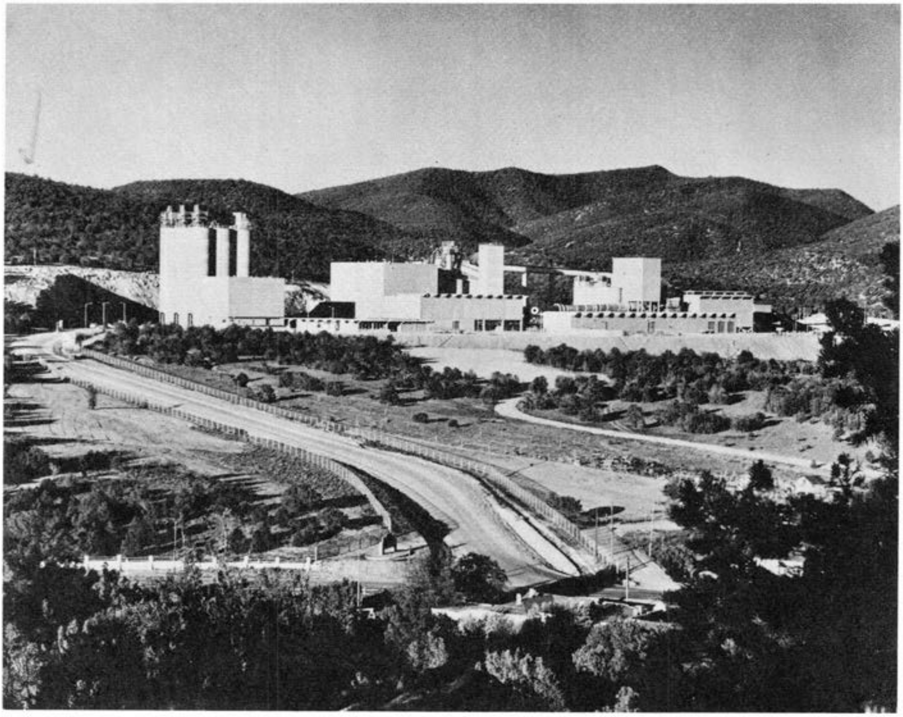
Summary of the Mineral Resources of Bernalillo, Sandoval, and Santa Fe Counties, New Mexico



FRONTISPIECE

Ideal Cement Company Plant, Tijeras, New Mexico, largest mineral-processing operation in the three-county area of this bulletin

BULLETIN 81

Summary of the Mineral Resources of Bernalillo, Sandoval, and Santa Fe Counties, New Mexico

(Exclusive of Oil and Gas)

by WOLFGANG E. ELSTON

I 9 6 7

STATE BUREAU OF MINES AND MINERAL RESOURCES

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

CAMPUS STATION SOCORRO, NEW MEXICO

For sale by the New Mexico Bureau of Mines and Mineral Resources
Campus Station, Socorro, New Mexico 87801—Price $2.00

Contents

Illustrations

TABLES

PLATES

Abstract

The oldest mines in the United States are in north-central New Mexico. Turquoise was mined before 900 A.D., lead and silver before 1600, and gold after 1828. Mining for base metals and coal began in 1880 but is now negligible. Since 1945, industrial nonmetals have been produced near Albuquerque.

The Cerrillos (turquoise, lead, zinc, silver, copper), Old Placer (gold, tungsten), and New Placer (gold, copper, lead, zinc, silver, tungsten) districts are in a belt of early Tertiary monzonite stocks and laccoliths. Production from placers, breccia pipes, pyrometasomatic deposits, limestone replacement pipes, and veins has totaled about $11 million. "Red beds" copper deposits (Nacimiento district) and epithermal gold-silver veins (Cochiti district) have each yielded more than $1 million.

Quaternary sediments of the Rio Grande provide sand and gravel. Brick and tile are made from Pennsylvanian and Cretaceous shales and building blocks of pumice and scoria from Quaternary volcanoes. A cement plant and two gypsum products plants, opened in 1959 and 1960, use limestone, dolomite, and shale from the Madera Formation (Pennsylvanian), gypsum from the Todilto Formation (Jurassic), and natural gas from the San Juan Basin. Annual production of nonmetals ranges from $9 to $13 million. Deposits of silica sand, bentonite, fluorspar, barite, marble, sulfur, perlite, and ocher are known but not currently (1966) worked.

Near Cerrillos, 7 million tons of coking bituminous coal and anthracite have been mined; thermal metamorphism accounts for the rank. Elsewhere, bituminous coal occurs in folded and faulted coal beds of intermontane basins and subbituminous coal in flat-lying beds of the Colorado Plateau. The coals are Upper Cretaceous (Mesaverde and Fruitland formations). Reserves are estimated at 5 billion tons, including 53 million tons near Cerrillos. Although oil and gas production of the three-county area is not large, proximity to the San Juan gas field is a favorable economic factor.

Introduction

This bulletin describes the mineral resources of the most populous area of New Mexico (pl. 1). No other part of the United States has had as long a history of mining as north-central New Mexico. Indians mined turquoise in the Cerrillos district six centuries before Columbus. The Mina del Tiro (or Mina del Tierra), Cerrillos district, was worked in Spanish-colonial times and may well be the oldest metal mine in the West. The first discovery of gold in the present United States west of the Mississippi was at the Old Placers in the Ortiz Mountains in 1828. It touched off a minor gold rush twenty-one years before the Forty-niners headed for California. Lode mines in the same area date back at least to 1833.

In 1967, the mineral industry is not so important in north-central New Mexico as in other parts of the state. Nevertheless, Bernalillo, Sandoval, and Santa Fe counties have many mineral resources. In the past decade, the annual production of industrial nonmetals has increased several times (table 1). Concurrent with the rapid growth of the urban population, sand and gravel have become multimillion-dollar products annually in the Albuquerque area. Cement, wallboard, plaster, pumice, block, brick, and tile made from local limestone, gypsum, pumice, scoria, and clay not only supply the home market but are shipped far afield. Coal, copper, gold, silver, lead, and zinc have lost their former pre-eminence, but price rises or new discoveries could bring about a revival.

In 1964, the mineral-producing and -processing industries of Bernalillo, Sandoval, and Santa Fe counties were larger than ever before. The annual output was about $13,227,000 in 1963 and $10,846,000 in 1964, compared with a little more than $1 million in 1952 and 1953. Bernalillo County in 1964 ranked eighth in mineral production among the 32 counties of the state.

This bulletin only briefly surveys mineral resources other than petroleum. It is based on a study of the literature and a few weeks of field work in the summers of 1960, 1961, 1962, and 1963. For a description of the regional geology, the reader is referred to the articles in Northrop (1961). Table 2 summarizes information on the rocks of the area, and Plate 2 shows the leading mineral deposits.

ACKNOWLEDGMENTS

The author is especially indebted to Edward C. Beaumont, who revised the section on coal; Henry S. Birdseye, who supplied information on nonmetallic resources; and Gilbert R. Griswold, who checked the section on metals. Discussions with Vincent C. Kelley, University of New Mexico, and Charles B. Read, U.S. Geological Survey, were most helpful. William W. Atkinson, Jr., and William G. Gustafson guided me through the areas their theses covered.

