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INTRODUCTION

This article is a preliminary report, part of a larger study sponsored by the New Mexico Bureau of Mines and Mineral Resources. It is a summary of the literature, supplemented by brief field checks.

HISTORY OF MINING

First Period: Beginning to 1880

From the beginning of the industry in prehistoric days to the arrival of the A., T. & S. F. Railway in 1880, mining was confined to two types of products: those used locally and those of small bulk and high value, such as precious metals and turquoise,[1] that could be carried on the backs of humans or animals to outside markets.

Among materials used locally were turquoise, pottery clay, mineral pigments, adobe, gypsum, and stone, worked by the Indians for centuries. The Spaniards introduced metals in the 16th century. At least one small mine, The Mina del Tiro (or Mina del Tierra) was worked by the Spaniards in the Cerrillos district, Santa Fe County. However, most stories of fabulously rich Spanish mines, filled in by Indians after the 1680 pueblo revolt, have been manufactured in recent years by promoters who "rediscovered" them. In the last couple of years I have been able to trace two of these stories (both of which made the Albuquerque newspapers) to their fraudulent sources.

Systematic mining for precious metals began only with the discovery of the Old Placers in 1828, followed by the discovery of gold-bearing quartz veins in the Ortiz Mountains in 1833, and of the New Placers in the San Pedro Mountains in 1839. In 1845 the combined gold production of the Old and New Placers is said to have reached $250,000 (Northrop, 1959).

More modern mining methods were introduced after the American occupation in 1846. By 1869 the 40-stamp mill of the Ortiz mine (Old Placers district) impressed the much-travelled F. V. Hayden, geologist of the U. S. Geological and Geographical Survey of the Territories, as the most substantial he had seen in the West. The stamps were powered by a steam engine fired by coal from the Cerrillos field (Jones, 1904).

Second Period: 1880-1945

The arrival of the Santa Fe Railroad revolutionized the mining industry in New Mexico. Now base-metal ores and coal could be carried cheaply to smelters and other markets, and low-grade precious metal deposits could be worked at a profit. The emphasis quickly shifted from placer mining to lode mining. In rapid order came the development of the lead-zinc veins of the Cerrillos district (1879), the sandstone copper deposits of the Nacimiento Mountains (1880), the San Pedro contact-metamorphic copper deposit (1884), and the low-grade gold-silver veins of the Cochiti (Bland) district in the Jemez Mountains (1893). Beginning in 1890, the ancient turquoise industry was put on a modern basis by the American Turquoise Co. Coal output of Santa Fe County rose from 3,600 tons in 1882 (the first year of accurate records) to 252,731 tons in 1900. A host of small and short-lived mills and smelters was active.

All this activity may give the impression of a flourishing mineral industry, but this would be misleading. Most mining enterprises during this period were able to operate only in times of high metal prices. Not a single metal mine in the three-county area was able to operate continuously for the 10 to 15 years ordinarily considered the minimum period for a profitable undertaking. Placer workings were plagued by lack of water. This problem stumped even Thomas A. Edison, who unsuccessfully attempted to work the Old Placers by a dry method in 1900. In consequence, the total metal production of Bernalillo, Sandoval, and Santa Fe Counties, from 1828 to the present, has been only a little under $11 million. By way of contrast, the Chino copper mine at Santa Rita, Grant County, has at times yielded that much in less than three months. Coal, the mainstay of mining during the entire period from 1880 to 1945, declined after 1929, first through competition with other coal fields and later through competition with oil and natural gas.

Third Period: 1945 to Present

The end of World War II brought radical changes into the mineral economy of north-central New Mexico, most of them adverse to existing producers. While the cost of mining, especially labor, doubled and tripled in the general inflation, gold prices remained fixed at pre-war levels. The rise in silver and base-metal prices lagged behind the rise in production costs. New pipelines brought petroleum products to consumers who had previously relied on coal, and the railroads switched to diesel fuel. To survive, the mineral industry switched to industrial non-metals and became a supplier to the booming construction industry (Table 1). Among the three counties, Santa Fe lost the leadership it held in mineral production since earliest days; its place was taken by Bernalillo County. Cement, gypsum wallboard, sand, gravel, and pumice blocks may lack the glamour of Indian turquoise and Spanish silver, but they provide the basis for a stable mineral industry.

METALS

From 1828 to 1959, Bernalillo, Sandoval, and Santa Fe Counties have produced metals valued at over $10,700,000 (Table 2). During the 19th century the total was a little over $6,000,000, about two-thirds of which can be credited to placer gold from the Old and New Placers in Santa Fe County before 1880. During the 20th century the yield has been about $4,500,000. Of this, about four-fifths came from two mines in the San Pedro (New Placers) district, Santa Fe County: the San Pedro copper-gold-silver mine, and the Lincoln-Lucky (Carnahan) lead-zinc-silver mine.

[1]This spelling is preferred by most dictionaries; Dana's System gives it as turquois.—Ed.

