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1998, pp. 299-307. https://doi.org/10.56577/FFC-49.299

in:

Las Cruces Country II, Mack, G. H.; Austin, G. S.; Barker, J. M.; [eds.], New Mexico Geological Society 49 th Annual Fall Field Conference Guidebook, 325 p. https://doi.org/10.56577/FFC-49

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A SUMMARY OF THE MINERAL RESOURCES IN DOÑA ANA COUNTY, NEW MEXICO

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Abstract—Value of production from 14 mining districts in Doña Ana County is estimated as $3 million during 1849–1961. The majority of past metal production came from the Organ Mountains district, which is the sixth largest lead-producing district in New Mexico. Deposit types found in the county include carbonate-hosted Pb-Zn replacements, skarns, Ag-bearing pegmatites, epithermal/mesothermal veins, Rio Grande rift barite-fluorite-galena deposits, Cu breccia deposits, sedimentary-hosted Fe, epithermal Mn, veins and replacements in Precambrian rocks, and volcanic-epithermal deposits. Copper-molybdenum porphyry deposits may also occur in the Organ district. Other mining districts with minor production include the Aden, Brickland, Bear Canyon, Black Mountain, Doña Ana Mountains, Iron Hill, Northern Franklin Mountains, Rincon, Potrillo Mountains, San Andrecito-Hembrillo, San Andres Canyon, Tonuco Mountain, and Tortugas Mountains. Only industrial minerals are being produced from the county currently.

INTRODUCTION

Doña Ana County, in southern New Mexico, was created in 1852 and once included much of Otero, Eddy, Hidalgo, Sierra, Luna, and Grant Counties. About 1901 the present boundaries were established (Fig. 1). Las Cruces is the second largest city in New Mexico. Today, the adjacent metropolitan areas of El Paso, Texas, and Juárez, Mexico, with a combined population of nearly 2 million, have a large economic and political impact on the less populated Doña Ana County.

Mining has been an integral part of the early economy of Doña Ana County, where 14 mining districts are found (Table 1, Fig. 1). Today, agriculture, construction, and light industry are economically more important. The majority of the past metal production came from the Organ Mountains district, east of Las Cruces (Table 2). The Organ Mountains district is the sixth largest lead-producing district in New Mexico (McLemore and Lueth, 1995). Current production consists of aggregate (i.e., sand and gravel), clay and shale for brick manufacture, scoria, gypsum, travertine, and minor dimension stone (Hatton et al., 1994). The American Eagle Brick plant (formerly the Eagle mill) near El Paso manufactures bricks for nearby population centers (Fig. 1). The White Sands Missile Range forms the northeastern portion of the county and is withdrawn from mineral entry.

This paper presents a summary of the mineral resources in Doña Ana County (excluding aggregate resources, see Austin and Barker, this guidebook). Additional information, including a mineral assessment, is in McLemore et al. (1996) and Bartsch-Winkler (1997). North and McLemore (1986), Bartsch-Winkler (1997), McLemore et al. (this guidebook), and McLemore (in press) described the deposit types and origins. The geology of the districts is described elsewhere in this guidebook and in cited references. Metal production since the late 1800s is listed by district in Table 2. Barite and fluorite production is in Table 3, and Table 4 shows production of other minerals. Mining and production records are generally poor, particularly for the earliest times and many early records are conflicting. These production figures are the best data available and were obtained from published and unpublished sources (New Mexico Bureau of Mines and Mineral Resources, NMBMMR, files). However, production figures are subject to change as new data are obtained.

ADEN DISTRICT

Scoria deposits occur in more than 150 cinder cones in the Aden (Potrillo, Black Mountain) district in the Potrillo Mountains, Doña Ana and Luna Counties (Seager and Mack, 1994), but only a few have been quarried. Total production is unknown, but value of production from 1950–1994 is estimated as $10 million (McLemore et al., 1996). In the West Potrillo Mountains, Mt. Riley, and Aden Lava Flow Wilderness Study Areas, Kilburn et al. (1988) estimates an inferred resource of at least 400 million yd^3. Active operations are located outside of these restricted areas.

Scoria and pumice are pyroclastic deposits formed as volcanic fragments ejected during explosive volcanic eruptions. Scoria or volcanic cinder is red to black to gray, vesicular, basaltic fragments.

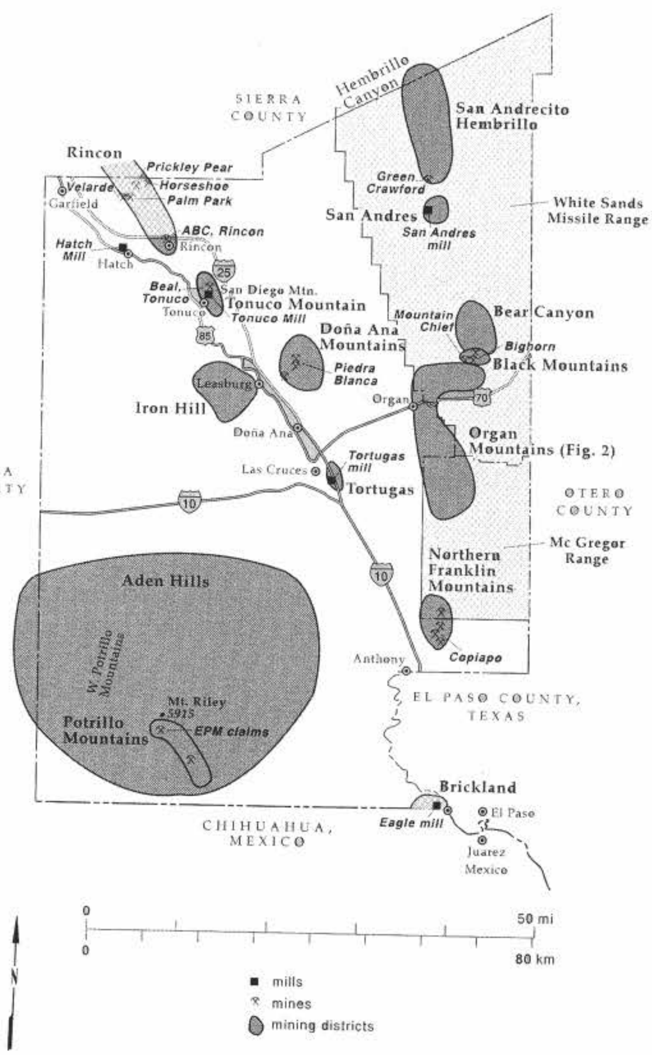

FIGURE 1. Mining districts in Doña Ana County, New Mexico.

TABLE 1. Mining districts in Doña Ana County (Fig. 1). Type of deposit after North and McLemore (1986), McLemore (in press) and includes USGS classification in parenthesis (Cox and Singer, 1986). [1]Black Mountain district is now restricted in this report to include only Rio Grande Rift deposits in the Black Mountain area. North and McLemore (1986) and McLemore (1994) included the description for Mineral Hill (veins and replacements in Precambrian rocks) as part of the Black Mountain district. However, the gold production from Mineral Hill was credited to the Organ Mountains district. The veins at Mineral Hill are now classified as epithermal/mesothermal veins and are included as part of the Organ Mountains district.