TABLE 1. VALUE IN DOLLARS OF MINERAL PRODUCTION OF BERNALILLO, SANDOVAL, AND SANTA FE COUNTIES, NEW MEXICO, 1949 to 1963

FISCAL YEAR	METALS[a]	PUMICE[a] & SCORIA	SAND,[a] GRAVEL, CLAY	COAL[a]	OTHER[a]	TOTAL[a]	TOTAL[b]
			BERNALILLO COUNTY				
1949	—	n.d.	367,610	—	—	367,610	n.d.
1950	—	45,000[c]	475,955	6,647	—	527,602	n.d.
1951	—	298,797	591,886	5,440	—	896,123	n.d.
1952	—	54,000[c]	541,740	7,000	—	602,740	355,751
1953	—	50,000	1,071,203	7,548	—	1,128,751	616,791
1954	—	35,226	963,718	4,293	—	1,003,237	1,361,136
1955	—	47,245	1,163,667	—	—	1,210,912	989,301[d]
1956	—	3,164	598,679	1,700	—	603,543	1,252,002
1957	—	17,619	1,437,597	—	—	1,455,216	833,300
1958	—	1,325	1,580,190	—	—	1,581,515	1,670,169
1959	—	1,200	2,446,388	—	942[e]	2,448,530	4,954,799
1960	—	5,834	1,748,355	—	97,521[e]	1,851,710	6,364,524
1961	—	7,000	1,345,290	—	578,833[e]	1,931,123	7,697,669
1962	—	19,727	1,084,611	—	507,126[e]	1,611,464	7,489,578
1963	—	20,563	1,783,101	—	796,032[e]	2,599,696	10,219,570
Totals		606,700	17,199,090	32,628	1,980,454	19,819,772	

TABLE 1. VALUE IN DOLLARS OF MINERAL PRODUCTION OF BERNALILLO, SANDOVAL, AND SANTA FE COUNTIES, NEW MEXICO, 1949 to 1963 (cont.)

FISCAL YEAR	METALS[a]	PUMICE[a] & SCORIA	SAND,[a] GRAVEL, CLAY	COAL[a]	OTHER[a]	TOTAL[a]	TOTAL[b]
			SANDOVAL COUNTY				
1949	—	314,778	450	38,959	—	354,187	n.d.
1950	—	358,796	—	40,206	—	399,002	n.d.
1951	—	309,635	—	25,704	—	335,339	n.d.
1952	—	257,337	3,123	15,269	—	275,729	n.d.
1953	—	102,784	—	9,000	—	111,784	104,791
1954	—	35,973	—	11,030	—	47,090	71,173
1955	6,447	38,768	—	12,030	—	57,245	101,942[d]
1956	8,328	42,378	—	15,533	—	66,239	164,631[f]
1957	7,379	11,070	—	11,953	—	30,369	313,269[f]
1958	—	61,005	—	9,364	—	70,369	487,181
1959	—	50,913	—	8,489	—	59,402	237,627
1960	—	86,127	—	9,363	—	95,490	261,311
1961	—	34,341	—	9,198	14,499[g]	58,038	347,655
1962	—	17,951	—	9,644	203,585[g]	231,180	525,343
1963	—	81,300	244,041	11,768	354,678[g]	691,787	1,461,329
Totals	22,154	1,803,156	247,614	237,597	572,762	2,883,283	
			SANTA FE COUNTY				
1949	3,000	187,500	26,822	224,963	—	442,285	n.d.
1950	6,000	30,759	318,225	197,803	—	552,787	n.d.
1951	5,035	125,018	134,078	240,450	—	504,581	n.d.
1952	17,358	160,410	150,557	213,018	—	541,343	210,001
1953	—	156,000	87,285	162,651	—	405,936	597,941
1954	—	30,000	79,382	105,031	—	214,413	370,697

1955	6,000	14,644	88,534	49,645	—	158,823	480,089
1956	122,007	13,334	101,912	52,809	550[h]	290,612	947,112[i]
1957	20,140	48,828	122,775	56,329	—	248,072	555,161
1958	1,012	12,883	132,794	18,740	—	165,429	732,813
1959	8,574	54,886	123,818	8,579	—	195,857	537,350
1960	3,480	38,018	140,148	3,500	19,775[g]	204,922	948,786
1961	12,653	43,484	166,576	7,167	576,820[g]	836,450	980,000
1962	43	31,100	162,895	1,518	29,750[h] 685,894[g] 117,706[h]	999,156	926,173
1963	16,942	70,227	513,436	—	73,580[g]	674,185	1,545,534
Totals	222,744	1,017,091	2,349,237	1,342,203	1,504,076	6,434,851	
Grand Totals	244,398	3,426,947	19,796,841	1,612,428	4,057,292	29,137,906	

[a]Figures from *Annual Report* of State Inspector of Mines for fiscal years July 1 to June 30.

[b]Figures for calendar year from *Minerals Yearbooks.* These figures are different from those of the State Inspector of Mines because of differences in estimating the value of minerals processed by producer (for example, pumice, scoria, and cement materials) and differences in periods covered. Figures for Sandoval County include oil and gas unless otherwise indicated.

[c]Estimated.

[d]Excluding manganese.

[e]Cement materials, minor quartz included.

[f]Excluding natural gas.

[g]Gypsum.

[h]Mica.

[i]Excluding uranium.

n.d., no data.

NOTE: The apparent decline of pumice and scoria after 1953 is because of a new method of valuation, not an actual decline in production.

TABLE 2. ROCKS OF BERNALILLO, SANDOVAL, AND SANTA FE COUNTIES

AGE	NAME	DESCRIPTION	ECONOMIC USES
	Alluvium and terrace deposits	Water-laid and windblown sand and gravel	Sand and gravel, aquifer for ground water, placer gold
Quaternary	Spring deposits	Travertine	"Marble"
	Volcanic rocks	Rhyolite and basalt	Pumice, scoria, perlite, crushed stone, sulfur, geothermal power
	Santa Fe Group	Fluvial, lacustrine, eolian sand, gravel, conglomerate, includes interbedded volcanic rocks	Placer gold, bentonite, ground water
	Espinaso Volcanics, and associated intrusive rocks	Latite flows and breccia, monzonite, felsite, syenite	Metal deposits, in and around porphyry bodies
Tertiary	Galisteo Formation San Jose Formation Nacimiento Formation	Continental conglomerate, sandstone, shale	Petrified wood, uranium?, selenium?, manganese
Cretaceous	Ojo Alamo Sandstone Kirtland Shale Fruitland Formation Pictured Cliff Sandstone Lewis Shale	Continental and marine sandstone and shale, minor coal	Coal, oil, and gas
	Mesaverde Group	Continental and marine sandstone, shale, coal	Coal, oil and gas, minor uranium
	Mancos Shale Dakota Sandstone	Marine and continental sandstone and shale	Brick clay, minor uranium

Jurassic	Morrison Formation	Continental mudstone and sandstone	Minor uranium (important uranium in Valencia and McKinley counties)
	Todilto Formation	Gypsum and limestone	Gypsum
	Entrada Formation	Eolian sandstone	None known
Triassic	Chinle Formation Santa Rosa Formation	Continental sandstone and mudstone (mainly red), conglomerate	Sandstone copper ores
Permian	North of 36°N: Cutler Formation South of 36°N: San Andres Limestone, Glorieta Sandstone, Yeso Formation, Abo Formation	Red arkosic sandstone and shale, gray sandstone and limestone	Minor copper and iron ores, ocher
Pennsylvanian and Permian	Sangre de Cristo Formation Unnamed (Manzano Mts.)	Arkosic sandstone and conglomerate shale	Brick clay
Pennsylvanian	Madera Formation Sandia Formation	Marine limestone, marine and continental sandstone and shale	Cement materials, stone, minor coal, brick clay
Mississippian	Arroyo Peñasco Formation Tererro Formation	Marine limestone, sandstone, shale	None known
Precambrian	Basement complex	Granite, gneiss, schist, quartzite, slate	Stone, pegmatite minerals (mica, beryl), formerly important metal deposits in Willow Creek district (San Miguel County) and adjoining parts of Santa Fe County

History of Mining

The history of mining in Bernalillo, Sandoval, and Santa Fe counties can be divided into three overlapping periods: (1) from earliest times to the arrival of the Santa Fe Railroad in 1880; (2) from 1880 to the beginning of the Albuquerque boom that started after the end of World War II in 1945; and (3) from 1945 to the present.

FIRST PERIOD: BEGINNING TO 1880

Before the arrival of the Atchison, Topeka, and Santa Fe Railroad Company 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, that could be carried by humans or animals to outside markets.