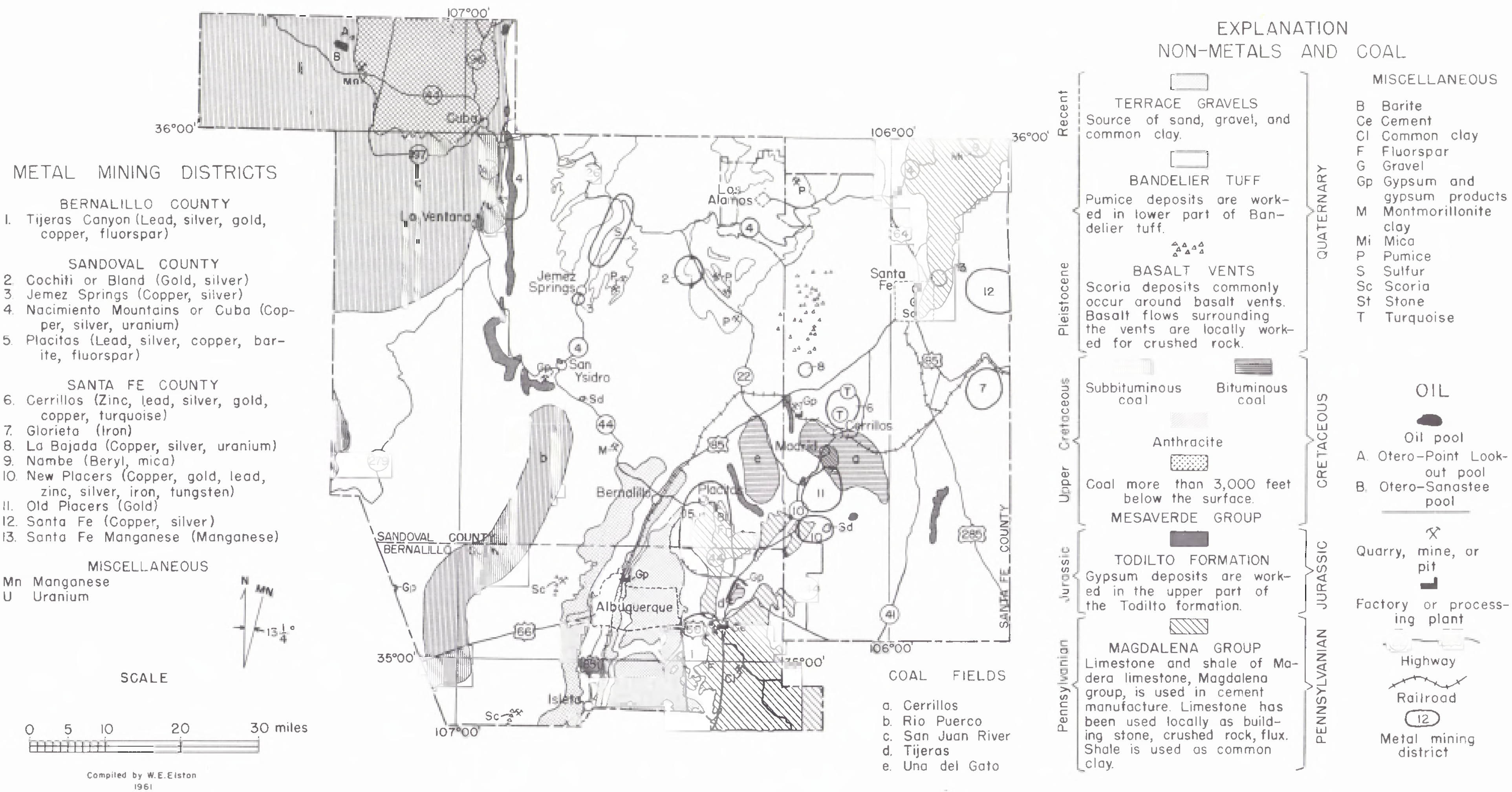

FIG. 1 ECONOMIC GEOLOGY OF BERNALILLO, LOS ALAMOS, SANDOVAL, AND SANTA FE COUNTIES, NEW MEXICO

Table 1. Value in Dollars of Mineral Production of Bernalillo, Sandoval, and Santa Fe Counties, New Mexico, Fiscal Years 1949 to 1960.

County	Metals	Pumice & Scoria	Sand Gravel, Clay	Coal	Other	Total
Bernalillo	-	559,410 1/	12,986,988	32,628	98,463 2/	13,677,489
Sandoval	22,154	1,669,564	3,573	206,987	-	1,902,278
Santa Fe	196,606	872,280	1,506,330	1,333,518	20,326 3/	3,925,060
Totals	214,760	3,101,254	14,496,891	1,573,133	118,789	19,504,827

1/ Estimated in part. Figure is for 1950 to 1960 only. 2/ Mainly cement materials. 3/ Mainly gypsum.

Source of data: State (of New Mexico) Inspector of Mines, Annual Reports, 1949 to 1960. The figures in the Annual Reports are consistently lower than those given by the U. S. Department of the Interior Minerals Yearbooks because of differences in estimating the value of minerals processed by the producer (e.g., pumice, scoria, and cement materials).

Note: This table does not yet include the cement and gypsum industry for a full working year, since the plants did not go into full production until late in 1960.

Bernalillo County

Tijeras Canyon (Soda Springs, Hell Canyon, Coyote Canyon) District

The Tijeras Canyon mining district includes the southern end of the Sandia Mountains, the Manzanita Mountains, and the Manzano Mountains as far south as the Torrance County line. It has yielded negligible amounts of fluorspar, gold, lead, and silver, and there has been some prospecting for copper. Metal production in this century has been worth only $4,100. Ross (1909) described most of the metal mines of the Coyote Canyon area during their most active period of development.

The rocks of the district consist of Precambrian gneiss, schist, slate, quartzite, and granite, capped by the Pennsylvanian Magdalena group on the higher mountains. The veins are post-Pennsylvanian, probably Tertiary. Most of them occupy north-trending high-angle faults, but some of them have a northeasterly trend. Their mineralogy seems to be controlled by distance from the Precambrian-Pennsylvanian contact. All shoots that have been mined since 1910 lie in Precambrian rocks directly or a short distance below Pennsylvanian limestone. The veins consist of brecciated fragments of wall rock cemented by fluorite and lesser amounts of barite, galena, quartz, and calcite. At depth, away from the limestone contacts, quartz increases at the expense of other minerals, copper minerals make their appearance, and gold values rise slightly. All ore shoots discovered up to now are small. The largest one is at the Blackbird fluorspar mine in SW¼ sec. 16, T. 9 N., R. 5 E. It is a few inches to 5 feet wide, 130 feet long, and has been stoped from the 42-foot level to the surface. The average fluorite content is a little less than 60 percent.

A few small deposits between Coyote Canyon and Tijeras Canyon belong to the "fahlband" type and were probably formed in Precambrian time. They consist of small lenses of fine-grained quartz, specularite, chalcopyrite, sphalerite, auriferous pyrite, and their oxidation products, oriented parallel to the northeastward trend of the enclosing greenstone schist.

The future of the Tijeras Canyon district looks no more promising than its past. The main product, fluorspar, has had no market in New Mexico since 1953. Some of the district lies on Sandia Base or in the Isleta Pueblo grant and is not open to the prospector.

Sandoval County

Cochiti (Bland) District

The Cochiti or Bland mining district is on the eastern side of the Jemez Mountains in western Sandoval County, about 30 miles west of Santa Fe and 15 miles northwest of the A., T. & S. F. Railway at Santo Domingo Pueblo. The more important mines are located in two separate areas where canyons have cut into mineralized andesite and monzonite below the Bandelier rhyolite tuff (Quaternary). The most important mine, the Albemarle, is in Colla Canyon in sec. 35 (unsurveyed), T. 18 N., R. 4 E.; most of the other mines are in Bland (or Pino) Canyon in secs. 24, 25, and 31, T. 18 N., R. 4 E. Between 1894 and 1948 the low-grade epithermal quartz veins of the district produced gold worth $861,983 and silver worth $457,034, making a total of $1,321,582. About four-fifths of this was mined in the boom years between 1894 and 1903. The district has been idle since 1948. All of the claims are now owned by Miss Effie Jenks of Santa Fe, New Mexico.

According to Bundy (1958), the oldest rocks in the district are a group of andesite flows and associated pyroclastic rocks and arkosic sandstones. The age is unknown, but is probably no older than late Cretaceous

Table 2. Metal Production of Bernalillo, Sandoval, and Santa Fe Counties, 1828 to 1959

County	District	Metal	Estimated Production in Dollars[1]	Geologic Type
Bernalillo	Tijeras	Gold, lead, silver	10,000	Telethermal veins, fahlbands
Sandoval	Cochiti (Bland)	Gold, silver	1,320,000	Epithermal veins
"	Nacimiento	Copper, silver	800,000[2]	"Redbeds"
"	Jemez Springs	Copper, silver	10,000 (Jemez Springs and Placitas)	"Redbeds"
"	Placitas	Lead		Telethermal veins and replacement deposits
Santa Fe	Cerrillos	Lead, zinc, silver, copper	620,000	Veins
"	Old Placers (Ortiz)	Gold	2,200,000	Placers, quartz veins
"	New Placers (San Pedro, Golden)	Gold, copper, lead, zinc, silver	5,750,000	Pyrometasomatic, limestone replacement pipes, quartz veins, placers
"	Santa Fe Manganese	Manganese	10,000 (Santa Fe Manganese through Nambe)	Epithermal replacement
"	La Bajada	Copper, silver, uranium		Epithermal veins
"	Santa Fe (Pecos, Cooper)	Copper, silver		High-temperature veins
"	Glorieta	Iron		Supergene replacement
"	Nambe			Pegmatites
		Total	$ 10,720,000	

1/ Rounded off to the nearest $10,000. 2/ Sandoval County only.

Sources: Jones (1904; Lindgren, Graton, and Gordon (1910); Lasky and Wootton (1933); Anderson (1957); Northrop (1959); U. S. Department of the Interior annual Mineral Resources of the United States (1882 to 1931); U. S. Department of the Interior annual Minerals Yearbook (1932 to 1959).

and not younger than early Tertiary. They were intruded and arched by a monzonite stock. Fracturing accompanied intrusion of monzonite and was followed, successively, by emplacement of andesite porphyry dikes, gold- and silver-bearing quartz veins with small amounts of base-metal sulfides, rhyolite dikes, and barren quartz veins with small amounts of pyrite. Later, erosion produced an irregular surface which was covered in mid-Pleistocene time by pumiceous and welded rhyolite tuff beds of the Bandelier formation.

Most of the veins in and around Bland Canyon have a northerly trend. The Albemarle vein and other veins in and around Colla Canyon trend to the northeast. All veins dip steeply (50° to 85°), some east, some west.