DISTRICT (ALIASES)	YEAR OF DISCOVERY	YEARS OF PRODUCTION	COMMODITIES PRODUCED (PRESENT)	ESTIMATED CUMMULATIVE VALUE OF PRODUCTION (IN ORIGIONAL DOLLARS)	TYPE OF DEPOSIT
Aden (Potrillo, Black Mountain)	1900s	1940s–present	scoria	<10,000,000	Volcanic
Bear Canyon (Stevens, San Augustin)	1883	early 1900s	Cu, Ag, Pb, Ba (F, V, Mo)	<5000	Rio Grande rift (32a)
Black Mountain[1] (Kent, Organ)	1883	1883–1900s	Cu, Au, Ag, Pb, F (Ba)	<78,000	Rio Grande rift (32a)
Brickland (Eagle, Cerro de Cristo Rey)	1900s	1900s–present	brick clay, silica, limestone	<10,000,000	Sedimentary
Doña Ana Mountains	1900	early 1900s	Cu, Au, Ag (Mn)	<5000	volcanic-epithermal (25b,c,d,e)
Iron Hill (Robledo Mts.)	1930s	?	Fe (gypsum, limestone)	<10,000	Sedimentary Fe deposits (34f), sedimentary
Northern Franklin Mountains	1914	1914	Ag, Pb, Fe, gypsum, limestone (F, Ba)	<1000	Rio Grande rift (32a), sedimentary
Organ Mountains (Mineral Hill, Bishops Cap, Organ, Gold Camp, Modoc, South Canyon, Texas)	1830s (perhaps as early as 1797)	1849–1961	Cu, Au, Ag, Pb, Zn, U, F, Ba, Bi (Mo, Te, W, Sn, Mn, Fe)	4,000,000	carbonate-hosted Pb-Zn replacement (19a), skarn (18a,19a), pegmatites, epithermal/mesothermal veins (22c), porphyry Cu-Mo (?) (21a), Cu breccia, Rio Grande Rift (32a)
Potrillo Mountains	1883	?	Cu, Au, Ag, Pb (Ba, F), travertine	<1000	Rio Grande rift (32a), sedimentary
Rincon (Hatch, Woolfer Canyon)	Early 1900s	1918	Mn, Ba (F, W, Cu, Pb, Zn, Ag), travertine	<100,000	epithermal Mn (25g), Rio Grande rift (32a), sedimentary
San Andrecito-Hembrillo (Membrillo, Capital Peak)	1890s	1914, 1915, 1918,1920–1930	Cu, Ag, Pb, talc (Ba, F, W?)	23,000	Rio Grande rift (32a), Precambrian veins and replacements (?) (22c)
San Andres Canyon	1900	1900–1904	Cu, Pb (Ag, Ba ,F)	<1000	Rio Grande rift (32a)
Tonuco Mountain (San Diego Mountain)	1900	1919–1935	Ba, F, Mn (U, Fe), travertine	<386,000	Rio Grande rift (32a), sedimentary
Tortugas Mountain	1900	1919–1943	F, Mn, Ba, geothermal, travertine	<1,000,000	Rio Grande rift (32a), travertine, geothermal

Most scoria occurs as loose and poorly consolidated fragments found in poorly- to well-sorted cones or mounds (Cima, 1978; Osburn, 1979, 1982; Peterson and Mason, 1983; Geitgey, 1994). Scoria is quarried by digging and ripping with tractors and rippers, stockpiled, and then crushed and screened (Osburn, 1982). Most cinder cones contain approximately 75% scoria (Cima, 1978; Osburn, 1979, 1982). Scoria is denser and more coarsely vesicular than pumice (Peterson and Mason, 1983), which is typically light in color, vesicular, and of dacitic to rhyolitic composition (Geitgey, 1994). The vesicular nature of scoria and pumice results in lower density and higher porosity than most rock types.

Most scoria in New Mexico is used to manufacture cinder block and concrete. In the 1950s, scoria was used in railroad ballast and road aggregate. Scoria from the Aden district is currently used in decorative stone for landscaping depending upon select size and color; reddish-brown color is more popular. Cinders are used on highways during winter storms to improve traction, as roofing granules, and as ground cover to control erosion. Scoria typically has a higher crushing strength than pumice, making it more desirable for certain aggregate uses.

Economic considerations of scoria include the color, grain size, sorting, density, degree of consolidation, and proximity to population centers. Scoria is marketed as a low-cost commodity in the Las Cruces and El Paso areas. Much of the cinder from the area is shipped out of state as decorative stone. Scoria resources in Doña Ana and Luna Counties are large, and are sufficient to meet local demand in the near future (Austin et al., 1982; Osburn, 1982).

BEAR CANYON DISTRICT

Rio Grande rift barite-fluorite-galena deposits are exposed by shafts, adits, and pits in the Bear Canyon (Stevens or San Augustin) district, in the southern San Andres Mountains. Deposits occur along the foothills (lower contact deposits) and near the crest (upper contact deposits). G. A. Bennett discovered the district in 1900 and production began a few years later (Table 1; Dunham, 1935; McLemore, 1994). Less than 10,000 lbs of Cu, <100 oz of Ag, and minor Pb were produced from the district (Tables 1, 4; Dunham, 1935; McLemore, 1994). In 1932, 50 short tons (st) of barite was produced from the Stevens mine (Williams, 1966).

The lower contact deposits occur in the foothills in limestone and dolomite along the low-angle thrust fault that separates Ordovician sedimentary rocks from Proterozoic granite. The upper contact deposits occur within Silurian dolomite beneath Percha Shale (Dunham, 1935; Williams et al., 1964; Bachman and Myers, 1963, 1969; Smith, 1981; McLemore, 1994). Vein, breccia-cement, cavity-filling, and minor irregular replacement deposits occur along faults and fractures, at unconformities, and along bedding planes in dolomitic limestone. The deposits contain barite, fluorite, calcite, and quartz with minor galena, malachite, and wulfenite. Assays as high as 89 ppm Ag, 12.2% Cu, and 34.8% Pb have been reported (W. E. Koch, unpublished report, July 1911, NMBMMR files). Samples from the lower contact deposits assayed as high as 5.4 ppm Ag, 3600 ppm Cu, 10,000 ppm Pb, and 180 ppm Zn (McLemore et al., 1996). The deposits are remote, inaccessible, and low grade.

BLACK MOUNTAIN DISTRICT

Pat Breen discovered the Black Mountain (Kent, Organ, and Gold Camp) district, north of the Organ Mountains district in 1883. The Mountain Chief and Black Mountain mines are the only productive mines in the district, producing less than $12,000 of Cu, Au, Ag, Pb, and fluorite (Table 1; Dunham, 1935; Williams, 1966; McAnulty, 1978; McLemore, 1994).