Among materials used locally, turquoise, pottery clay, mineral pigments, adobe, gypsum, and stone were worked by the Indians for centuries. The Spaniards introduced metals in the sixteenth century and mined them locally in small amounts. There are reports of lead bullets and copper bells made in colonial times from local ores. In spite of innumerable legends of "lost Spanish mines," most authorities agree that there is evidence for only one large metal mine anywhere in New Mexico during the Spanish-colonial period, the big Chino copper mine at Santa Rita, Grant County, which was worked in the early part of the nineteenth century (Jones, 1904). At least one small mine, the Mina del Tiro, was worked by the Spaniards in the Cerrillos district, Santa Fe County. The silver-bearing lead veins there were discovered by Fray Augustin Rodriguez and Captain Sanchez Chamuscado as early as 1581 (Northrop, 1959). However, most stories of fabulously rich Spanish mines, filled in by Indians after the 1680 Pueblo Revolt, have been concocted in recent years by promoters.

Turquoise from the Cerrillos district was an article of trade among the Indians before the Spaniards arrived. It was mined underground and in open pits with primitive stone tools, but on a remarkably large scale. Gustafson (1965) surveyed the pit and the dumps of the prehistoric workings on the southern slope of Mount Chalchihuitl. He estimated that not less than 500,000 cubic feet, or 30,000 to 50,000 tons, of rock were quarried from the pit.

The Spaniards probably obtained small amounts of gold and silver from New Mexico. When working the Mina del Tiro and other small mines in the Cerrillos district for lead, they probably did not waste the associated silver. Mining for precious metals alone does not seem to have begun until after the end of Spanish rule, with the discovery of the Old Placers in 1828. This stimulated further prospecting, which led to 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), an impressive figure considering the price of gold then and the fact that the gold was obtained by primitive methods of panning and sluicing. By comparison, the gold produced in Santa Fe County in 1961 was worth only $1695.

More modern mining methods were introduced after the U.S. occupation in 1846. By 1869, the 40-stamp mill of the Ortiz mine (Ortiz, or Old Placer, district) impressed F. V. Hayden (1869) as the most substantial he had seen in the West. The stamps were powered by a steam engine fired by coal from the Cerrillos (Madrid) field (Jones). Copper deposits at San Pedro and in the Nacimiento Mountains were known at that time but could not be worked profitably for lack of transportation.

SECOND PERIOD: 1880 to 1945

The arrival of the Atchison, Topeka, and Santa Fe Railroad in 1880 revolutionized the mining industry in New Mexico. 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 red-bed copper deposits of the Nacimiento Mountains (1880), the San Pedro contact-metasomatic copper deposits (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 Company. Coal output of Santa Fe County rose from 3600 tons in 1882 (the first year of accurate records) to 252,731 tons in 1900. Many small and short-lived mills and smelters were active in Santa Fe and Sandoval counties between 1880 and 1945; most of them are listed under the individual mining districts. Coal, anthracite, and coke from the Cerrillos field not only were used in the local metallurgical industries but were shipped to the steel mills at Pueblo, Colorado, and to mills and smelters in many other places.

This activity may have given the impression of a flourishing mineral industry, but 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 or 15 years ordinarily considered the minimum period for a profitable undertaking. In the past 60 years, the annual copper production of the San Pedro mine, by far the largest producer, exceeded one million pounds in only 6 years (1907, 1913, 1915, 1916, 1940, and 1941) and was less than 100,000 pounds in 43 years. The nearby Carnahan (Lincoln—Lucky) mine has produced more than twice as much lead and zinc as all other mines in the three-county area put together, but its longest period of continuous operation was only 5 years, from 1924 through 1928. Placer workings have been 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.

The lead-zinc-silver veins of the Cerrillos district generally have proved too narrow for profitable exploitation in peace time. At Cochiti, the gold and silver values of the low-grade veins decreased even further with depth; the camp was active from 1893 to 1904 but has seen only brief flurries of activity since then. The proposed railroad from Bernalillo to the copper and coal mines of the Cuba area never went beyond San Ysidro and was abandoned many years ago; the Nacimiento district has been virtually defunct since 1900, except for a brief revival during the copper boom from 1955 to 1957. The total metal production of Bernalillo, Sandoval, and Santa Fe counties from 1828 to the present has been only a little more than $11,000,000.

Coal, the mainstay of mining from 1880 to 1945, declined after 1900 and did not recover until World War I. Between 1919 and 1929, coal production of Santa Fe and Sandoval counties reached its peak. Every year an average of nearly 250,000 tons of coal was mined, valued at about $1 million. Then came the Depression and a progressive loss of markets, 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 to 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, gold prices remained fixed at prewar levels. The rise in silver and base-metal prices lagged behind the rise in production costs. Thousands of miles of new pipelines brought petroleum products to consumers who had previously relied on coal. The railroads, deprived of the coal-carrying business, dealt coal mining another blow by switching to diesel fuel.

However, the mineral industry has survived and prospered, though on a different basis from prewar days. As a result of the rapid increase in population, it became a supplier to the booming construction industry. Among the three counties, Santa Fe lost the leadership it held in mineral production since earliest days; its place was taken by Bernalillo County, which had long lagged in this field. Nearly half the sand and gravel in New Mexico comes from 14 pits in Bernalillo County. At Tijeras, eight miles east of Albuquerque, the Ideal Cement Company finished a $12 million cement plant with an annual capacity of 1,250,000 barrels in 1959 and started a $7 million expansion program to bring capacity to 2,500,000 barrels. A pit west of Isleta produces scoria for use in scoria blocks. Kinney Brick Company manufactures the bulk of Albuquerque's bricks, using clay from its own pits. In 1960, the American Gypsum Company plant north of Albuquerque went into production, using gypsum from White Mesa, near San Ysidro, in Sandoval County.

Santa Fe and Sandoval counties did not share in the population explosion to the same extent as Bernalillo County, but their mineral industries also made the switch from fuels and metals to industrial nonmetals. Sandoval County supplies gypsum to the American Gypsum Company plant. In the Jemez Mountains, not far from the abandoned gold-silver mines of the Cochiti district, pumice is quarried for use in pumice blocks. Its cumulative value now exceeds that of gold and silver. Santa Fe County has its own pumice quarries west of Espanola. Almost within sight of the abandoned turquoise and lead-zinc-silver mines of Cerrillos and the closed coal mines of Madrid stands the new Kaiser Gypsum plant and quarry at Rosario. Cement, gypsum wallboard, sand, gravel, and pumice blocks lack the glamour of Indian turquoise and Spanish silver, but they provide the basis for a stable mineral industry.

The gas-oil-uranium boom of northwestern New Mexico in the 1950's led to no important discoveries in Bernalillo, Sandoval, and Santa Fe counties, aside from oil in northern Sandoval County. However, the discovery of enormous gas and considerable oil reserves in the San Juan Basin has been a major factor in the development of the entire region. Among other industries, the mineral-processing plants in the Albuquerque—Santa Fe area are assured of cheap fuel. The nuclear-age boom towns of Los Alamos (Los Alamos County) and Grants (Valencia County) have been excellent markets for building materials produced by these plants.

At present (1966) metal prices are again on the rise. The metal-mining districts of the three counties have seen only a little exploration with modern techniques. With sufficient incentive, metal mining may yet regain some of its former importance.

Metals

From 1928 to 1959, Bernalillo, Sandoval, and Santa Fe counties produced metals valued at a little more than $11 million (table 3). This estimate was made from the figures in Northrop (1959), which probably are the most accurate estimates for the years 1828 to 1904, in the *Mineral Resources of the United States* (1904 to 1931), and in the *Minerals Yearbooks* (1932 to 1959). Figures prior to 1904 involve much guesswork and are accurate to only about 20 per cent. Of the total, Santa Fe County contributed about 80 per cent, Sandoval County 20 per cent, and Bernalillo County a negligible amount. (Figures for Sandoval County are for the present area of the county, even before its separation from Bernalillo County in 1903.)