The veins consist largely of quartz and chalcedony and were formed by replacement of wall rock. They are as much as 1,500 feet long. Like most replacement veins, they are highly irregular in width, but in places they are as much as 150 feet wide (Graton, in Lindgren, Graton, and Gordon, 1910). Some of the gold and silver were found in rich streaks of shipping-grade ore, usually $30-50 per ton, but ore mined before 1904 probably averaged only about $6 per ton, and ore mined since then (some of it sorted) averaged only $8 per ton. Some parts of the veins are barren.

Bundy (1958) described the paragenesis as follows. First calcite was emplaced along faults. Most of the calcite was then replaced by quartz. A period of brecciation was followed by the emplacement of pyrite, minor chalcopyrite, sphalerite (up to 3 percent of the veins), a minute amount of galena, quartz, gold-bearing pyrite, and argentite, in that order. All of the sulfides are in minute grains. The post-rhyolite phase of mineralization consisted of quartz and some pyrite, barren of precious metals. The veins are drusy, vuggy, and contain abundant inclusions of wall rock, sometimes surrounded by haloes of metallic minerals. Hydrothermal alteration, according to Bundy (1958), has taken the form of regional propylitization and more local argillization and silicification. All veins are oxidized from the outcrop down to a variable depth. The oxidized zone was leached of base-metal sulfides but enriched in residual gold. Silver remained roughly constant. Gold can be extracted by amalgamation from oxidized ore and by cyanidation from primary ore.

The largest mine in the district was the Albemarle, in Colla Canyon, credited with an output of $667,500 (Jones, 1904). The Lone Star—Iron King—Crown Point group of claims in Bland Canyon is next in importance. They were at different times worked separately or as a group. Since 1904 they have been the scene of sporadic unsuccessful attempts to revive the district. Cossak Mining Co. operated the Lone Star—Iron King—Crown Point group from 1914 to 1916 and treated the ores by cyanidation. Some shipments were recorded during the 1930's. A post-war attempt to revive the Iron King mine ended when mine and mill were attached by the Sandoval County sheriff in 1947.

The decline and fall of the Cochiti district was caused by: (1) low grade of ore; (2) decline in width and tenor of veins at depth; no minable ore was found deeper than 585 feet; (3) high transportation costs; (4) lack of water; (5) mismanagement; (6) litigation; and (7) declining silver prices after 1893. Only after 1897, when a ruling of the U. S. Supreme Court against the absentee owners of the Canada de Cochiti grant placed the district in the public domain, did outside capital become available. The Cochiti Gold Mining Co. and its successor, the Navajo Gold Mining Co. of Boston, finished the Albemarle mill in 1899 and acquired other major mines in the district by 1900. In February 1902 it went into receivership.

As far as known, all ore shoots in the Albemarle mine were mined out, but a considerable tonnage of low-grade material remains in some other mines. A revival of mining could occur only if the government should raise gold and silver prices appreciably. Ores average 85 to 95 percent SiO_2 (Wynkoop, 1900) and could be sold as siliceous flux, but transportation to a smelter would be expensive.

Nacimiento (Cuba) District

The Nacimiento district is in northeastern Sandoval County and southwestern Rio Arriba County, on the western face of the Nacimiento Mountains. Most of the mines are 3 to 5½ miles southeast of Cuba, but one mine, the San Miguel, lies about 6 miles south of the others. Between 1881 and 1960 the district produced about 7,500,000 pounds of copper and several tens of thousands of ounces of silver, valued at over $1,100,000. The deposits are of the "redbeds" or sandstone type.

The rocks of the district range from Precambrian to Tertiary, but commercial mineralization is confined to the Agua Zarca sandstone member of the Chinle formation (Triassic). Noncommercial showings occur in the Cutler formation (Permian) and the Poleo sandstone member of the Chinle formation (Triassic).

The dominant structure of the region is a large westward-directed reverse fault, the Nacimiento fault. The rocks near the fault are steeply tilted to the west, or are overturned, for about a mile west of the fault and for a few hundred yards east of it. Farther west they dip gently westward into the San Juan Basin, and farther east they are nearly horizontal (Wood and Northrop, 1946).

The Eureka and Cliff mines are in nearly horizontal sandstone and conglomerate beds of the Agua Zarca member east of the Nacimiento fault in sec. 32 (unsurveyed), T. 21 N., R. 1 E., and in sec. 6, T. 20 N., R. 1 E., respectively. All other mines in the district seem to be in steeply dipping Agua Zarca sandstone near the Nacimiento fault. One group is east of Copper City, in and around sec. 1, T. 20 N., R. 1 W. Schrader (in Lindgren, Graton, and Gordon, 1910) mentioned the Copper Glance and Kelley mines; of these two the Copper Glance was the more important. Another mine, the Bluebird, is about 1½ miles farther south, near Senorito, in sec. 11, T. 20 N., R. 1 W. Finally, the San Miguel mine is in NW¼ sec. 24, T. 19 N., R. 1 W., about 5½ miles northeast of La Ventana.

All of the mines have the same type of mineralization. The primary ore mineral is chalcocite, formed by replacement of fossil wood and carbonaceous trash. Malachite, azurite, and chrysocolla, formed by oxidation of chalcocite, occur in an irregular halo dispersed around accumulations of organic material, as well as in the organic material itself. Most of the ore assays less than 3 percent copper, but hand sorting raised the grade of material smelted before 1900 to 25-65 percent. The silver content is 0.5 to 2 ounces for every 100 pounds of copper, and there is almost no gold.

The copper deposits form small, discontinuous lenticular bodies in several stratigraphic horizons. Most of them are in cross-bedded coarse fluvial sandstone or conglomerate. Although the enclosing rocks may be red the mineralized rocks usually are not. Since the uranium boom of the mid-1950's the behavior of ore deposits in ancient stream channels has been better understood than formerly, and there has been a slight revival of interest in sandstone copper deposits.

In the Chalcocite prospect, about three-fourths of a mile north of the Copper Glance mine, malachite and chalcocite occur in a 35-foot band of Precambrian schist contained in granite. Since low-grade copper deposits in Precambrian basement rocks have been postulated as the ultimate source of copper in the sandstone deposits, this occurrence is of theoretical interest.

The Nacimiento copper deposits were known as early as 1859 (Newberry, 1876). Systematic mining did not begin until the early 1880's and ended around 1900. During this period the mines yielded about 6,300,000 pounds of copper and several tens of thousands of ounces of silver, valued at about $700,000. Of this, 5,000,000 pounds came from San Miguel mine and about 1,250,000 pounds from the Copper Glance (Lindgren, Graton, and Gordon, 1910). Hand-sorted high-grade ore was hauled by wagon to a 30-ton smelter at Copper City or a 25-ton smelter at Senorito, and matte was hauled by wagon 60 miles to the railroad at Bernalillo. Mining was done in open pits and shallow underground workings at low cost.

Since 1900 there have been two short-lived attempts to revive the district, the first from 1916 to 1920, the second from 1955 to 1957. The dollar value of production in 1956, $231,831, was probably the highest in the history of the district. Most of it can be credited to the Eureka mine in Rio Arriba County.

The known deposits were thoroughly high-graded by the oldtimers, but considerable reserves of low-grade material, containing 0.75 to 3 percent copper, remain. The Eureka, Copper City, and San Miguel areas could each probably yield several tens of thousands of tons of low-grade ore. The high cost of transportation remains a severe handicap.

Jemez Springs District

The Jemez Springs district consists of only one insignificant mine, the Spanish Queen, which is at the bottom of Jemez Canyon, 2.7 miles south of Jemez Springs. It formerly worked a low-grade copper deposit of the sandstone type. Geologically it is similar to the copper deposits of the Nacimiento district, except that the host rock consists of nearly horizontal beds of the Abo formation (Permian). Since 1904 the mine has produced copper and silver worth $3,138, from 233 tons of ore.