Rio Grande rift deposits are hosted by El Paso Formation dolomites and limestones cut by north- and west-trending faults (Dunham, 1935; Talmage and Wootton, 1937; Seager, 1981). An irregular replacement body within Fusselman Dolomite is exposed by 60-ft shaft and prospect pits at the Mountain Chief mine (NW¹/₄ sec. 11, T21S, R4E) that contains gold, quartz, calcite, limonite, pyrite, and chlorite (Dunham, 1935). The Bighorn deposit (sec. 12, T21S, R4E) is an irregular replacement body of galena in Paleozoic dolomite exposed by a 500-ft adit that occurs along a N50°W-trending vein. Another small barite-galena deposit is found at the summit of Black Mountain (sec. 1, T21S, R4E) (Dunham, 1935). These deposits are remote and inaccessible, and were not examined during this study. None of these deposits are economic.

BRICKLAND DISTRICT

The Brickland district is on the flank of Cerro de Cristo Rey (Cerro de Muleros) at the junction of Doña Ana County, New Mexico; El Paso County, Texas; and Chihuahua, Mexico. Clay and shale for brick manufacture have been produced from the district for 100 years. Plants are in New Mexico (Fig. 1) and Juárez, Mexico. The clay and shale are mined by open-pit quarrying, followed by crushing, screening, and firing at 900–1100°C (Ntisimanyana, 1990; Cudahy and Austin, 1996). Clay and shale deposits occur in the Mesilla Valley Formation, which crops out on the eastern flank of Cerro de Cristo Rey laccolith, a Tertiary andesitic intrusion (Lovejoy, 1976).

The quartz-rich Anapra Sandstone has been mined sporadically for silica flux for the nearby ASARCO smelter and for aggregate. Limestone was quarried from the Edwards Limestone by the Southwestern Portland Cement Co., and is now closed. However, the limestone is interbedded with quartz sandstone and shale, and would not yield a mineable high-calcium limestone (Kottlowski, 1962).

DOÑA ANA MOUNTAINS DISTRICT

Oligocene–Miocene volcanic-epithermal deposits were discovered about 1900 in the Doña Ana Mountains district, northeast of Doña Ana (Fig. 1). A small amount of Cu, Au, and Ag were produced (Table 1; North and McLemore, 1986). Marble and tactite crops out locally in these mountains.

Three shafts and several pits at the Piedra Blanca prospect (sec. 15, T21S, R1E) expose thin quartz veins along a 4-ft wide rhyolite dike intruding Cleofas Andesite (Dunham, 1935; Seager et al., 1976). Samples of a high-grade ore shoot collected in 1913 assayed 463 ppm Au, 62,915 ppm Ag and 466 ppm Au, 52,320 ppm Ag (Dunham, 1935). The silicified vein is less than 2-ft wide and contains quartz, Fe and Mn oxides, chlorite, calcite, and pyrite (Dunham, 1935; Farnham, 1961; Seager et al., 1976). Another

TABLE 2. Base- and precious-metal production in Doña Ana County, New Mexico (McLemore et al., 1996; U.S. Geological Survey, 1902–1927; U.S. Bureau of Mines, 1927–1990); ( ) estimated data; small = production not available; - = no data; ? = uncertain; < = less than.

District	Period of production	Copper (pounds)	Gold (troy ounces)	Silver (troy ounces)	Lead (pounds)	Zinc (pounds)	References	Comments
Bear Canyon	early 1900s	(<10,000)	—	(<100)	small	—	Dunham (1935), McLemore (1994)	—
Black Mountain	1883–1900s	(<10,000)	(600)	(<1000)	small	—	Dunham (1935), North and McLemore (1986), McLemore (1994)	$12,000 of Au production from Mountain Chief mine
Doña Ana Mountains	early 1900s	small	(100)	(5000)	—	—	North and McLemore (1986)	—
Northern Franklin Mountains	1914	—	—	Small	small	—	North and McLemore (1986)	—
Organ Mountains	1849–1961	(4,636,000)	(11,500)	(820,000)	(25,000,000)	(1,700,000)	USBM files, Jones (1965), North and McLemore (1986), Seager (1981), Dunham (1935), Eveleth (1983)	Produced about $2.7 million 1849–1961
Potrillo Mountains	?	small	small	small	small	—	Dunham (1935)	Minor production
San Andrecito-Hembrillo	1914, 1915, 1918, 1920–1930	(<10,000)	—	(<100)	small	—	Dunham (1935), Anderson (1957), McLemore (1994)	<$10,000 produced
San Andres Canyon	1900–1904	(<10,000)	—	—	small	—	Dunham (1935)	—

TABLE 3. Known production of barite and fluorite from mines in Doña Ana County. Symbols described in Table 2.

District	Barite production (st)	Fluorite production (st)	Period of production	References
Bear Canyon (Stevens)	50	—	1932	Dunham (1935), Williams et al. (1964), McLemore (1994)
Bishops Cap (Organ Mountains district)	—	150	1944, 1969–1972	Williams (1966), McAnulty (1978), Seager (1981)
Black Mountain	—	1100	?	Dunham (1935), Williams (1966), McAnulty (1978), Smith (1981), McLemore (1994)
Organ Mountains (White Spar, Tennessee, Golden Lily, Ruby)	—	1500	1933, mid-1900s	Talmage and Wootton (1937), Rothrock et al. (1946), Williams (1966), Williams et al. (1964), McAnulty (1978), McLemore (1994)
Rincon (Palm Park, Horseshoe)		—	?	Williams et al. (1964), Filsinger (1988)
Tonuco Mountain	200	7220	1919–1935	Rothrock et al. (1946), Clippinger (1949), Williams et al. (1966), McAnulty (1978)
Tortugas Mountain	100	20,751	1919–1943	Ladoo (1923), Rothrock et al. (1946), McAnulty (1978)

occurrence similar to the Piedra Blanca is found along a north-trending dike in sec. 15, T21S, R1E where a 20-ft shaft and pits expose thin quartz-pyrite veins. A sample assayed <50 ppm Cu, 75 ppm Pb, and 150 ppm Zn (McLemore et al., 1996). Similar veins in sec. 20, T21S, R2E near Dagger Flat are exposed by two shafts and pits. There, quartz and malachite occur along fractures in Cleofas Andesite.

Several prospects northwest of Doña Ana Peak (sec. 15, T21S, R1E) expose Mn veins and carbonate-hosted Ag-Mn replacement deposits. Four samples from these Mn veins assayed 120–1500 ppm Cu, <50–75 ppm Pb, and 61–120 ppm Zn (McLemore et al., 1996). Additional small occurrences are found in marble and recrystallized limestone of the Hueco Formation and are similar in texture and mineralogy to other carbonate-hosted deposits in southwestern New Mexico. One sample assayed 210 ppm Ag, <50 ppm Cu, 63 ppm Pb, and 87 ppm Zn. Traces of Fe oxides, pyrite, and chalcopyrite are found, but the metal potential is probably low.