During the nineteenth century, the total yield was a little more than $6 million, 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 twentieth century, the yield has been about $5 million. Of this, about 80 per cent came from the two mines in the San Pedro (New Placers) district, Santa Fe County, the San Pedro copper-gold-silver mine and the Carnahan lead-zinc-silver mine. The lead of Santa Fe County in metal mining has never been threatened since the beginning, except perhaps during the 1890's when the Nacimiento and Cochiti districts in Sandoval (then Bernalillo) County were at their peak.

BERNALILLO COUNTY

TIJERAS 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 (Anderson, 1957; Northrop, 1959). It includes all mines and prospects in Bernalillo County except for a few in the Sandia Mountains that are included with the Placitas district, Sandoval County. The northern end of the Tijeras. Canyon district has been called the Coyote Canyon or Soda Springs subdistrict, and the southern end, which is mainly in Valencia County, the Hell Canyon subdistrict. The district has yielded only small amounts of fluorspar in addition to the metals listed in Table 4.

No comprehensive account of the mines of the Tijeras Canyon district has been published. Reiche (1949) described the general geology of the district and mentioned some of the old mines, especially those in the Hell Canyon area. Brown (1962) described some minor prospects in the Cedro Canyon area. Rothrock, Johnson, and Hahn (1946) gave an account of the occurrence of fluorspar, the only com-

TABLE 3. METAL PRODUCTION OF BERNALILLO, SANDOVAL, AND SANTA FE COUNTIES, 1828 to 1959

COUNTY	DISTRICT	METAL	PRODUCTION IN DOLLARS[a]	GEOLOGIC TYPE
Bernalillo	Tijeras	Gold, lead, silver	10,000[b]	Telethermal veins, fahlbands
Sandoval	Cochiti (Bland)	Gold, silver	1,320,000	Epithermal veins
Sandoval	Cuba Manganese	Manganese	250,000[b]	Sedimentary
Sandoval	Jemez Springs	Copper, silver	}	"Red beds"
Sandoval	Placitas	Copper, lead, silver	} 10,000[b]	Telethermal veins and replacement deposits
Sandoval	La Ventana	Uranium	}	Coal and carbonaceous shales
Sandoval	Nacimiento Mountains	Copper, silver	800,000[c]	"Red beds"
Santa Fe	Cerrillos	Lead, zinc, silver, copper	620,000	Veins
Santa Fe	Old Placers (Ortiz)	Gold	2,200,000	Placers, quartz veins
Santa Fe	New Placers	Gold, copper, lead, zinc, silver	5,750,000	Pyrometasomatic, limestone replacement "chimneys," quartz veins, placers
Santa Fe	Santa Fe Manganese	Manganese	}	Epithermal replacement
Santa Fe	La Bajada	Copper, silver, uranium	} 60,000[b]	Epithermal vein
Santa Fe	Santa Fe (Pecos, Cooper)	Copper, silver	}	High-temperature veins
Santa Fe	Glorieta	Iron	}	Supergene replacement
Santa Fe	Nambe	—		Pegmatites
		Total	$11,030,000	

[a]Rounded off to the nearest $10,000.

[b]Author's estimate.

[c]Sandoval County only.

SOURCES: Jones (1904); Lindgren, Graton, and Gordon (1910); Lasky and Wootton (1933); Anderson (1957); Northrop (1959); *Mineral Resources of the United States* (1882-1931); *Minerals Yearbooks* (1932-1959); Farnham (1961).

TABLE 4. METAL PRODUCTION OF THE TIJERAS CANYON (COYOTE CANYON, SODA SPRINGS) MINING DISTRICT, BERNALILLO COUNTY, NEW MEXICO, 1909 to 1952

			GOLD		SILVER		COPPER		LEAD		
YEAR	NAME OF MINE	ORE (short tons)	OUNCES	VALUE (dollars)	OUNCES	VALUE (dollars)	POUNDS	VALUE (dollars)	POUNDS	VALUE (dollars)	TOTAL VALUE (in dollars)
1909[a]	nd.	31	24.0	485	65	33	23[b]	3	3,882	168[b]	689
1910	Octaroon	24	—	—	37	20	—	—	24,568	1061	1081
1916	Octaroon	24	0.2	5	32	21	—	—	14,188	979	1005
1938	n.d.	11	4.4	154	3	2	—	—	—	—	156
1940	n.d.	30	7.0	245	7	5	200	23	100	5	278
1941	Little Daisy	16	4.0	140	1014	721	—	—	—	—	861
1952	Great Combination	5	3.0	105	4	4	—	—	—	—	109
Totals		141	42.6	$1134	1162	$806	223	$26	42,738	$2213	$4179

[a]Includes a small amount from Tecolote district, San Miguel County.
[b]Estimated.
n.d., no data.

modity mined in recent decades. Ladoo (1927) described the Galena King (Octaroon) mine, which was then the most developed in the district. Ross (1909) visited most of the metal mines of the Soda Springs subdistrict when they were in their most active period of development.

The rocks of the district consist of Precambrian gneiss, schist, slate, quartzite, and granite overlain by the Pennsylvanian Magdalena Group. Pennsylvanian rocks cap the highest mountains. The Precambrian rocks have been tightly folded and are cut by thrust faults and normal faults; most of the Precambrian structures have a northeasterly trend. The Pennsylvanian rocks have been folded only slightly and generally dip gently to the east. From late Cretaceous time into Recent, they were repeatedly broken by large, north-trending, normal faults (Reiche).

The veins are post-Pennsylvanian, probably Tertiary. Most of them occupy north-trending high-angle faults, but some have the older, northeasterly, trend. All rocks in the district harbor a few veins, but a Precambrian pink granite gneiss, the Sevilleta Metarhyolite of Reiche, seems to be the most favored. It extends in a broad belt from the southern side of Coyote Canyon to the northeastern corner of the Isleta Pueblo grant.

The mineralogy of the veins seems to be controlled by distance from the Precambrian—Pennsylvanian contact. All shoots mined since 1910 lie in Precambrian rocks, just below Pennsylvanian limestone. The veins consist of brecciated fragments of wall rock cemented by fluorite and lesser amounts of barite, galena, quartz, and calcite. Fluorite makes up about 30 per cent of the total but may be more than twice as abundant if wall-rock fragments are scarce. At depth, away from the limestone contact, quartz increases at the expense of other minerals, copperminerals make their appearance, and gold values rise slightly. At the southern end of the district, south of Hell Canyon, mineralization is confined to low-grade, gold-bearing, quartz fissure and replacement veins in Precambrian greenstone schist. According to Reiche, the Milagras mine in sec. 29, T. 8 N., R. 5 E., Valencia County, yielded 1000 to 1500 tons of oxidized ore in the 1880's and early 1890's, from which gold valued at about $5 a ton was extracted in a 10-stamp mill. One mine, the Belvidere, in sec. 29, T. 8 N., R. 5 E., Valencia County, widely advertised itself from 1959 to 1961 as a platinum mine but failed to ship any platinum.

A group of copper prospects lies near a northeast-trending thrust fault in Sevilleta Metarhyolite in secs. 5 and 6, T. 8 N., R. 5 E. Fluorspar and small amounts of lead have been mined in a belt that runs from the southern side of Hell Canyon in secs. 15 and 16, T. 9 N., R. 5 E. south to sec. 9, T. 8 N., R. 5 E. Near the southern end of the belt is the Galena King, or Octaroon, mine, which shipped three cars of lead ore and one of fluorspar between 1910 and 1923 (Ladoo). At the northern end is the Blackbird mine, which was worked under lease by American Fluorspar Company during World War II. Similar prospects occur in the Sandia Mountains near the Bernalillo—Sandoval county line. They are described under *Sandoval County, Placitas district.*

Some of the veins are quite conspicuous, but all ore shoots discovered up to now are short and narrow. The largest known shoot seems to be at the Blackbird fluorspar mine in the SW1/4 sec. 16, T. 9 N., R. 5 E. The shoot, which lies immediately south of the 74-foot shaft, ranges from a few inches to 5 feet wide, is 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 per cent. It lies in a vein that can be traced on the surface for 700 feet in a S. 32° E. direction from the shaft; both ends are covered.