Placitas District

The Placitas district includes the northern end of the Sandia Mountains in Bernalillo and Sandoval Counties. Its fluorspar-barite-galena veins resemble those of the Tijeras Canyon district in mineralogy, texture, size, and geologic setting. Being close to Albuquerque and Santa Fe, the district has attracted more than its share of promoters, but actual production since 1904 has been only 35 tons of ore valued at $848. The district had a minor boom around 1880, but it soon died down.

Santa Fe County

Cerrillos District

The Cerrillos district covers Los Cerrillos, a group of low hills 15 miles southwest of Santa Fe. The main line of the A., T. & S. F. Railway skirts the southern edge of the hills. The district is best known for its turquoise deposits, but has also yielded zinc, lead, silver, copper, and gold worth $620,000.

According to Disbrow and Stoll (1957) the mineralized rocks of the district are the Jurassic Morrison formation, the Cretaceous Dakota sandstone, Mancos shale, and Mesaverde group, the Eocene Galisteo formation, and a group of intrusive Oligocene (?) monzonites with their extrusive equivalents, the Espinaso volcanics. Four distinct phases of monzonite have been recognized. All except the first have volcanic equivalents and have the form of central plugs or stocks, surrounded by dikes and swarms of sills and laccoliths spread out in the incompetent Mancos shale. The intruded rocks have been arched into a steep-sided dome. Following intrusion of the monzonites the rocks were fractured and mineralized. Most veins have a northerly or northeasterly trend.

The major metal mines are grouped in three distinct areas. Monzonite forms most of the bedrock in all three. The first is in SE¼ sec. 5, T. 14 N., R. 8 E., the second is in and around S½ sec. 30, T. 15 N., R. 8 E., and the third is in secs. 19 and 20, T. 15 N., R. 8 E. The veins are controlled by shear zones and are usually 1 to 6 feet wide and a few hundred feet long. A few are as much as 16 feet wide and 2,500 feet long. Only a fraction of the shear zones is filled with vein matter.

Commercial ore occurs in definite shoots, but their structural control is not known. The two largest shoots discovered up to now are in the Pennsylvania and Tom Payne mines, both probably on different segments of the same north-trending vein in sec. 30, T. 15 N., R. 8 E. Each contained a few thousand tons of ore.

Disbrow and Stoll (1957) described the veins as follows:

> "In the Pennsylvania mine, ore occurs as thin tabular seams of coarse interlocking sphalerite and galena crystals, or as similar seams of crustified ore in which sphalerite, galena, quartz, and pyrite occur in parallel bands of almost pure mineral. The Tom Payne ore is similar but contains more quartz. In the Mina del Tiro deposit the ore shoot is an elongate lens of vuggy quartz, containing disseminations and thick streaks of galena and sphalerite. In the Franklin mine, galena and sphalerite occur without gangue as small masses and disseminations in a thin zone of highly sericitized monzonite porphyry. The other shoots probably originated largely by filling of narrow openings, to judge from the crustification, but ore in the Franklin mine has formed by replacement of the rock."

The rocks are usually altered to sericite and smaller amounts of pyrite, carbonates, quartz, and tourmaline. To a distance of 1 to 10 feet on either side of the veins, chlorite has locally formed beyond the sericite zone. Oxidation has affected all veins down to the water table, 50 to 150 feet below the surface. Zinc has been leached from the upper part of the oxidized zone and added to the lower part; other metals are present in about the same amounts as in primary ore. The rich silver strikes reported from the early days of mining probably were made in small oxidized pockets.

The district was known in Spanish colonial days, but went through its boom only after 1879. By 1890 mining had switched to turquoise, having resulted in production of lead and silver "not likely to exceed a few hundred thousand dollars" (Lindgren, in Lindgren, Graton, and Gordon, 1910). Turquoise mining declined sharply between 1904 and 1906. From 1904 through 1959 there has been some metal production in 30 years out of 56, but the output has exceeded 1,000 tons in only 7 or 8 years, when lead and zinc prices were unusually high. No mine has operated continuously for more than 5 years. The output since 1904 has been 26,816 tons of milling-grade ore, containing 735 ounces of gold, 27,884 ounces of silver, 181,824 pounds of copper, 1,578,340 pounds of lead and 1,935,727 pounds of zinc, valued at $422,743.

In 1959 Bear Creek Mining Co., a subsidiary of Kennecott Copper Corp., began an intensive exploration campaign, but the results have not been announced. According to newspaper stories the main target was a low-grade copper deposit disseminated in monzonite porphyry. Signs of low-grade disseminated copper ores are abundant, especially in the southern end of the district, northeast of the Mina del Tiro, where dumps show small grains of pyrite and chalcopyrite in altered monzonite. The Evelyn mine, at the northern end of the district, formerly produced low-grade oxidized copper-gold ores disseminated in monzonite.

Glorieta District

The Glorieta district covers a large area near Glorieta pass, 15 miles southeast of Santa Fe. The only recorded shipments have been a few thousand tons of supergene limonitic iron ore from clastic beds of the San Andres formation (Permian) on the rim of Glorieta Mesa. Most of the ore was used as flux in lead smelters, but some was used in paint factories and steel mills. The remaining reserves are small (Kelley, 1949). Copper occurs in several small sandstone and vein deposits.

La Bajada District

The La Bajada district consists of only one mine, also called La Bajada. It lies in La Bajada Canyon, at the foot of La Bajada Hill, about 2 miles north of U. S. Highway 85. The ore body follows a north-trending fault cutting Miocene (?) Cieneguilla limburgite.

Mineralization probably occurred in Pliocene or Pleistocene time, under near-surface conditions. Lustig (1957) described 17 minerals from the deposit and 6 from an oxidized dump. The chief hypogene metallic minerals are pyrite, sphalerite, marcasite, colusite, chalcopyrite, and bornite, formed in that order. Brannerite has been reported and its uranium content is said to account for the anomalous radioactivity of the deposit. Colloform textures characterize the ore minerals and indicate a low temperature of formation.

The deposit was developed by La Bajada Mining Co. in the 1920's, but total production came to only 8 tons of copper-silver ore valued at $363. In the 1950's the discovery of uranium in the deposit caused a renewal of interest. A small shipment of uranium by Lone Star Mining Co. was recorded in 1957.

Nambe District

The name Nambe district was assigned by Northrop (1959) to an area of granite pegmatites in the Sangre de Cristo Mountains east of Cordova, along the Santa Fe—Rio Arriba County line. The bedrock consists of Precambrian mica schist, granite gneiss, and migmatite, all trending northeastward and containing small lenses of granite pegmatite. The largest known pegmatite body is on the Rocking Chair claim, which was prospected for feldspar, mica, and beryl. Only a few pounds of beryl have been found.

Concentrations of scrap mica, usually only a few inches wide, occur around the contacts of pegmatites and mica schist and in small irregular (hydrothermal?) albite-quartz-muscovite replacement veins that cut across the earlier microcline-quartz phase of the pegmatites. Books of sheet mica are present here and there, but only in small amounts. Santa Fe County has since 1949 produced muscovite mica worth only $550. In addition, mica from Rio Arriba County has been processed at Santa Fe.

New Placers (San Pedro, Golden, Tuerto) District

The New Placers district is in southern Santa Fe County, in T. 12 N., R. 12 E., directly southeast of the village of Golden. It includes the San Pedro or Tuerto Mountains, a low range formed by the intrusion of early Tertiary stocks and laccoliths. The igneous intrusions are part of a north-trending porphyry belt that also includes Los Cerrillos, Ortiz Mountain, and South Mountain. Production of copper, gold, silver, lead, and zinc since 1904 has been worth $3,694,431.

