± galena, silver) veins in northern New Mexico. [1]—Trace of gold (<0.7 ppm); [2]—0.02 oz/ton Au (0.7 ppm).

Location	Name of Mine	Ag oz/ton (ppm)	% Pb	% Zn	% Cu	% $BaSO_4$	% $CaCO_3$	% CaF_2
Placitas district								
SW1/4 5 T12N R5E	Victo-Roco	0.20 (7)	0.21	0.0006	0.001	52.51	9.36	10.99
NW1/4 34 T13N R5E	Montezuma[1]	0.10 (3)	0.19	0.001	0.004	--	0.85	62.41
NW1/4 9 T12N R9E	Sec. 9	0.46 (16)	4.99	0.65	0.0007	18.3	0.40	38.88
SW1/4 6 T11N R5E	La Luz[2]	0.20 (7)	0.23	0.13	0.12	0.70	5.24	58.90
Edgewood								
NW1/4 5 T9N R7E	Shockley	0.20 (7)	0.74	0.001	0.002	67.72	0.97	16.46
NW1/4 5 T9N R7E	Shockley[1]	0.08 (3)	0.34	0.11	0.001	66.67	3.02	13.07
Crow Butte (El Cuervo)								
22 T10N R10E	Section 22	0.20 (7)	0.0006	0.0005	--	0.12	--	--
23 T10N R10E	Section 23[1]	0.22 (8)	2.31	0.001	--	27.28	--	--

1 Trace of gold (<0.7 ppm)
2 0.02 oz/ton Au (0.7 ppm)

Although stratabound sedimentary copper deposits (red-bed deposits) are not genetically related to the Rio Grande rift, several of them occur in the vicinity of the rift (localities 18-23, Fig. 1). In the Rio Grande rift area, stratabound copper deposits occur in the Permian Abo and Cutter Formations and the Triassic Chinle Formation. Minor occurrences are also present in the Pennsylvanian Madera and Permian Yeso Formations. In addition to copper mineralization, these deposits contain varying amounts of silver, uranium, vanadium, and rarely lead, zinc, and gold (Table 5). Silver contents average about 0.5 oz/ton (17 ppm), but may range in value from 0.03 to 20 oz/ton (1 to 600 ppm) Ag. Uranium values range from trace amounts up to 0.10% U_3O_8 (Table 5).

TABLE 5. Chemical analyses of selected samples from stratabound sedimentary copper deposits in northern New Mexico. No gold was detected in any of these samples.

Location	Name	% Cu	% U_3O_8	Ag oz/ton	(ppm)
Gallinas					
NW1/4 20 T23N R1E	Max Jacque	0.25	0.05	0.03	(10)
Coyote					
NW1/4 12 T21N R2E	Section 12	35.4	0.14	20.5	(703)
SE1/4 12 T21N R2E	Jarosa	0.22	0.06	0.3	(10)
Nacimiento					
NW1/4 35 T18N R1E	Deer Creek	5.92	0.144	0.88	(30)
Jemez Springs					
SW1/4 3 T17N R2E	Spanish Queen West	3.49	0.006	1.06	(36)
SE1/4 3 T17N R2E	Spanish Queen East	4.90	0.018	0.62	(21)

These mineral deposits were probably derived from: (I) erosion of Precambrian rocks enriched in these metals; (2) erosion of Precambrian mineral deposits; or (3) leaching of detritus in fluvial sediments (LaPoint, 1974).

DEPOSITS IN PRECAMBRIAN ROCKS

Twining and Red River Districts

Vein deposits of similar composition are restricted to Precambrian rocks in the Twining (#24, Fig. 1) and Red River districts. The veins contain quartz, chalcopyrite, malachite, azurite, pyrite, and minor gold and silver. They are probably of both Tertiary and Precambrian ages (Clark and Read, 1972, p. 109). Uranium occurs in some of these veins, and has been produced from the Black Copper mine (Table 2).

Hopewell and Bromide Districts

The lode deposits of the Hopewell (#4, Fig. 1) and Bromide (#25, Fig. 1) districts are similar and best considered together. The deposits are quartz fissure veins and replacement veins in schists of the Precambrian Moppin Metavolcanic Series. The replacement veins are from a few to about 70 cm wide and contain auriferous pyrite, chalcopyrite, galena, sphalerite, fluorite, and uranium. The quartz fissure veins are 1-100 cm wide and contain quartz, siderite, limonite after pyrite, and gold (Bingler, 1968).

The age of mineralization is uncertain. The replacement veins are structurally controlled by schistosity and hence the mineralization is post-metamorphic. No mineralization cuts Tertiary rocks, but mineralized clasts are found in the early Tertiary Ritito Conglomerate (Bingler, 1968). The mineralization is probably Precambrian, as deduced from the following lines of evidence: (1) the mineralization is restricted to Precambrian rocks; (2) there is no evidence of Tertiary intrusive-igneous activity in the area; and (3) the overall regional tectonic setting favors a Precambrian age over an early Tertiary age. In the Hopewell district uranium occurs with fluorite and is probably also of Precambrian age (Goodknight and Dexter, 1984a).

Placitas District

Minor base-metal and fluorite veins containing silver and traces of gold occur along faults in the Precambrian Sandia Granite (Kelley and Northrup, 1975). These veins, including the La Luz mine, are probably related to barite—fluorite, fluorite, and base-metal veins previously discussed.