Marble crops out in sec. 10 and 15, T21S, R1E and tactite crops out in sec. 15 and 16, T21S, R1E. The tactite consists of fine-grained garnet and Fe oxides with traces of pyrite. Marble was quarried for local use as riprap and road fill. The marble varies in color from white to pink, but is highly fractured and contains impurities and is not suitable for use as dimension stone. Local occurrences of high-calcium limestone are found in the Bursum and Hueco Formations (Kottlowski, 1962).

IRON HILL DISTRICT

The Iron Hill district, in the southwestern Robledo Mountains, was discovered in the early 1930s; no production is reported. Nearly two dozen pits, shafts, and adits expose the sedimentary-hosted Fe deposits (Dunham, 1935; Kelley, 1949; Harrer and Kelly, 1963). Travertine is common and is mined sporadically. High-calcium limestone and gypsum are also found in the district, but have not been exploited.

Lenticular replacements, breccia cement, and cavity fillings in Hueco Formation limestone (Hawley et al., 1975; Seager and Clemons, 1975) contain predominantly hematite, goethite, and limonite with local concentrations of Mn oxides, gypsum, calcite, quartz, and ocher (Dunham, 1935; Kelley, 1949). Numerous bodies range in size from small replacement pods to massive zones as much as 200 ft long and 120 ft wide (Dunham, 1935). The deposits both parallel and cut bedding. The ore is porous and banded, commonly encrusted, and has botryoidal and stalactitic textures (Kelley, 1949; Harrer and Kelly, 1963). Kelley (1949) estimated the indicated reserves at Iron Hill as 5010 st and inferred reserves as 15,030 st, both with a grade of 50–55% Fe. It is unlikely that these deposits will be mined because of small tonnage, low grade, poor quality, and inaccessibility.

The origin of the Iron Hill deposits is speculative. Dunham (1935) suggests that they were formed as a result of the leaching of hematite cement from overlying Permian Abo Tongue and precip-

TABLE 4. Other production from mines in Doña Ana County.

Mine	District	Location	Period of production	Production	References
Hembrillo, Redrock	San Andrecito-Hembrillo	sec. 1, 12, T22S, R4E	1917–1930, 1942–1945	13,000 st of talc	Chidester et al. (1964), Fitzsimmons and Kelly (1980), McLemore (1994)
Texas Canyon	Organ Mountains	sec. 34, T22S, R4E	1908–1921	small amount of ore containing 1% Bi	Dasch (1965)
Scoria pits	Potrillo Mountians	T24, 25, 26, 27, 28, 29S, R1E, 1, 2, 3, 4, 5W	1975–1988	Approximately $582,000 st of scoria worth $1.75 million, additional production unknown from 1940s–present	New Mexico State Inspector of Mines Annual Reports
various	Iron Hill	T21, 22S, R1W	1930–1950	Unknown amount of 50–55% Fe	Harrer and Kelly (1963)
Copiapo jarosite mine	Northern Franklin	sec. 8, T26S, R4E	1925–1928	Several hundred short tons of jarosite	Dunham (1935)

itated into voids in the underlying Hueco limestones. Kelley (1949) suggests that surface, subsurface, or magmatic waters of varying temperatures formed these deposits.

Travertine occurs in the district along the Cedar Hills and other north-trending faults in sec. 23 and 25, T21S, R1W (Hawley et al., 1975; Clemons, 1976). Banded travertine, known locally as "Radium Springs marble or onyx," occurs in veins and apron-like deposits in sec. 25, T21S, R1W. It was quarried and used as decorative stone. Additional pits occur in sec. 23, 26, 35, T21S, R2W (Clemons, 1976). The travertine is pink, orange, lavender, white, brown, or gold.

Gypsum occurs in the basal Tertiary sequence (Palm Park Formation) near Apache Canyon, Robledo Mountains (Weber and Kottlowski, 1959). Thin, faulted beds, composed of up to 80% gypsum, are 2–4 ft thick (Weber and Kottlowski, 1959). A chemical analysis of limestone from the Hueco Formation in Apache Canyon was found to contain 91.4% $CaCO_3$ (Kottlowski, 1962). The limestone is locally silicified. At Limestone Mesa south of Shalem Arroyo, the limestone is 5.5 ft thick with scattered chert nodules and thin shale lenses.

NORTHERN FRANKLIN MOUNTAINS DISTRICT

The Northern Franklin Mountains district, discovered in 1914, is in the New Mexico portion of the northern Franklin Mountains, but the range extends southward into Texas. Minor amount of Pb and Ag were produced from a Rio Grande rift deposit in sec. 32, T25S, R4E (Table 1). Deposits containing galena, barite, fluorite, calcite, Fe oxides, and quartz occur in dolomitic limestones of the Fusselman Formation. Dunham (1935) reports small shipments of argentiferous galena from the deposits. Samples assayed 0.7–20 ppm Ag, 3–54 ppm Cu, 28–18,000 ppm Pb, 15–12,000 Zn, and 890–300,000 ppm Ba (unpublished chemical analyses; McLemore et al., 1996). The largest vein is less than 3 ft wide and several hundred feet long.

F. Schneider Co. mined several hundred short tons of jarosite in 1925–1928 from the Copiapo mine in Webb Gap (NE¼ sec. 8, T26S, R4E), for use as pigment in paints. The deposit, exposed by a 200-ft shaft and six pits, occurs along a north-trending, low-angle, fault zone (N10°E 40–50°E) within the Bishop Cap Formation (Kelley and Matheny, 1983). At the shaft, the deposit is 10–15 ft wide and 100–200 ft long. The deposit pinches out to the north and thins to the south (<10 ft wide). Vein and replacement bodies along the fault zone contain jarosite (red to yellow to orange), limonite, hematite (red to black to brown), gypsum, calcite, fluorite, and aragonite. Jarosite occurs only within the upper 100 ft. Samples assayed 0–108 ppm Ag, 10–32 ppm Cu, 22–61 ppm Pb, 44–650 ppm Zn, and 2–55% Fe (McLemore et al., 1996). $^{40}Ar/^{39}Ar$ age dates on jarosite from the deposit range from 5.0 ± 0.3 to 4.6 ± 0.06 Ma (Lueth and Goodell, 1996; Goodell et al., 1996). The economic potential for use in paint is low, because of small size and distance from paint manufacturers. Additional uneconomic occurrences of jarosite, limonite, and hematite occur in the limestones in sec. 22 and 27, T26S, R4E.

The origin of the deposit is speculative, but the poorly crystalline and very fine-grained minerals and crude zonation are suggestive of a supergene origin. The deposit may overlie epithermal base- or precious-metal deposits, but drilling is needed to confirm their presence. The mineralogy and age of the deposit also suggest formation by basinal brines, similar to the process that formed Rio Grande rift barite-fluorite-galena deposits (McLemore and Lueth, 1995; Lueth and Goodell, 1996; McLemore et al., this guidebook; McLemore, in press).