A few small deposits between Coyote and Tijeras canyons (U.S. Highway 66) are different from the rest. They may have formed during a Precambrian period of mineralization. They are small lenses of fine-grained quartz, specularite, chalcopyrite, sphalerite, pyrite, and their oxidation products, oriented parallel to the northeastward trend of the schistosity of the enclosing greenstone. Native gold has been panned out of the oxidized parts of some veins. The lenses are too small to mine profitably. Examples are the York mine (mainly chalcopyrite) in the NE1A sec. 6, T. 9 N., R. 5 E. and the Mary M—Great Combination group (mainly gold) one mile to the south. The Great Combination claim produced one truckload of low-grade gold ore in 1954. It is active at present but not as a gold mine; angular blocks of Precambrian quartzite from a talus slope in the NEV$_{I}$ sec. 12, T. 9 N., R. 41/$_{2}$ E. are sold in Albuquerque as building stone, and a number of attractive buildings have recently been faced with it. One example is the Town and Country shopping center at Menaul Boulevard and Pennsylvania Street.

Also included in the Tijeras district are a few small gold prospect pits on a prominent ridge of Precambrian quartzite that crosses U.S. Highway 66 about three miles east of the Albuquerque city limits and some prospect pits in a granite pegmatite phase of the Sandia Granite near the mouth of Tijeras Canyon, north of U.S. Highway 66.

The future of metal mining in the Tijeras Canyon district looks unpromising. The ore shoots are all small and the main product, fluorspar, has had no market in New Mexico since the mill at Los Lunas closed in 1953. Some of the district lies on Sandia Base or 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 thirty miles west of Santa Fe and fifteen miles northwest of the Atchison, Topeka, and Santa Fe Railway at Santo Domingo Pueblo. The country is a high volcanic plateau capped by Bandelier Rhyolite Tuff (Quaternary), deeply dissected by steep-walled canyons. The important mines are located in two separate areas where canyons have cut into mineralized pre-Bandelier andesite and monzonite. The most important mine, the Albemarle, is in Colla Canyon in sec. 35 (unsurveyed), T. 18 N., R. 4 E.; nearly all 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, silver worth $457,034, and a few thousand dollars' worth of lead and copper, making a total of $1,321,582 (table 5). About four fifths of this was mined in the boom years between 1894 and 1903. The district has been essentially idle since 1948, although six tons of ore valued at $338 were shipped in 1963. All claims are now owned by Miss Effie Jenks of Santa Fe, New Mexico.

The best description of the mines is by Graton (Lindgren, Graton, and Gordon, 1910). Recently, geology and hydrothermal alteration were described by Bundy (1958), whose bulletin contains an excellent geologic map. Brief accounts of the district were published by Wynkoop (1900), Barbour (1908), and Statz (1912). An interesting nontechnical history of Bland during the boom years was compiled from many sources by Vieth (1950). Ross, Smith, and Bailey (1961) summarized the geology of the Jemez Mountains.

According to Bundy, the oldest rocks in the district are andesite flows and associated pyroclastic rocks and arkosic sandstones. Their age is unknown, but it is probably no older than late Cretaceous and no younger than late Tertiary. The rocks 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-sliver-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 that 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 others in and around Colla Canyon trend to the northeast. All veins dip steeply (50 to 85 degrees), some to the east, some to the west.

TABLE 5. METAL PRODUCTION OF THE COCHITI MINING DISTRICT, SANDOVAL COUNTY, NEW MEXICO, 1894 to 1948

YEAR	TONS MINED	GOLD OUNCES	GOLD VALUE (dollars)	SILVER OUNCES	SILVER VALUE (dollars)	TOTAL VALUE (dollars)	ACTIVE MINES
1894-1904	170,000[a]	33,200[a]	695,000	n.d.	345,000	1,040,000	All
1914	4,373	824	17,036	24,460	11,964	29,000	Lone Star
1915	18,701	4,021	83,131	93,314	47,310	133,006[d]	Lone Star, Iron King
1916	9,300	2,070	42,800	56,404	37,100	79,900	Lone Star
1932	659	364	7,519	13,440	3,817[b]	11,336	Crown Point, Iron King, Free Trade, Laura, Lone Star
1933	465	158	3,267[a]	7,940	2,785[a]	6,052	Washington
1934	580	110	3,850	7,060	4,591[c]	8,441	Crown Point, Iron King
1935	159	20	700	1,575	1,451[b]	2,151	Crown Point, Domingo
1938	276	164	5,740	1,700	1,106	6,846	Lone Star, Cossak Mill dump
1939	514	66	2,310	2,130	1,456[c]	3,766	Lone Star, Iron King, Crown Point, Cossak Mill dump
1947	3	9	315	4	46[c]	361	Iron King
1948	9	9	315	451	408	723	Iron King
Totals	205,039	41,015	$861,983	n.d.	$457,034	$1,321,582	

[a]Estimated.
[b]Includes small payment for lead.
[c]Includes small payment for copper.
[d]Includes payment of $2565 for 14,657 pounds of lead.

SOURCES: Lindgren, Graton, and Gordon; *Mineral Resources of the United States,* 1904-1932; *Minerals Yearbooks,* 1933-1948.

The veins consist largely of quartz and chalcedony and were formed by replacement of wall rock. They are as much as 1500 feet long and highly irregular in width, but in places they are remarkably wide. On the surface, widths up to 50 feet are not unusual, and underground, Graton (Lindgren, Graton, and Gordon) reported shoots 150 feet wide. Some of the gold and silver was found in rich streaks of shipping-grade ore, usually $30 to $50 a ton, but most of it was disseminated irregularly through the veins. Estimates vary, but ore mined before 1904 probably averaged about $6 a ton. Table 5 shows that the ore mined since then (some of it sorted) averaged only $8 a ton. Some of the veins are barren.

Bundy described the paragenesis as follows: First, calcite was emplaced along the faults. Quartz then replaced most of the calcite. Some of the quartz is pseudomorphous after platy calcite and has the peculiar "hackly" texture typical of many other epithermal mining districts (Mogollon, Kimball). Parts of veins consisting of unreplaced calcite are unproductive. A period of brecciation was followed by the emplacement of pyrite, minor chalcopyrite, sphalerite (up to 3 per cent of the veins), a minute amount of galena, quartz, gold-bearing pyrite, and argentite, in that order. All the sulfides occur in minute grains. The postrhyolite phase of mineralization consisted of quartz and abundant pyrite, barren of precious metals. Traces of arsenic, antimony, and tellurium have been reported in the ore (Barbour; Wynkoop). The veins are drusy and vuggy and contain abundant inclusions of wall rock, sometimes surrounded by halos of metallic minerals. The varieties of silica range from cryptocrystalline chalcedony to quartz crystals one inch long. The coarser crystals line cavities and are amethystine in places.

Hydrothermal alteration, according to Bundy, took the form of propylitization, argillization, and silicification. Propylitization pervades all the pre-Bandelier rocks, giving them a green color. Chlorite and montmorillonite are the most common alteration products, but vermiculite and halloysite appear nearer the veins. Argillization occurs around veins and in unmineralized shear zones. Near veins, it is a good guide to ore, especially since it is more persistent than ore shoots. A zone characterized by illite and kaolinite is up to 1000 feet wide next to the larger veins. Dickite appears in a narrow band directly next to veins. Silicification is widespread, and silicified rock commonly grades into quartz replacement veins. Bundy attributed the sequence, chlorite-montmorillonite-vermiculite-halloysite-illite-kaolinite-dickite, to a single continuous phase of mineralization during which the mineralizing fluid became more acid as alkalies were progressively leached out of the wall rock.

All veins are oxidized from the outcrop down to variable depths. According to Graton (Lindgren, Graton, and Gordon), primary sulfides were abundant in the 136-foot level of the Iron King mine and on the 425-foot level of the Albemarle mine. The oxidized zone was leached of base-metal sulfides but enriched in residual gold. Silver remained roughly constant. Gold was extracted by amalgamation from oxidized ore and by cyanidation from primary ore.