According to Atkinson (1960), the sedimentary rocks of the district include the Madera limestone (Pennsylvanian), the Abo, Yeso, and San Andres formations (Permian), and the Dockum group (Triassic). The prevailing dip is to the east. The sedimentary rocks were arched, irregularly fractured, and metamorphosed in early Tertiary (?) time by a variety of igneous intrusions. First came a few diabase porphyry dikes, then five small monzonite stocks, then rhyolite porphyry dikes and sills, and finally two monzonite porphyry laccoliths and a large number of monzonite porphyry and latite porphyry dikes and sills. Of the five monzonite stocks, four are in the eastern end of the range. One stock and both monzonite porphyry laccoliths are in the western end, in the neighborhood of the San Pedro and Lincoln-Lucky mines.

The district has six types of ore deposits. (1) Pyrometasomatic copper-gold-silver-tungsten deposits. Chalcopyrite is the chief ore mineral; the tungsten is in scheelite. An example is the San Pedro mine. (2) Replacement pipes and veins of sphalerite and argentiferous galena in limestone. An example is the Lincoln-Lucky mine. (3) Iron veins and bedded replacement deposits containing magnetite, specularite, or both. These are economically unimportant, although formerly they were worked for flux and the Oro Quay mine made small shipments in 1958. (4) Small shear zones and fissures filled with quartz and auriferous pyrite. In the oxidized zone, usually within 100 feet of the surface, they contain free gold. There are many deposits of this type, but none has produced more than $30,000. (5) Small pockets of auriferous pyrite disseminated in tactite, containing free gold in the oxidized zone. These are economically unimportant. (6) Placers derived from types 4 and 5. Before 1880 they probably yielded between $1,000,000 and $2,000,000 in gold; since 1880 they have been relatively unimportant.

Atkinson (1960) demonstrated the existence of hypogene zoning in the lode deposits. Copper occurs in contact-metamorphosed limestone, not far from igneous rocks. The controlling structure is a highly irregular "marble line." On the southeastern side of the "marble line", limestone that has undergone contact metasomatism has turned into garnet tactite, and on the northwestern side limestone that has undergone only thermal metamorphism has turned into marble. Lead and zinc are found farther away from igneous rocks, replacing unmetamorphosed limestone. Of the iron minerals, Atkinson (1960) wrote:

"Deposits containing magnetite alone are generally closer to the stock than those containing specularite alone, while those containing both magnetite and specularite occupy an intermediate position."

The gold-bearing veins do not seem to have a zonal distribution.

The pyrometasomatic San Pedro deposit is by far the most important in the district. It is on the southern end of a belt of garnet tactite, 150 feet thick, that runs for about 1½ miles along the western side of San Pedro Mountain, from SW¼ sec. 15 (unsurveyed), T. 12 N., R. 7 E. to NW¼ sec. 27, T. 12 N., R. 7 E. The replaced beds are in the upper part of the Madera limestone. The tactite lies directly below a rhyolite porphyry sill and 50 to 150 feet above a monzonite porphyry laccolith. The best ore irregularly replaces marble beds at the crest of a small anticline, 75 to 90 feet below the rhyolite porphyry sill. The ore body is cut by several post-ore faults, one of which seems to terminate it on its eastern end.

The San Pedro mine dates back to the middle of the 19th century. From 1889 until 1938 the mine was operated intermittently by the Santa Fe Gold and Copper Co. During the 1890's a small smelter treated the ore at the village of San Pedro; from 1900 to 1919 a 125-ton smelter stood near the mine. In 1938 the mine was purchased by Raskob Mining Interests, Inc. and was worked by 70 men at the rate of 110 tons per day in 1940 and 1941. The ore was concentrated by a 150-ton flotation mill on the property. The present owner is C. F. Williams of Santa Fe, the present lessee Tom B. Scartaccini.

In spite of the relatively high grade of ore, the mine has never been profitable for long. Distance from the railroad, smelter, and refinery, high exploration and mining costs, and metallurgical problems are to blame. The mine was worked on a large scale only in times of unusually favorable copper prices. A total output of 250,000 to 300,000 tons of ore, yielding about 15,000,000 pounds of copper, 15,000 ounces of gold, and 200,000 ounces of silver, seems reasonable. The ore mined during 1940 and 1941 averaged 3.54 percent copper, 0.056 ounce of gold, and 0.81 ounce of silver per ton. During World War II the presence of tungsten in the San Pedro mine was brought to the attention of the U. S. Geological Survey by V. C. Kelley. Detailed mapping by Smith and others (1945) established the fact that significant amounts of low-grade copper and tungsten ores remained in the mine.

The Lincoln-Lucky (Carnahan) lead-zinc-silver mine is in NW¼ sec. 28, T. 12 N., R. 7 E., half a mile southwest of the San Pedro mine and part of the same property. It is a limestone-replacement deposit of pipelike shape that plunges about 15° E. The pipe is elliptical in cross-section, measuring about 60 feet across in the widest places. It follows the intersection of a steeply dipping, eastward-trending fault and a particular bed of the Madera limestone down-dip for about 3,600 feet. The primary minerals are coarsely crystalline sphalerite and argentiferous galena, a little pyrite, chalcopyrite, and alabandite, in a quartz-calcite gangue. A complex gossan was found near the surface. The deposit was mined out for a length of 2,300 feet in the 1880's. A second period of operation was from 1919 to 1928, first by Collier Mines Co. (1919 to 1926) and then by Carnahan Mines Co. (1926 to 1928). From 1925 to 1928 a 50-ton selective flotation mill milled 27,377 tons of ore, containing 380 ounces of gold, 97,972 ounces of silver, 15,973 pounds of copper, 3,540,515 pounds of lead, and 3,995,000 pounds of zinc. The drop in metal prices during the Great Depression discouraged a search for additional ore after 1928.

Placer gold of 920 fineness occurs in unconsolidated eluvial and alluvial deposits in many places. The most important ones are the San Lazarus placer on the southern edge of the range, and the Golden placer off the northwestern end of the range. The tenor ranges from 10 cents to $1.75 per cubic yard. Placer gold also occurs in consolidated gravels (the so-called "cement beds") halfway between Golden and the Una del Gato coal field. All large-scale modern placer operations have failed because there is insufficient water for wet methods of extraction and the ground is too wet for dry methods.

Old Placers (Ortiz, Dolores) District

The Old Placers district covers the Ortiz or Placer Mountains, 7 miles south of Cerrillos and 3 miles northeast of Golden. The district has yielded about $2,200,000, almost all of it from gold. Placers have been more important than lode mines. The entire district lies within the Ortiz Mine grant, owned by Potter and Sims Mining Co. of Joplin, Missouri. In recent years G. R. Griswold of Albuquerque has been in charge of mineral exploration.

The geology of the Ortiz Mountains has many similarities with the geology of Los Cerrillos and San Pedro Mountain. In the Ortiz Mountains the intruded sedimentary rocks are almost entirely Cretaceous (Dakota sandstone, Mancos shale, Mesaverde group). Only in the southwestern tip of the range do pre-Cretaceous rocks crop out. The regional dip is 10° to 30° E. The Cretaceous rocks were intruded by two stocks of nepheline-bearing augite monzonite, two small stocks of quartz monzonite, and a swarm of laccoliths, sills, and plugs of latite-andesite porphyry. A hydrothermally altered body of trachyte-latite with brecciated border was interpreted as a volcanic vent by Peterson (1958) and McRae (1958). It occupies both sides of Cunningham Gulch in the western part of the range, and the most important lode mines of the district are in its brecciated border zones.