Nacimiento Mountains

Although no production of silver, gold, or uranium has been reported from deposits in Precambrian rocks in the Nacimiento Mountains, several minor prospects and occurrences are found in these rocks. Copper mineralization, possibly with gold and silver, occurs in a schist xenolith in Precambrian granite at the Chalcocite prospect near the Nacimiento copper mine (Lindgren and others, 1910). Oxidized copper minerals and free gold occur in a 1 m wide vein along a shear zone in Precambrian granite at the Morningstar prospect south of the Nacimiento copper mine (R. H. Weber, field notes 1961; Woodward and others, 1972). Minor radioactive anomalies occur in Precambrian granite in the southern Nacimiento Mountains (Easton, 1955).

Costilla Massif

Uranium occurrences and geochemical anomalies in stream sediments occur in the Costilla massif (Precambrian) in northern Taos County (#26, Fig. 1). Uranium mineralization occurs along faults in the coarse-grained granite and in Precambrian pegmatites. Uranosilicates are common to many mineralized samples and chemical analyses up to 0.38% U_3O_8 are reported (Goodknight and Dexter, 1984). No sulfide mineralization is known to occur in the area.

The age of the mineralization is problematical. The Costilla Granite is anomalously high in uranium (Goodknight and Dexter, 1984), indicating a potential source. However, the massif may have been covered by Tertiary volcanics of the Amalia Tuff, which could have released uranium during weathering (Goodknight and Dexter, 1984b).

Picuris District

Mineralization in the Picuris district (#27, Fig. 1) consists of quartz veins, disseminated sulfides, and mineralization filling small fractures in quartz veins and quartzite. The mineralogy of all of these is similar, consisting of varying amounts of malachite, chrysocolla, and chalcocite with small amounts of gold, silver, and uranium (Williams, 1982). Tungsten (wolframite) has also been produced.

The ore deposits are restricted to the Precambrian Ortega Quartzite. The quartz veins and disseminations show some evidence of metamorphism. The mineralization is probably epigenetic and formed during the Precambrian (Williams, 1982).

Santa Fe District

In the Santa Fe district (#28, Fig. 1) the mineralization is disseminated in Precambrian biotite-rich phyllite and two-mica schist and consists of chalcopyrite, pyrite, bornite, pyrrhotite, and magnetite with rare sphalerite, tennantite, chalcocite, and covellite (Fulp, 1982). The formation of these deposit was associated with submarine-shelf volcanic activity (Fulp, 1982) during late Precambrian time.

ASSOCIATION OF GOLD, SILVER, AND URANIUM

The association of gold and silver with uranium is not common, although uranium is found in some of the world's largest gold deposits. Among the most important sources of gold in the world are the lower Proterozoic conglomerates, which produce a substantial amount of uranium as well (Pretorius, 1981). Platinum-group metals, silver, and thorium also occur in substantial quantities in some of these ancient conglomerates. Lower Proterozoic rocks are absent in New Mexico, and there is no potential for these gold—uranium deposits in the state. An unusual copper—uranium—gold deposit occurs in the hematite-rich sedimentary breccias of the Olympic Dam Formation (Precambrian) at Roxby Downs, Australia (Roberts and Hudson, 1983). A unique deposit at the Virgen de Guadalupe mine, Chihuahua, Mexico, contained radiating "sunbursts" of native gold in spheroidal masses of pitchblende (Leach, 1946). Uranium is also associated with a few of the Canadian gold deposits, but is rare in most of the Canadian precious-metal districts (Boyle, 1979).

In New Mexico, uranium is typically associated with copper deposits containing gold and silver. Some gold—quartz veins may also contain uranium minerals (McLemore, 1983). Most of the stratabound sedimentary copper deposits contain minor amounts of silver, uranium, and vanadium. Gold is rare in these deposits. Many of the copper deposits in Precambrian rocks, and vein deposits associated with Tertiary volcanic and intrusive rocks also contain varying amounts of gold, silver, and uranium (Table 1).

The association of copper, gold, silver, and uranium may be a result of a common source, mixing, and similar transport—deposition conditions. Much of the gold and silver is possibly derived from hydrothermal systems associated with Tertiary intrusives. Although some uranium may be derived from the same systems, most of uranium is probably in ground waters where it is leached from Precambrian rocks, older uranium deposits, and Tertiary volcanics. Copper may be derived from both hydrothermal systems and ground waters. The high heat flow associated with the Rio Grande rift and Tertiary intrusives would raise the temperature of the uranium- and copper-rich ground waters. Mixing of the heated ground waters with gold- and silver-bearing (with or without copper) hydrothermal fluids along faults produced by rifting could result in the copper, gold, silver, and uranium association.

ECONOMIC POTENTIAL

Precious Metals

Some of the gold deposits in northern New Mexico could have significant economic potential. Production continues at the Ortiz mine and from several small placer deposits. Gold and silver veins and base-metal deposits have a probable mineral-resource potential in the Red River district, Taos County (Ludington and Brown, 1984), and silver veins also have a probable mineral-resource potential in the Placitas district, Sandoval County (Hedlund and Kness, 1984). Both the districts are located in Federal Wilderness areas. The mineral-resource potential for gold and silver deposits in the Cochiti, Elizabethtown-Baldy, Old and New Placers, Cerrillos, and Hopewell districts is moderate to high; however, additional geologic work is needed in many of these areas.

Uranium

The mineral-resource potential for uranium in northern New Mexico is poor partly due to the present economic decline of the uranium industry. Most of the deposits in northern New Mexico are insignificant because of small size and low grade. However, should economic conditions improve, the uranium deposits in the Galisteo Formation in the Hagan Basin and at La Bajada could have a high potential. The U.S. Department of Energy (1980) estimates that probable resources of 185 tons (168 mt) of U_3O_8 at $30/lb exist in the Hagan Basin.

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