Gypsum and limestone were quarried in the northern Franklin Mountains. Gypsum at Anthony Gap occurs in two beds up to 25–40 ft thick in the Panther Seep Formation (Weber and Kottlowski, 1959; Harbour, 1972). The El Paso Cement Company (Southwestern Portland Cement Co.) quarried gypsum about 1932 (Dunham, 1935). However, the gypsum is steeply dipping (20–23°S), erratic in thickness (up to 40 ft thick), and overlain by shale. These characteristics make it difficult to mine. Limestone was quarried in the area for aggregate. Locally, high-calcium limestones occur in Pennsylvanian and Hueco Group rocks (Kottlowski, 1962).

ORGAN MOUNTAINS DISTRICT

The Organ Mountains district, near Organ, includes the Mineral Hill, Bishops Cap, Gold Camp, Modoc, South Canyon, Soledad Canyon, and Texas Canyon subdistricts. The district was discovered in the 1830s and may have been discovered as early as 1797 (Dunham, 1935). The value of metal production from the district is estimated as $2.7 million worth of Cu, Pb, Zn, Ag, and Au (Table 2). Other production from the Organ Mountains district is given in Table 4. Local occurrences of Fe, Mn, Mo, Sn, Te, and W are also reported (McLemore et al., 1996). Eleven mills operated in the district (McLemore et al., 1996).

From 1960 to early 1980s, several companies examined the Organ Mountains for potential Cu-Mo porphyry deposits (Kerr-McGee in 1963, AMAX in 1969, Bear Creek in 1970, Conoco in 1972–1976). More than 60 drill holes were drilled northeast of Organ, ranging in depth from 195 to 3100 ft (Newcomer and Giordano, 1986). Lithology, alteration assemblages, mineral zoning, and stockwork veining suggest that a Cu and/or Cu-Mo porphyry may occur in the Organ Mountains district. Drilling has not delineated any ore bodies, but assays range from 0.001 to 0.065% Cu and as high as 0.15% Mo (Newcomer, 1984; Newcomer and Giordano, 1986).

Seven deposit types occur in the Organ Mountains district (Table 1) and form five metal zones (Fig. 2; Dunham, 1935; Seager, 1981; Seager and McCurry, 1988; Lueth and McLemore, this guidebook). The core is formed by Cu-Mo mineralization, surrounded by Zn-Pb, Pb-Zn, Ag-Au, and outer fluorite-barite zones (Fig. 2). This district-wide zoning is best preserved in the northern Organ Mountains, where disseminated Cu-Mo mineralization has been encountered in drill holes northwest of Organ and is interpreted as a faulted portion of a Cu-Mo porphyry deposit (Newcomer and Giordano, 1986).

To the east at San Augustin Pass, a zone of disseminated and veined pyrite occurs in the Sugarloaf Peak quartz monzonite, the next to last and most volatile-rich phase of the Organ batholith, and forms the center zone of the northern district. The Organ batholith is a complex pluton made up of multiple intrusions (Seager, 1981; Seager and McCurry, 1988); three major phases are the granite of Granite Peak, Sugarloaf Peak quartz monzonite, and Organ Needle quartz syenite. All three phases are related to mineral deposits. The Sugarloaf Peak quartz monzonite has been dated as 34.4 ± 0.3 Ma ($^{40}Ar/^{39}Ar$, hornblende, McLemore et al., 1995). Silver-bearing pegmatites occur near San Augustin Pass in the Sugarloaf Peak quartz monzonite (Dunham, 1935; McLemore et al., 1995). Copper-breccia deposits occur west of the Sugarloaf Peak quartz monzonite at the Torpedo and Memphis mines. A transition from disseminated Cu-Mo to Cu skarns and breccias to Zn-Pb skarns and replacement deposits occurs in carbonates northwest of the Memphis mine and near the Excelsior mine in the northern district (Lueth, 1988). The Homestake and Memphis deposits are Zn-Pb skarns. The Merrimac mine contains predominantly Zn replacements; Pb with Ag becomes more dominant to the east. The Hilltop and Black

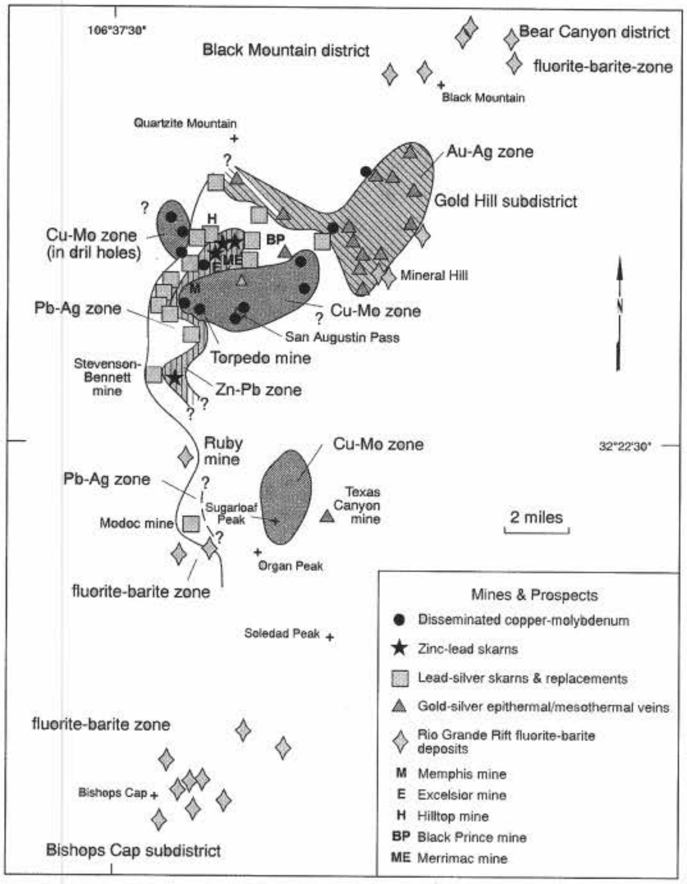

FIGURE 2. District zoning in the Organ Mountains (Dunham, 1935; Seager, 1981; McLemore et al., 1996).

Prince mines are predominantly carbonate-hosted Pb-Ag deposits. The Stevenson-Bennett mine contains carbonate-hosted Pb-Ag and Zn-Pb deposits. Gold and silver epithermal/mesothermal veins occur in the Proterozoic rocks in the Gold Hill area, east of the Sugarloaf Peak quartz monzonite. Silver decreases to the north and barite becomes dominant. The Modoc and Orejon deposits along the west side of the Organ Mountains are Pb-Zn skarn and replacement deposits and may be related to a third Cu-Mo zone in the central Organ Mountains near Organ Peak. An outer zone, surrounding the Organ Mountains batholith, consists of Rio Grande Rift barite-fluorite deposits, locally with Cu, Pb, U, Ag and V; examples include the Bishops Cap and the Ruby mines.