The district has four types of ore deposits. (1) Gold in quartz fissure veins in the brecciated border zone of the Cunningham Gulch vent. Examples are the Ortiz, Benton, and Liveoak mines, which produced several hundred thousand dollars in gold in the 19th century. (2) Gold and scheelite disseminated in the brecciated border zone, near the southeastern end of the Cunningham Gulch vent. Production has been small. (3) Contact pyrometasomatic auriferous pyrite and chalcopyrite disseminated in garnet tactite at the southern tip of the mountains. The Greenhorn limestone member of the Mancos shale is the replaced horizon. Production has been small. (4) Placers, which have accounted for 80 to 90 percent of the total output. The most important placers are at the mouth of Cunningham Gulch, near the Dolores ranch. Modern attempts at exploitation have been frustrated by the same difficulties as at the New Placers. The unsuccessful attempt of Universal Placer Mining Corp. to work the gravels in 1939 and 1940 accounted for $38,000 of the $53,000 produced by the district in this century.

Santa Fe District

The Santa Fe district covers a large and ill-defined area of Precambrian granite, schist, and diabase in the southern end of the Sangre de Cristo Mountains, east of Santa Fe. It has showings of placer gold and base-metal sulfides, but has never produced ore commercially. Its proximity to the important Willow Creek district in San Miguel County has stimulated intensive prospecting.

Santa Fe Manganese District

The Santa Fe Manganese district was described by Wells (1918) as being 4 miles northeast of Santa Fe. Pyrolusite and psilomelane partially replace Pennsylvanian shale along bedding planes; the ore occurs in nodules and small irregular pockets. The district was worked on a very small scale during World Wars I and II, and the years during and since the Korean War. Total manganese production of Santa Fe County (including gossan material from the Lincoln-Lucky mine and other deposits in the New Placers district) has amounted to only a few thousand dollars, and ceased entirely with the termination of the U. S. Government carlot purchasing program in August, 1959.

Miscellaneous Metal Deposits

Small amounts of various metals have come from places not included under the several mining districts. Bernalillo, Sandoval, and Santa Fe Counties were caught up in the prospecting fever for uranium and "rare metals" that gripped the entire country a few years ago, but the results were negligible. Mesozoic and early Cenozoic sandstones in the foothills of the Nacimiento Mountains and the Hagan basin, both in Sandoval County, were the rocks most favored by prospectors.

Manganese has come from the Lander and Jicarilla mines, on Jicarilla tribal lands in sec. 21, T. 22 N., R. 4 W., Sandoval County, about 17 miles northwest of Cuba. The San Jose formation (Eocene) is the bedrock of the area.

INDUSTRIAL NON-METALS

Barite and Fluorspar

Barite and fluorspar deposits are discussed under Metals, Tijeras Canyon district (Bernalillo County) and Placitas district (Sandoval County). The deposits are very small.

Cement

The Ideal Cement Co. plant at Tijeras, 8 miles east of Albuquerque, is the largest single operation in the mineral industries of the three-county area and the only cement plant in New Mexico. Limestone and shale of the lower gray limestone member of the Madera formation (Pennsylvanian) are quarried next to the plant. In the fiscal year 1959-1960 the plant consumed 289,060 tons of limestone and dolomite, 42,266 cubic yards of shale, and 10,385 tons of gypsum. Natural gas brought in from Albuquerque by Southern Union Gas Co. is used as fuel. The plant cost $19,000,000 and has a capacity of 2,500,-000 bbls. per year. It employs 100 men, including 8 or 9 in the quarry. The product is a complete line of Portland and masonry cements, sold all over New Mexico and southern Colorado.

Common Clay

Kinney Brick Co. of Albuquerque is at present the only large producer and consumer of common clay in the area. Its plant on South Second Street has a capacity of 1 million bricks per month, and employs 40 men. A pit in the Manzano Mountains just west of State Highway 10, about 8 miles south of Tijeras, supplies the plant with 90 to 95 percent of its raw material—shale from the Magdalena group (Pennsylvanian). The rest is Mancos shale (Cretaceous) from a small pit west of Cerrillos, on the north side of the A., T. & S. F. railroad tracks. The Pennsylvanian shale burns light coral-red; the Cretaceous shale is used for lighter shades. Before 1946 the company used Recent alluvial clay from a pit next to its plant, but shale has been found to be a superior material. In recent years the plant has run at 60 to 95 percent of capacity, using on the average 4,000 tons of clay per month. Brick and tile are trucked to all major cities in northern and central New Mexico, within a 200-mile radius of Albuquerque.

Brick and tile were made at the old State Penitentiary at Santa Fe from about 1884 to 1957. The raw material was shale of the Magdalena group (Pennsylvanian) obtained from a pit on leased land east of Palace Avenue (Talmage and Wootton, 1937).

A small brick plant was formerly located near Tonque, north of Hagan, Sandoval County. It used Mancos shale (Cretaceous).

Gemstones

Turquoise has been the outstanding gemstone produced in the area since the 8th century A. D. (Northrop, 1959). It occurs in two localities in the Cerrillos mining district, Santa Fe County: (1) Mt. Chalchihuitl, near the center of sec. 5, T. 14 N., R. 8 E., and (2) Turquoise Hill, near the center of sec. 31, T. 15 N., R. 8 E. In modern times the most important operation was by American Turquoise Co., which worked the Turquoise Hill deposits from 1890 to about 1904. Estimates of production vary from $2,000,000 to $9,000,000. George F. Kunz, the famous gemologist, described the turquoise in 1893 as sky-blue, resistant to fading, and equal or superior to Persian material. Stones up to 60 carats were found, which sold for as much as $4,000. Mining was by surface and underground workings. In recent years the production has been negligible.

Turquoise occurs in irregular narrow veinlets and stringers cutting altered monzonite porphyry. Its origin is the subject of dispute, one school holding that it is hydrothermal, and another that it is supergene.

Precious opal has been reported from the Cochiti mining district (Wynkoop, 1900). Petrified wood is abundant in the Galisteo formation on Sweet's Ranch, 3 miles east of Cerrillos.

Gravel and Sand

At present 14 sand and gravel companies are active in the Albuquerque area, employing 98 men. The largest operations are by Springer Transfer Co. and Albuquerque Gravel Co. The only sand and gravel producer in the three-county area outside Greater Albuquerque is Kauffman Trucking Co. at Santa Fe.

All of the sand and gravel in Bernalillo County comes from Quaternary terraces of the Rio Grande, especially the lowest terrace above the present floodplain. This terrace is made up of well-sorted and well-rounded axial gravels. Figure 1 shows that terrace gravels are scarce north of Bernalillo, although small deposits have been used locally in construction work.

Gypsum

Aside from the new cement industry in Tijeras Canyon, the most important development in the mineral industries of the three-county area in the last few years has been the emergence of a sizeable gypsum products industry. Three quarries and two manufacturing plants are now active.

The gypsum resources of New Mexico have recently been described by Weber and Kottlowski (1959). Virtually all the gypsum in Bernalillo, Sandoval, and Santa Fe Counties occurs in the Todilto formation (Jurassic), which consists of thinly laminated limestone, 2 to 10 feet thick, overlain by 50 to 100 feet of gypsum 95 to 99 percent pure. Its outcrops are shown on Figure 1.

In June 1960 Kaiser Gypsum Co. began production at its quarry and plant at Rosario, Santa Fe County. Here the A., T. & S. F. Railway crosses the outcrop of the Todilto gypsum on the western side of the Galisteo monocline, 5 miles northwest of Cerrillos. At present the plant turns out plaster board, a fireproof 5/8-inch board made of plaster and fiberglass, plain and impregnated gypsum sheathing, and gypsum lath. When operating at capacity, the plant will require more than 100,000 tons of gypsum annually. At present, the company has 110 employees at the plant site, including 5 men in the quarry. The sales territory of the Kaiser plant includes southern Wyoming, western Louisiana, and all of Missouri, Kansas, Oklahoma, Texas, Colorado, and New Mexico.

American Gypsum Co. is quarrying gypsum at White Mesa, south of San Ysidro, Sandoval County, and trucking it to its plant north of Albuquerque. The plant began production on November 2, 1960, and is now operating four 24-hour days per week. The raw gypsum consumption is 252 tons per working day, the output 300,000 square feet of ½-inch plaster board per day. The company employs 85 to 90 men, including 5 men at the open-pit quarry. Its largest markets are in Phoenix and Los Angeles, but shipments are also made to Denver, Oklahoma City, El Paso, Lubbock, and Amarillo.