Texture, mineralogy, and field association place the veins clearly in the epithermal class of "bonanza" deposits. Bundy concluded from the presence of dickite that the temperature of the ore-forming fluid must have been higher than the epithermal range established by Lindgren (1933). Following Schmitt (1950), Bundy classified the deposits as Tertiary siliceous, epithermal, shallow, or volcanic.

The largest mine in the district was the Albemarle, in Colla Canyon. Its inclined shaft opened a vein that strikes N. 30°-35° E. and dips 45°-62° NW for 1000 feet and to a depth of 625 feet. A winze carried the workings down another 90 feet. The mine had eight levels, but the main workings were above the fifth (325-foot) level. It is credited with an output of $667,500 (Jones), mostly while operated by the Navajo Gold Mining Company between 1899 and 1902.

The Lone Star—Iron King—Crown Point claims in Bland Canyon were next in importance. At different times, they were worked separately or as a group. The Lone Star vein strikes N. 25° E. and dips 80° E. It was opened, over a length of more than 1000 feet, by six adits and crosscut tunnels connected by raises, to a depth of 800 feet below the highest outcrop. Different accounts give the maximum width of the vein as 70, 100, and 150+ feet, but the average was nearer 25 feet. The mine shipped about $60,000 worth of ore before 1903. About 1900, it was acquired by the ill-fated Navajo Gold Mining Company. The Iron King mine is a short distance northeast of the Lone Star. Its vein strikes N. 25° E. and dips 55° E at the outcrop and 76° W at depth; it may or may not be a continuation of the Lone Star vein, slightly offset to the right. The mine has a 100-foot shaft and a short adit with a winze going down to the 136-foot level. Its output is said to have been $50,000 between 1896 and 1902; most of the ore was milled at the Woodbury mill (amalgamation, later cyanidation) seven miles below Bland. The Crown Point mine is on the opposite (east) side of Bland Canyon, about half a mile north of the Iron King. The vein strikes N. 19° W. and dips 50°-70° W. Most of the $50,000 it produced in the mid-1890's came from an open cut, but the mine also has a crosscut tunnel, a 250-foot winze, and 1000 feet of drifts.

Since the bankruptcy of the Navajo Gold Mining Company in 1902, sporadic unsuccessful attempts to revive the district centered on the Lone Star—Iron King—Crown Point group. It was operated by Cossak Mining Company from 1914 to 1916, the ores being treated by a 100-ton cyanidation mill at Bland. Some shipments were recorded during the 1930's, partly from cleanup work at the Cossak mill. During World War II, the Albemarle and other mills were scrapped. A postwar attempt to revive the Iron King mine ended when mine and mill were attached by the Sandoval County sheriff in 1947.

Other mines have been less important. The Washington mine, south of the Iron King and Lone Star, follows a north-trending vein that dips 60° W. Workings include a 300-foot shaft, 200 feet of adits, and 1000 feet of drifts. Production included several cars of sorted ore averaging more than $100 a ton (Wynkoop), but after 1895 the mine was shut down by litigation.

According to Jones, "In Peralta Canyon a curious example occurs in the presence of uranium and vanadium oxide filling the interstices of a silicified volcanic vent breccia found on the property of the Peralta Gold Mining and Milling Company." This cryptic statement caused some prospecting activity a few years ago.

The rise and fall of the Cochiti mining district parallels that of many other districts of the same geologic type throughout the West. The main reasons for its ultimate extinction are as follows:

1. *Low average grade of ore.* Graton estimated the average value as $6 a ton (1894-1903 prices). Rich but shallow residual deposits at the outcrop and sporadic rich streaks at depth stimulated unwarranted optimism.

2. *Decline in width and tenor of veins at depth.* In the Albemarle mine, values declined from between $6.50 and $7.50 a ton above the fourth (230-foot) level to $4.00 or $4.50 a ton below the sixth (425-foot) level, to $3.50 a ton on the eighth (625-foot) level (Jones; Lindgren, Graton, and Gordon). The main ore shoot reached from 20 feet below adit level to the fifth (325-foot) level. Its maximum dimensions, 200 feet long and 60 feet wide, occurred on the fourth (230-foot) level. All other ore shoots were smaller. The deepest known shoot in the district, also in the Albemarle mine, pinched out 585 feet below the collar.

3. *High transportation costs.* The projected railroad spur to the camp was never built.

4. *Lack of water.* The mill at Albemarle could be run for only nine months a year.

5. *Mismanagement.* This may have been the most important factor of all. The Albemarle mine earned its owners, the Navajo Gold Mining Company, $667,500 (Jones), but expenditures were completely out of proportion. The road across the divide from Bland to Albemarle—aptly called "The Teamster's Nightmare"—cost $150,000 (Vieth). An electric power station at Madrid and a 35-mile high-tension transmission line to the mine cost $250,000 (Barbour). The company's cyanidation mill, the first all-steel building in New Mexico, was one

of the wonders of the age, but why was steel shipped into an area where cheap lumber was locally available? The capacity of the plant was rated at 250 tons a day, but it was repeatedly shut down by mechanical troubles. Finally, the mill was grossly inefficient. The tailings assayed between $2.00 and $2.15 a ton, more than one third the value of the ore. Barbour called the operations of the Navajo Company a "colossal failure" and goes as far to question the decrease of values with depth, implying that this was an invention by the company to cover up its inefficiency.

6. *Litigation.* The absentee owners of the Canada de Cochiti land grant claimed that the entire district belonged to the grant rather than to the public domain. Their final appeal was not rejected by the U.S. Supreme Court until 1897 (Vieth). This explains the delayed development. Although Maj. Edward Beaumont discovered the district in 1880, the first claims (the Iron King—Lone Star—Crown Point group) were not located until 1890. Outside capital did not become available until 1898. The Cochiti Gold Mining Company and its successor, the Navajo Gold Mining Company 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. The peak of production was 1900, when the output was $359,135. The Cochiti district clearly missed the great boom period of high prices for precious metals that ended in 1893.

As far as known, all ore shoots in the Albemarle mine have been mined out, but a considerable tonnage of low-grade material remains in some other mines. A revival of mining could occur if gold and silver prices should rise appreciably. Ores would probably have to be cyanided. Untreated ore is said to average 85 to 95 per cent SiO_2 (Wynkoop) and would probably be acceptable as siliceous flux, but transportation to the El Paso smelter would be expensive.

CUBA MANGANESE DISTRICT

The Cuba Manganese district is 12 to 24 miles west and northwest of Cuba, a few miles south of State Highway 44. Under the stimulus of government price support, the district produced manganese ore during World War II and again from 1954 until the termination of the U.S. Government Carload-Lot Purchasing Program in 1959. Farnham (1961) estimated the total output between 1942 and 1957 at about 3400 tons of concentrates, ranging from 35 to 44 per cent manganese.

The mines, listed in order of importance, were the Lander, or Crook, group of claims in secs. 22 and 28, T. 21 N., R. 4 W.; the Taylor, or Miller, deposit in the SW1/4 sec. 26, T. 21 N., R. 3 W.; and the Jicarilla Apache deposit, on the Jicarilla Apache Indian Reservation in the west-central part of T. 22 N., R. 4 W. (unsurveyed). The last lessee of all three deposits was J. F. McRee.

Farnham's geologic description of the district was partly based on an earlier, unpublished report by S. K. Neuschel of the U.S. Geological Survey. The ore occurs as concentrically layered concretionary nodules of pyrolusite and wad in flat-lying, near-surface sandy shale lenses of the Eocene San Jose Formation. The nodules range from one-quarter inch to one and one-half inches in diameter and constitute about half the rock. Since the rock is soft and friable, the nodules can be readily concentrated by screening or jigging.