Carbonate-hosted Pb-Zn replacement and skarn deposits were the most economically important types of deposits in the Organ Mountains. Grades of ore from the Stevenson-Bennett mine, the largest deposit, averaged 1.8% Pb, 1.1% Zn, 0.2% Cu, and 4.9 oz/ton Ag. The deposits typically contain malachite, galena, sphalerite, and galena in a gangue of calcite, quartz, pyrite and locally garnet and epidote. The Au-Ag veins at Mineral Hill contain banded, vuggy quartz, massive calcite, and vugs shaped as cubes, indicating the occurrence of pyrite. Locally, quartz is bladed after calcite, indicating boiling occurred. Argillic alteration is common with local epidote present. Locally, the veins contain pyrite, hematite, malachite, chalcopyrite, bornite, galena, sphalerite, and acanthite.

The largest fluorite deposits are Rio Grande rift veins and replacements at Bishops Cap in the southwestern portion of the area, consisting of narrow veins along faults and bedding planes and irregular replacement deposits in the Fusselman Dolomite, Canutillo, Rancheria, and La Tuna Formations. Fluorite with uranium minerals, barite, quartz, calcite, and trace amount of galena occurs in limestone. Production amounted to 150 st of fluorite. Veins and replacement bodies are 20–40 ft long and up to 2 ft thick. A sample assayed 6.8% $BaSO_4$ and 40.1% CaF^2. Jasperoids are common.

Brucite and magnesite occur in the southern Organ Mountains as xenoliths within the Organ batholith (Dunham, 1935). The xenoliths are up to 1000 ft long and 500 ft wide and exposed by prospect pits. The area is restricted access because of unexploded ordinance and was not examined for this study. Magnesite is also reported to occur in the northern Organ Mountains, where it has replaced Montoya and Fusselman Dolomite.

Marble occurs locally north of Organ along the intrusive contact between the limestone and rhyolite dikes and quartz monzonite porphyry (Dunham, 1935; Seager, 1981). The marble is typically white and locally contains pyrite, garnet, and epidote disseminations. The economic potential of the marble is low because of small size and distance to potential markets.

Alteration, mineralization, and drilling indicate that at least three Cu-Mo porphyry systems probably occur in the Organ Mountains, but the potential for an economic deposit is low (Schilling, 1965; Luddington et al., 1988). The potential for Cu breccias, skarns, carbonate-hosted Pb-Zn replacements, epithermal/mesothermal veins, and fluorite deposits in the Organ Mountains is moderate (Luddington et al., 1988).

POTRILLO MOUNTAINS DISTRICT

The Potrillo Mountains district, southeast of Las Cruces (Fig. 1), was discovered in 1883. Dunham (1935) and unpublished reports indicate that some Au, Ag, Cu, and Pb were produced from the area in the late 1800s and early 1900s, but actual production is unknown. Heylman (1986) reports that John Graham discovered a gold pocket in quartzite in the northern portion of the East Potrillo Mountains. It is unlikely that total production value exceeded a few thousand dollars.

In 1970, J. Peter Rogowski and William A. Bowers (Jenkins, 1977) filed the EPM (East Potrillo Mountains) mining claims. Subsequently, several companies including Phelps Dodge Corp., Anaconda Minerals, Corp., and Exxon Minerals, Inc. examined the area, but no ore discoveries were announced. Exxon drilled 10 holes with depths ranging from 25 to 465 ft and located several mineralized zones containing high silver values (Gese, 1985). There is no current activity in the Potrillo Mountains.

Rio Grande rift deposits occur in limestones of the Yeso and San Andres Formations (Bowers, 1960; Jenkins, 1977; Seager and Mack, 1994). Jasperoid is common and occurs as pods along faults, fractures, breccia zones, and bedding planes. The zones are brown to gray to yellow to red and contain quartz, calcite, barite, Fe and Mn oxides, and trace amounts of galena, pyrite, sphalerite, malachite, cerusite and local jarosite. Textures include brecciation, jigsaw-puzzle, xenomorphic, reticulated, granular, ribbon-rock (banded), and massive (Jenkins, 1977). Temperatures of homogenization range from 185° to 238°C (Jenkins, 1977). Samples of jasperoids assayed <0.69–269 ppm Ag, 3–63,000 ppm Cu, 14–5100 ppm Pb, 22–41,000 ppm Zn, and <0.15–0.68% CaF_2 (McLemore et al., 1996).

Travertine crops out in the southern East Potrillo Mountains (sec. 24, T28S, R2W). It was described as a marble (Dunham, 1935), but it is a fissure-ridge type of travertine deposit that is fault controlled. Production is unknown, but presumed small. The travertine is white with thin black bands. Most travertine occurs as fractured, small pods. It is recrystallized limestone of the Yeso and San Andres Formations (Hoffer, 1976; Seager and Mack, 1994) and occurs along the range-bounding fault (Robledo fault of Hoffer, 1976). A sample assayed 22,000 ppm Cu (McLemore et al., 1996).

The deposit is too small and too fractured to have any major potential as dimension stone, but could be used locally as a decorative stone or road fill.

RINCON DISTRICT

The Rincon (Hatch and Woolfer Canyon) district, discovered in the early 1900s, includes numerous barite-galena and Mn deposits in the southern Caballo Mountains (Fig. 1). Production from the district amounts to 10,250 st of barite and 1,529 st of 27–40% Mn (Farnham, 1961; Dorr, 1965; Williams et al., 1964; Filsinger, 1988).

Rio Grande rift deposits occur in the Fusselman Dolomite, stratigraphically below Percha Shale (Seager and Hawley, 1973; Seager and Clemons, 1975). The Palm Park deposit, the largest deposit, contains calcite, barite, fluorite, and trace amounts of malachite, azurite, pyrite, galena, chalcopyrite, sphalerite, covellite, and quartz (Filsinger, 1988). Samples assayed <0.02–0.11% Cu, 0.01–11.5% Pb, and 99 ppm Ag (Filsinger, 1988). Brecciation, banded ore, and veins are common textures. Jasperoids are common. Fluid inclusion temperatures range from 163° to 341°C (barite, fluorite, and quartz) and have moderate salinities (4.8–17.0 wt.% eq. NaCl), indicating formation by mixing of saline connate-meteoric waters with heated hydrothermal fluids. The Horseshoe and Prickly Pear deposits are smaller, but similar to the Palm Park deposit. A rhyolite sill intrudes the Paleozoic sedimentary rocks north of the Horseshoe deposit (Seager and Hawley, 1973; Seager and Clemons, 1975). In one locality, jasperoid contains rhyolite fragments (Filsinger, 1988). These relationships suggest that the barite deposits are probably younger than the rhyolite sill, which is probably mid-Tertiary in age.

Drill data indicates that the Palm Park deposit contains 1.5 million st of ore grading 27% $BaSO_4$ (Filsinger, 1988). The Horseshoe deposit contains as much as 50,100 st of 5–20% $BaSO_4$, but in thin deposits (less than 5 ft thick). The Prickly Pear deposit contains as much as 200,000 st of 5–25% $BaSO_4$, also in thin deposits (Filsinger, 1988). These barite deposits are uneconomic and would be mined only if petroleum exploration increases the demand for barite in drilling muds. However, the high whiteness and brightness of the barite is desired in certain paints and fillers and could be produced if these specialized markets were developed nearby.