A small quarry supplies gypsum to the Ideal Cement Co. plant in Tijeras Canyon. It is 5 miles northeast of the cement plant, at the point where State Highway 10 crosses the steeply dipping Todilto formation on the western limb of the Tijeras basin. The quarry is operated by Duke City Gravel Products Co. In the fiscal year 1959-60 it quarried 10,385 tons of gypsum valued at $18,692.

The reserves of gypsum in the three-county area are virtually inexhaustible. Weber and Kottlowski (1959) estimated that the 1,180-acre site owned by American Gypsm Co. on White Mesa alone contains 98,000,000 tons under a 5- to 8-foot overburden of unusable gypsite. An additional 123,000,000 tons are present under thin overburden of Morrison sandstone. The Kaiser quarry has open-pit reserves sufficient for at least 50 years, and large additional reserves could be developed within a few miles.

Marble

All American Marble Co. of Albuquerque recently announced plans to exploit a deposit of banded travertine on the Laguna Indian Reservation in Valencia County. Similar deposits, formed by Pleistocene to Recent mineral and thermal springs, occur in many places along the Rio Puerco-Nacimiento fault zone in western Bernalillo and Sandoval Counties, especially near San Ysidro. Nothing is known about their commercial possibilities. While not true marble in the sense in which geologists use the term, the travertine would be considered marble by the building trade.

True marble occurs in the San Pedro Mountains, Santa Fe County, where Madera limestone (Pennsylvanian) and San Andres limestone (Permian) have been recrystallized by thermal metamorphism near igneous contacts.

Mica

The mica deposits of the Nambe district, Santa Fe County, have already been described in connection with the metal-mining districts.

Montmorillonite Clay

Montmorillonite clay (including bentonite) has not been produced in the three-county area, but at least two occurrences have been reported. One deposit lies just south of Santa Ana Pueblo, near State Highway 44, in secs. 30 and 31, T. 15 N., R. 3 E., Sandoval County. The deposit was recently explored by New Mexico Quartz Manufacturing Co., Inc. Talmage and Wootton (1937) mentioned a deposit of bentonite near Waldo, Santa Fe County, but gave no details. Both deposits appear to be part of the late Tertiary Santa Fe formation.

Pumice and Scoria

Pumice and scoria are both used in light-weight aggregate, especially in the manufacture of building blocks. The largest producer is the Pyramid pumice mine near Cochiti, Sandoval County. The annual report of the State Inspector of Mines for the fiscal year 1959-60 lists seven producing companies, two each in Bernalillo and Santa Fe Counties, and three in Sandoval County. Although it was a poor year in the building trade, they produced 94,651 cubic yards of raw pumice and scoria, valued at $129,979, and employed 35 men, not counting those engaged in manufacturing blocks.

Scoria is obtained from the swarm of small Quaternary basalt volcanoes on the western side of the Rio Grande (Fig. 1). In many volcanoes the eruptions began with an explosive outpouring of scoriaceous lapilli tuff, followed later by quiet lava flow eruptions. Even where no scoriaceous tuff is exposed at the surface near a volcanic vent, it may yet be found under a thin crust of flow rock. Pumice comes from the basal member of the middle Pleistocene Bandelier tuff in the Jemez Mountains. The upper part of the Bandelier formation is a cliff-forming welded rhyolite tuff, unsuitable for use as aggregate, but the lower member is an unconsolidated slope-forming pumiceous lapilli tuff. Many active and abandoned pumice quarries lie on the edge of the outcrop area of the Bandelier tuff (Fig. 1).

The reserves of pumice in the Bandelier tuff are inexhaustible. The reserves of scoria are more limited but are sufficient for the foreseeable future.

Specialty Sand and Sandstone

Wind-blown dune sand occurs along Jemez River near Santa Ana Pueblo in secs. 20 and 21, T. 14 N., R. 3 E., Sandoval County. It is sold to Marvel Roofing Co., Albuquerque, for use as roofing sand.

New Mexico Quartz Manufacturing Co., Inc., of Albuquerque, has recently explored the Glorieta sandstone (Permian) in secs. 23 and 26, T. 12 N., R. 7 E., in the eastern end of the San Pedro Mountains, Santa Fe County. The Glorieta sandstone here is a nearly pure quartz sand, poorly aggregated. Elsewhere it has a calcareous or ferruginous cement.

Stone

Building stone and flagstone have been quarried for local use in many places. They include Precambrian granite, Pennsylvanian limestone, and several types of sandstone from Mesozoic formations. Recently, angular talus blocks of Precambrian quartzite, obtained from the Great Combination gold mining claim in NE¼ sec. 12, T. 9 N., R. 4½ E., Tijeras Canyon district, have become popular in Albuquerque.

Crushed stone of many types has been used for construction work. An attempt has been made recently to

Table 3. Total Original Coal Reserves of Bernalillo, Sandoval, and Santa Fe Counties, New Mexico

County and Field	Geologic Formation	Reserves in Millions of Short Tons: Measured	Indicated	Inferred	Inferred on Coal Zone Basis	Total	Rank
Bernalillo							
Tijeras	Mesaverde	0.4	1.2	-	-	1.6	Bituminous
Rio Puerco	Mesaverde	1.0	-	-	-	1.0	Subbituminous
Sandoval							
San Juan River	Mesaverde	67.3	320.9	547.9	2,399.1	3,335.2	Subbituminous
San Juan River	Fruitland	0.2	0.5	-	1,609.6	1,610.3	Subbituminous
Una del Gato	Mesaverde	0.6	15.9	0.8	-	17.3	
Santa Fe							
Cerrillos	Mesaverde	6.6	14.6	26.3	-	47.5	Bituminous
Cerrillos	Mesaverde	2.8	2.9	-	-	5.7	Anthracite
Totals		78.9	356.0	575.0	4,008.7	5,018.6	

This table includes all anthracite and bituminous coal beds more than 14 inches thick, less than 3,000 feet deep, and all subbituminous coal beds more than 30 inches thick, less than 3,000 feet deep.
Source of data: Read and others (1950).

develop a large vein of white bull quartz on Sandia Pueblo land, in the Sandia Mountains near Juan Tabo Canyon, for use as roofing granule. Similar veins are known also in the Manzano Mountains.

Sulfur

Sulfur occurs in two areas of active solfataras in Jemez Canyon, Sandoval County. The deposits were discovered by Spaniards in the 16th century and worked on a small scale into the 20th century. The larger locality, called Jemez Sulphur Springs, covers about 10 acres, 11 miles north-northeast of Jemez Springs. The second locality covers about an acre, 4½ miles north-northeast of Jemez Springs. It contains 15 to 39 percent free sulfur and 6 to 8 percent sulfur combined as sulfate. In 1933 New Mexico Acid Co. built a 150-ton plant at this deposit but it was never operated successfully (Talmage and Wootton, 1937).

COAL

Bernalillo, Sandoval, and Santa Fe Counties contain measured, indicated, and inferred reserves of coal amounting to nearly 5,300,000,000 tons, or 8.6 percent of the entire reserves of the State of New Mexico (Read and others, 1950). Most of the reserves are in relatively inaccessible parts of Sandoval County. The bulk of production has come from the Cerrillos district, Santa Fe County, where the coals are high-grade anthracite and bituminous coking coal and lie near the main line of the A., T. & S. F. Railway. Total production in the three counties has been more than 7,000,000 tons. Most of the coal beds are part of the Mesaverde group of late Cretaceous age, but about one-third of the reserves of Sandoval County are in the Fruitland formation, which is late Cretaceous also, but younger than the Mesaverde group. Coal beds are present in other formations, ranging in age from Pennsylvanian to Tertiary, but have no economic value.