Individual ore lenses ranged from 100 to 300 feet in diameter and from a feather edge to 5 feet in thickness. They could be easily worked by earth-moving equipment and were essentially exhausted when operations ceased. Should the demand for manganese justify exploration in the future, stratigraphic studies could determine whether all ore lenses are at the same stratigraphic horizon and, if so, where additional lenses could be expected under shallow cover.

JEMEZ SPRINGS DISTRICT

The Jemez Springs district consists of only one small mine, the Spanish Queen, near the bottom of Jemez Canyon, two and seven-tenths miles south of Jemez Springs. It formerly worked a low-grade copper deposit of the sandstones type. Geologically, it is similar to the copper deposits of the Nacimiento Mountains district, except that the host rock consists of nearly horizontal beds of the Abo Formation (Permian). Chalcocite and copper carbonates replace fossil wood fragments in arkosic sandstone and also occur disseminated in partings of gray shale. The main ore-bearing horizon is about 2.5 feet thick. A second mineralized bed, about 13 feet thick, lies 40 feet below the main bed but seems to be of lower grade. The mine has a 90-foot shaft that intersects an adit and a number of drifts opening into small rooms.

The Spanish Queen mine is surrounded by legends of fabulous treasures in gold and silver it supposedly yielded in the days of the *conquistadores*. The legends ignore the low tenor of precious metals typical in deposits of this type. Even the U.S. Army Map Service's 1:250,000 Albuquerque topographic map shows the Spanish Queen as a gold mine. Actually, most of the development work was done by Burnett Mining Company between 1926 and 1929 and in 1937 (table 6). The company installed a 15-ton Mace furnace but does not seem to have operated it, since all ore was shipped directly to the El Paso smelter.

TABLE 6. METAL PRODUCTION OF THE JEMEZ SPRINGS MINING DISTRICT, SANDOVAL COUNTY, NEW MEXICO 1928 to 1937

YEAR	ORE (short tons)	GOLD (oz.)	SILVER (oz.)	COPPER (lbs.)	VALUE (dollars)	OPERATING MINE
1928	66	—	29	6,500	953	Spanish Queen
1929	113[a]	1	90	10,000	1827	Spanish Queen
1937	54	—	40		358	Spanish Queen
Totals	233	1	159	19,200	$4138	

[a]Includes one carload from Conglomerate mine, Nacimiento Mountains district.

LA VENTANA DISTRICT

The La Ventana district is located east of the settlement of La Ventana in the southern half of T. 19 N., R. 1 W. The area has moderate reserves of uranium in Cretaceous coal and carbonaceous shale, but only a little production. According to Bachman et al. (1959), the chief deposits are on La Ventana Mesa in secs. 28, 29, 33, and 34, T. 19 N., R. 1 W. Uranium, ranging from a trace to 0.62 per cent, occurs in three lenticular beds of coal and carbonaceous shale at the base of the La Ventana Tongue of the Cliff House Sandstone, the uppermost formation of the Mesaverde Group (stratigraphic nomenclature from Beaumont, Dane, and Sears, 1956). Bachman et al. estimated the reserves of material averaging 0.1 per cent uranium at 132,000 tons. Coffinite is among the uranium minerals present. Cannon and Sterrett (1956) outlined areas favorable for exploration by analyzing the ash from living and dead wood of junipers and pinons growing on top of the La Ventana Mesa. The mineralized horizon is below the fractured 65-foot sandstone bed that caps the mesa; apparently the juniper and pinon roots reached the mineralized zone. Concentrations of uranium in ash ranged from 0.1 part to 2.3 parts per million.

East of La Ventana Mesa, in the NEB/ sec. 23, T. 19 N., R. 1 W., uranium mineralization occurs in the Cretaceous Dakota Sandstone. Gabelman (1956) described the Butler deposit, which is only one mile west of the San Miguel copper mine, Nacimiento Mountains district *(see below).* Because of drag caused by the Nacimiento reverse fault, exposed at the San Miguel mine, the Dakota dips 43° to 67° W, and is warped into open but steeply plunging folds. Gabelman reported that a one-foot bed, or lens, of black peat at the base of the Dakota Sandstone contains up to 1.4 per cent uranium. The peat bed was exposed for 100 feet along the outcrop and for 100 feet downdip. A shipment of uranium from the Butler mine valued at $106 was listed by the State Inspector of Mines in 1959. A small additional shipment was reported in 1959 from the Warm Springs mine in sec. 25, T. 17 N., R. 1 W., midway between La Ventana and San Ysidro.

Gypsum and coal deposits of the La Ventana Mesa area are described under industrial nonmetals and coal, respectively.

NACIMIENTO MOUNTAINS (CUBA) DISTRICT

The Nacimiento Mountains district is in northeastern Sandoval County and southwestern Rio Arriba County, on the western face of the Nacimiento Mountains. Most of the mines are within five and one-half miles southeast of Cuba, but one mine, the San Miguel, lies about six miles south of the others. Between 1881 and 1960, the district produced about 7,500,000 pounds of copper and several tens of thousands ounces of silver, valued at more than $1,100,000 (table 7).* The deposits are of the red beds or sandstone type. A good description of the mines was given by Schrader *(in* Lindgren, Graton, and Gordon).

A circular by Soule (1956) contains several claim and assay maps. The general geology was mapped by Wood and Northrop (1946).

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.

The dominant structure of the region is the large westward-directed reverse 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).

The Eureka, Conglomerate, and Cliff mines are in nearly horizontal sandstone and conglomerate beds of the Agua Zarca Member east of the Nacimiento fault on the southern side of Eureka Mesa. The Eureka is in the NE1/4 sec. 32, T. 21 N., R. 1 E. (unsurveyed), Rio Arriba County, and the Cliff is in the NW1/4 sec. 6, T. 20 N., R. 1 E., Sandoval County. All other mines in the district seem to be in steeply westward-dipping Agua Zarca Sandstone near the Nacimiento fault. One group east of Copper City, in and around sec. 1, T. 20 N., R. 1 W., is directly east of the Nacimiento fault. The mineralized beds dip about 30° W. Schrader *(in* Lindgren, Graton, and Gordon) mentioned the Copper Glance and Kelley mines; of these two, the Copper Glance was the more important. Another mine, the Bluebird, is about one and one-half miles farther south, near Senorito, in or near the SW1/4

*Soule gave the production of the Sandoval County part of the district (presumably prior to 1951) as 6,560,546 pounds of copper, 8921 ounces for silver, and 0.41 ounce of gold. The tonnage of ore, 6379, must refer to the hand-sorted material treated by local smelters.

TABLE 7. METAL PRODUCTION OF THE NACIMIENTO MOUNTAINS (CUBA) MINING DISTRICT, RIO ARRIBA AND SANDOVAL COUNTIES, NEW MEXICO, 1880 to 1964

YEAR	ORE MINED (tons)	SILVER		COPPER		TOTAL VALUE (dollars)	PRODUCING MINES
		OUNCES	VALUE (dollars)	POUNDS	VALUE (dollars)		
1880-1900	n.d.	63,000[a]	70,000[a]	6,300,000	630,000[a]	700,000[a]	San Miguel, Copper Glance
1911	10	46	24	5,734	717	741	n.d.
1916[b]	130	274	220[c]	26,276	6,464	6,684	San Miguel
1917	20	153	126	12,901	3,522	3,648	Copper Glance
1918	6	118	118	10,935	2,701	2,819	n.d.
1919	166	1,317	1,475	100,000	18,600	20,075	San Miguel
1920	89	700	710[a]	53,821[a]	9,956[a]	10,666	San Miguel
1929[d]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Eureka
1943	13	45	20	4,000	532	552	San Miguel
1945	19	28	14[a]	2,000	276[a]	290	San Miguel
1950	465	10	7	6,000	1,250	1,257	San Miguel, Senorita
1951	132	11	8	4,000	970	978	San Miguel, A. D. Miller
1955	1,729	410	371	60,000	22,380	22,751	San Miguel, Chalcocite, Cecil-Hope
1956[e]	12,903	7,564	6,845	548,200	232,986	239,831	Eureka, Bluebird, San Miguel Landon, Dam
1957[f]	10,094	1,392	1,260	421,700	126,932	128,192	Eureka, two others
1959	nd.	n.d.	n.d.	n.d.	n.d.	n.d.	San Miguel
1964	1,010	n.d.	n.d.	6,000	1,923	1,923	Cuprite-Copper Glance
1880-1900	n.d.	63,000[a]	70,000[a]	6,300,000	630,000[a]	700,000[a]	
1900-1964	26,786	12,068	11,198	1,261,567	429,209	440,407	
1880-1964	n.d.	75,068	81,198	7,561,567	1,059,209	1,140,407	

[a]Estimated. [b]Includes a small amount from Pay mine, Jarosa district, Rio Arriba County. [c]Includes about $8 for gold and $8 for lead. [d]Production one carload, included with Jemez Springs district. [e]Includes 11,168 tons of ore valued at $220,107 from Rio Arriba County, mainly from Eureka mine. [f]Mostly from Eureka mine, Rio Arriba County.