Manganese deposits are also common in the Rincon district. The Velarde (Blackie, Sheriff) mine, the largest, contains replacements, veins, and open-space fillings of Mn oxides, calcite, Fe oxides, quartz, and, barite. Manganese oxides also form cement in breccias and sandstones. The Montoya Formation hosts the deposits that are as much as 3–8 ft wide and 50–80 ft long. They contain psilomelane, pyrolusite, calcite, and quartz. Ore shipments in 1942 (14 st) and 1952–1953 (101 st) averaged 20–28% Mn. These deposits are low tonnage, low grade, and uneconomical.

Banded travertine is common in the Palm Park Formation in the northern Rincon district (Seager and Hawley, 1973). It is white, pink, brown, or gray and is up to 6 ft thick (Barker et al., 1995). The deposits are typically small and would meet only local needs as a decorative stone. Gypsiferous clay deposits occur in the Rincon Valley Formation near Rincon. A clay mill operated at Hatch 1937–1940.

SAN ANDRECITO-HEMBRILLO DISTRICT

Rio Grande rift, Precambrian vein and replacement, and talc deposits are found in the San Andrecito-Hembrillo district, in the San Andres Mountains (T16S, T17S, R3E, R4E, Fig. 1). Very little information exists on the discovery, history, or production of these small deposits. Many could not be located in 1993–1994. The Green Crawford and Hembrillo Canyon prospects were worked in the late 1890s or early 1900s and again during 1920–1930. The amount of production from the Hembrillo Canyon prospects in 1914, 1915, and 1918 is unknown (Anderson, 1957; NMBMMR files). Total value of production from the district amounts to less than $10,000 worth of Cu, Pb, and Ag (Dunham, 1935; NMBMMR files). Total talc production from 1920 to 1945 is 12,062 st (Fitzsimmons and Kelley, 1980; Chidester et al., 1964).

Although the Rio Grande rift barite-fluorite-galena deposits are small, most of the reported metal production has come from them. The Green Crawford mine, in San Andrecito Canyon (NW¼ sec. 31, T17S, R4E) is exposed by two adits, several pits, and shallow shafts on opposite sides of the canyon. The deposits are fissure veins that contain covellite, chalcocite, chalcopyrite, cuprite, malachite, and azurite in a gangue of quartz, calcite, Fe oxides, and barite. The host rocks adjacent to the veins are silicified and replaced by Fe oxides. Samples assayed as much as 6400 ppm Cu, 32 ppm Pb, and 26 ppm Zn (McLemore et al., 1996).

At the Hembrillo Canyon prospects (Lot OM-69; SE¼ sec. 9, T16S, R3E), two shafts and two pits expose thin veins and small replacement bodies in limestones within a faulted block of Lead Camp Limestone. The deposit is less than 300 ft long and contains galena, barite, quartz, calcite, Fe oxides, and wulfenite. Samples assayed 180–500 ppm Cu, 21,000 ppm Pb, and 14–33 ppm Zn (McLemore et al., 1996).

In Hospital Canyon (SW¼ sec. 18, T16S, R4E), prospect pits and a 15-ft shaft expose minor vein and replacement deposits along faults adjacent to amphibolite dikes in Proterozoic rocks. Additional veins of Cu and barite are reported to occur in the San Andrecito-Hembrillo district, but could not be located during this study.

Adits and pits in Proterozoic granite and metamorphic rocks in Hembrillo Canyon expose the Precambrian talc deposits, the most extensive deposits in the district. The deposits are pod shaped and approximately 100 ft long and 8–12 ft wide. The central part of the pods contains predominantly pure talc. The outer zone is 2–3 ft wide and contains talc, carbonate, and chlorite. The talc grades into banded quartz-chlorite phyllite and schist. Foliation is subparallel to foliation of the metamorphic rocks, indicating a Proterozoic age. Fitzsimmons and Kelley (1980) reported a reserve of 6500 st.

SAN ANDRES CANYON DISTRICT

The San Andres mine, San Andres Canyon district in the San Andres Mountains (SE¼ sec. 18, T18S, R4E, Fig. 1), was discovered and developed in 1900. It is developed by a 100-ft open cut, 550-ft adit with a 130-ft drift and a winze, and several pits and shafts (Dunham, 1935; Smith, 1981), but all are caved and inaccessible. A mill and smelter were erected in 1900–1904. Capacity was expected to be 100 tpd. However, the mill and smelter were built before any reserves were delineated and the entire operation failed with very little Pb and Cu production (Dunham, 1935). Only the foundations are left.

The Rio Grande rift deposits are small, irregular replacement bodies in Fusselman dolomite adjacent to a N15°W-trending fault that dips steeply to the west (Dunham, 1935; Bachman and Myers, 1963, 1969; Smith, 1981). The deposits are approximately 200 ft long and up to 20 ft wide (Dunham, 1935) and contain barite, quartz, minor galena, calcite, fluorite, Fe oxides, and clay. Samples assayed as much as 2.2 ppm Ag, 170 ppm Cu, 24,000 ppm Pb, and 31 ppm Zn (McLemore et al., 1996).

TONUCO MOUNTAIN DISTRICT

The Tonuco Mountain (San Diego) mining district, southeast of Rincon, includes two small uplifts; Tonuco and West Selden Hills (Seager et al., 1971). Rio Grande rift deposits in Proterozoic rocks were discovered in 1900 and from 1919 to 1935, 200 st of barite and 7720 st of fluorite were produced (Table 3; Rothrock et al., 1946; Clippinger, 1949; Williams et al., 1964; McAnulty, 1978). A fluorite mill was erected at the Tonuco mine in 1922 (Ladoo, 1923).

The Rio Grande rift veins are typically small (less than 1.5 ft wide), discontinuous, and trend north to northwest. The veins occur along faults and fractures in Proterozoic rocks and as open-space fillings in the silicified Hayner Ranch Formation. The Beal vein is several hundred yards long, less than 2 ft wide, strikes N25°W, and dips 70°SW. Samples from the Beal vein assayed 21.4–38.7% CaF_2 and 28.1–49.2% $BaSO_4$ (NMBMMR files). The Tonuco vein is 1000 ft long, less than 10 ft wide, strikes N70°W, and dips 60°SW. A sample assayed 35.7% CaF_2 and 47.2% $BaSO_4$ (NMBMMR files). Both veins contain barite, quartz, calcite, Fe and Mn oxides, and fluorite. Stratigraphic relations indicate that the veins are probably Miocene (Seager et al., 1971).

The discontinuous Mn vein deposits contain Mn and Fe oxides and calcite. The Garcia deposit occurs in fractures trending N60°W in sandstone, is 60 ft long, is 3–5 ft wide, and contains a few hundred st of 5–10% Mn. At least three similar bodies crop out at the Iron Mask mine that are 4–10 ft wide and 20–60 ft long.