In the western parts of Bernalillo and Sandoval Counties, which are within the relatively undeformed Colorado Plateau province, the coals are subbituminous. Bituminous coals occur in the structurally complex intermontane basins of Santa Fe County and eastern Bernalillo and Sandoval Counties. Thermal metamorphism near the contacts of a monzonite sill has raised parts of the uppermost coal beds in the Cerrillos field to anthracite rank. The Cerrillos field is one of the few areas in the United States outside eastern Pennsylvania where anthracite has been mined in significant amounts.

The thickness of coal beds in the region ranges from a feather edge to more than 5 feet. Commercial beds are 3 feet or more thick, although thinner beds have been worked from time to time for local markets. Cretaceous coals are notoriously discontinuous. They pinch out laterally because of non-deposition, erosion beneath minor unconformities, or facies changes.

Coal mining began in the Cerrillos region around 1835 (Lee, 1913), but only about 10,000 tons was produced before 1880. Commercial mining began in the late 1880's and was greatly expanded after a railroad spur was built to Madrid in 1895. Production reached its peak between the end of World War I and the beginning of the Great Depression in 1929, when the annual output was about 250,000 tons, valued at $1,000,000. The decline that began in 1929 became precipitous after World War II and finally led to the virtual extinction of the industry by 1960. The annual report of the State Inspector of Mines for the fiscal year 1959-60 lists only two small coal mines as active in the entire three-county area: the Padilla No. 2 mine near La Ventana, Sandoval County, and the Tabor No. 2 mine at Madrid, Santa Fe County.

Bernalillo County

Bernalillo County has two coal fields, neither of them important. The small Tijeras field is about 20 miles east of Albuquerque, just north of U. S. Highway 66. The coal measures of the Mesaverde group are preserved over an area of 2½ square miles in the core of a syncline on the east side of the Sandia Mountains. Beds dip steeply on the sides of the syncline but are nearly horizontal in the middle. Small amounts of bituminous coal have been mined in the past for consumption in Albuquerque (Lee, 1912). The beds are thin and badly fractured.

Subbituminous coal occurs in the Rio Puerco valley of western Bernalillo County. Small coal mines and prospects were formerly worked on the Canoncito Navajo Indian Reservation, but have never had commercial importance.

Sandoval County

Sandoval County has two coal fields, the La Ventana-Chacra Mesa section of the San Juan River field in the western part of the County, and the Una del Gato or Hagan field in the southeastern part.

The San Juan River field contains 89 percent of the total coal reserves of New Mexico. The La Ventana-Chacra Mesa area is on its southeastern and eastern border, where the coal measures are turned up steeply along the front of the Nacimiento Mountains and then dip gently westward into the San Juan Basin. A number of subbituminous coal beds are present at two stratigraphic levels: the Creary coal member of the Menefee formation of the Mesaverde group (Beaumont, Dane, and Sears, 1956), and the Fruitland formation. The geology has been described in detail by Dane (1936). The field is far from rail transportation and has never been exploited on a large scale. In the past, coal from the La Ventana-Chacra Mesa field supplied the copper smelters at Copper City and Senorito, near Cuba.

The Una del Gato field is a faulted eastward-dipping homocline in the southeastern part of Sandoval County, between the Sandia and Ortiz Mountains. Several beds of high-quality bituminous coal occur in an area of 30 square miles (Read and others, 1950; Harrison, 1949). The beds may correlate with those in the Cerrillos field. At the Hagan mine, in the center of sec. 33, T. 13 N., R. 6 E., the main coal bed—the Hopewell bed—is a constant 48-52 inches thick, folded but not faulted, has a strong sandstone roof and floor, and dips from 15° N. to 15° E. (Campbell, 1907). Mining conditions are not everywhere as favorable as the Hagan mine; locally the coal is faulted or contains shaly partings.

Santa Fe County

Santa Fe County has only one coal field, the Cerrillos field, about 25 miles southeast of Santa Fe. The main line of the A., T. & S. F. Railway skirts the northern edge of the field; Cerrillos is the nearest shipping point. The Cerrillos field has produced approximately 7,000,000 tons.

The Cerrillos coal field is a structural basin, bordered on the northwestern and southwestern edges by igneous rocks of Los Cerrillos and the Ortiz Mountains. Almost all production has come from its western edge, where the beds dip 7° to 15° E. The extent of the field has been estimated at between 30 square miles (Lee, 1913) and 80 square miles (Read and others, 1950). On the northern and northeastern side of the basin, all or part of the Mesaverde group was removed by erosion prior to deposition of the early Tertiary Galisteo formation (Lee, 1913; Stearns, 1953), but the exact extent of the unconformity is unknown. There are indications that the two most productive beds in the field are cut out by the pre-Galisteo unconformity a few miles north, and possibly east, of the outcrop at Madrid.

Read and others (1950) computed the reserves of the field on the basis of the three minable beds in the Cerrillos-Waldo-Madrid area: the Miller Gulch bed, 190 feet above the base of the Mesaverde group, the Cook and White bed, about 465 feet higher in the section, and the White Ash bed, 100 feet above the Cook and White bed. A thick monzonite sill lies between the Miller Gulch and Cook and White beds, and another lies above the White Ash bed.

The Miller Gulch bed was described by Turnbull and others (1951) as high-volatile bright banded bituminous coal, producing coke not quite so good as coke from the Sunnyside bed, Carbon County, Utah, which is used as a standard for western coking coal. They also showed by four diamond-drill holes that the bed does not continue far downdip in minable thickness. The Miller Gulch bed has not been traced southward into the area west of Madrid.

The Cook and White bed, and its northward continuation—the Waldo bed—has yielded large quantities of bituminous coal in the Madrid area. It is 3 to 4½ feet thick, but locally has shaly partings. Turnbull and others (1951) classified it as high-volatile bright banded bituminous coal, producing coke definitely stronger than coke from the Sunnyside bed in Utah. Mine workings and a drill hole have shown that the coal changes laterally into carbonaceous shale 1½ to 2 miles north of Madrid. At its northernmost surface exposure, a mile south of Waldo, the Galisteo formation lies directly on the Cook and White (or Waldo) bed, and the fuel value of the coal was destroyed by pre-Galisteo weathering. The southern and eastern limits of the Cook and White bed have not been determined. The Jones and Cook & White mines were among the important ones working this bed.

The White Ash bed is coking bituminous coal at the White Ash mine, about a quarter of a mile northeast of Madrid. Farther south it changes into anthracite and thins from about 5½ feet to about 3 feet. The change from bituminous coal to anthracite via semianthracite takes place within a few hundred feet opposite the town of Madrid.

The rank of coal possibly depends on the distance between the coal bed and the overlying monzonite sill. At the White Ash mine, chief producer of bituminous coal from this bed, the sill is 30 to 50 feet above the coal; at the Lucas mine, chief and northernmost producer of anthracite, the sill is 8-9 feet above the coal, and at the Anthracite No. 4 mine, a quarter of a mile south of Madrid, only a few inches of shale separate the sill from the coal. The White Ash bed has been traced from a locality about three-fourths of a mile north of Madrid into a faulted area three-fourths of a mile south of Madrid.

Several other coal beds are known in the Madrid area, but have not yet proved to be commercial. Outside the Madrid area, the Cerrillos field has produced coal in only one place—the Omera or Block mine in sec. 32, T. 13 N., R. 9 E. The coal here is in two beds, 40 and 36 inches thick, separated by a 9-foot bed of sandstone. The coal is bituminous in rank (Gardner, 1910) and was formerly used at the copper mine and smelter at San Pedro. The coal at the Omera mine is stratigraphically lower than the Cook and White and White Ash beds at Madrid, and is unconformably overlain by the Galisteo formation.

Outside the Cerrillos field, thin and impure Pennsylvanian coals are known at the southern end of the Sangre de Cristo Mountains.

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