Radioactive travertine occurs along the northwest base of San Diego Mountain (Boyd and Wolf, 1953; Seager et al., 1971; Seager, 1975) and was formed by springs during the Pleistocene (Barker et al., 1995). Travertine was quarried in the Buckle Bar area of Selden Hills (sec. 20 and 21, T20S, R1W). White is the predominant color. Most of these deposits are small and would meet only local needs as a decorative stone.

TORTUGAS MOUNTAIN DISTRICT

The Tortugas Mountain district ("A" Mountain), east of Las Cruces (sec. 23, 24, T 23S, R2E, Fig. 1) was discovered in 1900. Rio Grande Rift fluorite-calcite, barite, and Mn deposits occur along numerous faults in Permian limestones and dolomites (Dunham, 1935; McAnulty, 1978; Macer, 1978; King and Kelley, 1980). From 1919–1943, 20,751 st of fluorite and 100 st of barite were produced. A mill operated from 1927 to 1933. Numerous adits, shafts and pits exposed the veins that are 1200 ft long and 285 ft deep (Dunham, 1935); the mines were reclaimed in 1990. The largest fluorite-calcite vein, up to 10 ft thick, occurs along the Tortugas fault and was mined to 530 ft (Rothrock et al., 1946; King and Kelley, 1980). Ore averaged 77.4% CaF_2 (Ladoo, 1927). Fluid inclusion analyses indicate formation temperatures of 180° to 191°C and low salinities of less than 2 wt.% eq. NaCl (Macer, 1978; North and Tuff, 1986); indicating formation by hydrothermal meteoric fluids. Ore remaining in the pillars underground at the Tortugas mine is probably insufficient tonnage to be produced (G. B. Griswold, unpublished report, December 1980, on file at NMBMMR archives).

At least eight drill holes were drilled south and east of Tortugas Mountain for geothermal resources (Gross and Icerman, 1983). A small travertine deposit occurs on the northern part of the mountain (secs. 23 and 24, T2E, R23S). The travertine is white to gray and probably suitable only for local use.

ACKNOWLEDGMENTS

This paper is part of a study of the mineral resources of the Mimbres Resource Area (Doña Ana, Luna, Hidalgo, and Grant Counties), in cooperation with the U.S. Geological Survey and U. S. Bureau of Land Management. Susan Bartsch-Winkler, David Sutphin, James McLemore, and Chuck O'Donnell are acknowledged for field assistance, discussions, and providing data. Frank Kottlowski, William Seager, George Austin, and Susan Bartsch-Winkler reviewed an earlier draft of this manuscript and their comments are appreciated. Daniel Hack and Tim Pease provided additional technical assistance. Bob Myers provided access to the White Sands Missile Range. This work is part of ongoing research of mineral resources in New Mexico at NMBMMR, Charles Chapin, Director and State Geologist.

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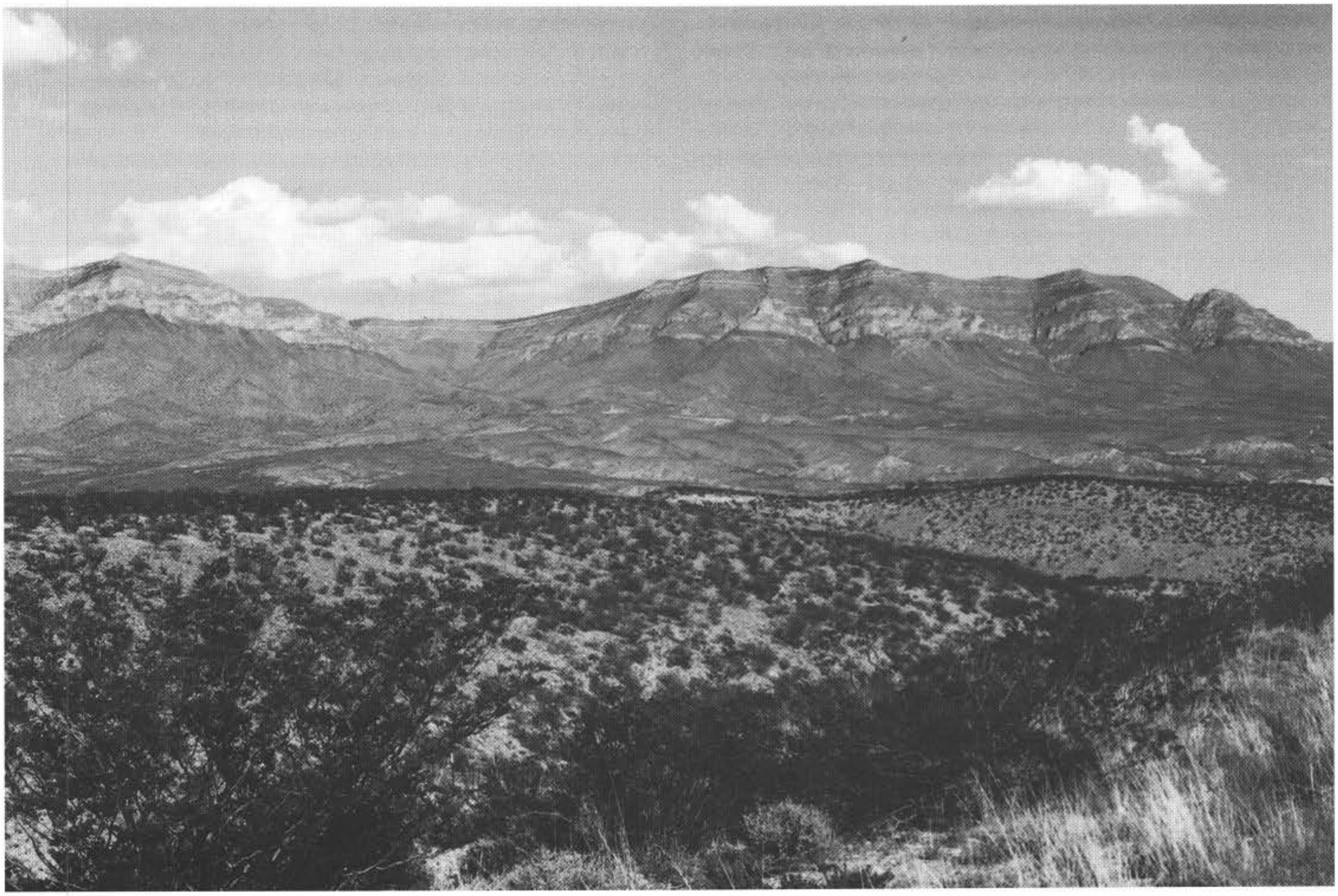

View of the west-facing scarp of the Caballo Mountains. Scarp exposes Precambrian crystalline basement and Cambrian through Pennsylvanian sedimentary rocks. In the foreground are the Plio–Pleistocene Palomas Formation and younger alluvium inset against it. Photograph by Greg Mack.