SOURCES: Lindgren, Graton, and Gordon; *Mineral Resources of the United States*, 1904-1931; *Minerals Yearbooks*, 1932-1959.

sec. 12, T. 20 N., R. 1 W. Finally, the San Miguel mine is in the NE¼ sec. 24, T. 19 N., R. 1 W., about five and one-half miles northeast of La Ventana and directly west of the Nacimiento fault.

All the mines have the same type of mineralization. The primary ore mineral is chalcocite, formed by replacement of fossil wood and "carbonaceous trash." Malachite and azurite, formed by oxidation and redistribution of copper formerly contained in chalcocite, occur on fractures and in irregular halos around accumulations of organic material, as well as in the organic material itself. At the Eureka mine, chrysocolla largely takes the place of malachite and azurite. Most of the ore assays less than 3 per cent copper, but hand-sorting raised the grade of material smelted before 1900 to 25 to 65 per cent, with an average of 35 to 40 per cent. The silver content was 0.5 ounce to 2 ounces for every hundred pounds of copper; there was almost no gold.

Copper deposits of the sandstone type are notoriously discontinuous, and the ores of the Nacimiento district are no exception. They occur as 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, and there has been a slight revival of interest in sandstone copper deposits.

Field relations are best shown at the Eureka mine, where the ore zone is a flat-lying Triassic stream channel about 600 feet wide at the base of the Agua Zarca Sandstone Member. It consists of interfingering lenses of sandstone and quartz-pebble conglomerate. The conglomerate lenses contain clay galls as well as abundant fragments of carbonized wood and are irregularly mineralized in zones 6 to 20 feet thick. Soule gave assays ranging from 1.37 to 6.07 per cent. Sandstone beds are barren except for a little secondary mineralization on fractures. Cross-bedding is prominent in both sandstone and conglomerate; the direction of cross-bedding consistently shows that the current direction was from northeast to the southwest. This was confirmed by the orientation of the long axes of pebbles and carbonized wood fragments. Their azimuth shows considerable range, but the mean is about N. 30° E. The extension of the exposed ore body should be sought in this direction; its southwesterly extension has eroded away. The operators of the mine appear to have been unaware of the orientation of the ore channel. The ore body was opened by four large and two small adits ranging in direction from N. 05° E. to N. 30° W.; the main tunnel (which, though now blocked, is said to go clear through Eureka Mesa) has a direction of N. 30° W.

The channel direction at the Copper Glance and adjoining deposits also was from northeast to southwest. Numerous workings open small mineralized conglomerate lenses, about 3 feet thick, over a strike length of 2000 feet; the majority of the workings go straight downdip, with westerly azimuth.

Conditions are more complicated at the San Miguel mine. The dump from an open pit, dug 1956-1957, obscures most of the older workings. The pit seems to be in a large slump block. *In situ* ore is exposed in two smaller pits, one directly east of the main pit and the other to the north, beyond a fault that offsets the ore zone to the left. Cross beds and oriented pebbles indicate that the current flowed about S. 80° W. Curiously, carbonized wood fragments are oriented normal to the pebbles; silicified wood fragments act the same as pebbles. In 1966, several thousand tons of ore were hauled from the San Miguel mine to a leaching plant in Cuba by M, C, B, and L Mining Company.

The Chalcocite prospect, about three quarters of a mile north of the Copper Glance mine, is different from the others. According to Schrader *(in* Lindgren, Graton, and Gordon), 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 Mountains copper deposits were known as early as 1859 (Newberry, 1876). Systematic mining did not begin until the early 1880's and ended about 1900. Most of the mines were successively in the hands of the Nacimiento Mining Company, the New Mexico—Illinois Company, the Providence Company, and the Juratrias Copper Company. During this period, the mines yielded about 6,300,000 pounds of copper and several tens of thousands ounces of silver valued at about $70,000. Of this, 5,000,000 pounds came from the San Miguel mine and about 1,250,000 pounds from the Copper Glance (Lindgren, Graton, and Gordon). Mining was profitable only because coal for smelting occurs within a few miles of the copper deposits in the La Ventana—Chacra Mesa coal field. Hand-sorted, high-grade ore was hauled by wagon to a 30-ton smelter at Copper City or to a 25-ton smelter at Senorito, and the matte was then 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 in times of high copper prices, 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, Rio Arriba County (table 7).

The known deposits were thoroughly high-graded by the old-timers, but considerable reserves of low-grade material, containing 0.75 to 3 per cent copper, remain. The Eureka, Copper City, and San Miguel mines could each probably yield several tens of thousands of tons of low-grade ore. Drilling along the trend of the Eureka channel, through the few tens of feet of sandstone that cap Eureka Mesa, would be an inexpensive first step in exploration. The high cost of transportation remains a severe handicap, as much now as in the past.

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 has been insignificant. The district had a minor boom about 1880, but it soon died down.

The better known mines include the La Luz (argentiferous galena, fluorspar, and barite), which lies 600 feet below the crest of North Sandia Peak in the SE1/2 sec. 6, T. 11 N., R. 5 E. (unsurveyed). It has the dubious honor of having the highest elevation (10,050 feet) of any mine in New Mexico. Access is by a narrow foot trail. There has been no production in this century, but development work was done iri 1908 (Northrop, 1959). The Capulin prospect is in or near the SE1/4 sec. 33, T. 12 N., R. 5 E., and the Schmidt and Darrel prospects are in secs. 3 and 10, T. 11 N., R. 5 E. (unsurveyed), respectively. There has been a little development for fluorspar, but no mining (Rothrock, Johnson, and Hahn). Another group of prospects lies on a low hill in the SW1/4 sec. I and SE1/4 sec. 2, T. 11 N., R. 5 E. Bulldozer cuts testify to recent prospecting for fluorspar; the ruin of an old lead smelter on the western foot of the hill testifies to former activity. Significantly, there is no slag at the smelter.

A number of prospects are on the western side of Montezuma Mountain, about one mile east of Placitas. Chief among them is the Montezuma mine located at the faulted contact of Precambrian and Mississippian—Pennsylvanian rocks at the foot of the mountain. It is famous mainly for tall tales about buried treasures and extensive Spanish workings, allegedly hundreds of feet below the ground; however, most of the workings date back only to the 1920's. In 1926, *Mineral Resources of the United States* reported that 300 feet of development work had been done that year, bringing the total of all workings to one 65-foot shaft, one 85-foot shaft, and 400 feet of drifts. The total value of ore shipped in this century has been about $800 (table 8),

TABLE 8. METAL PRODUCTION OF THE PLACITAS MINING DISTRICT, BERNALILLO AND SANDOVAL COUNTIES, NEW MEXICO, 1920 to 1926

YEAR	ORE (short tons)	SILVER (oz.)	COPPER (lbs.)	LEAD (LBS.)	VALUE (dollars)	OPERATING MINE
1920	21	11	—	5262	433	Montezuma
1926	14	37	2400	700	415	Montezuma, one other
Totals	35	48	2400	5962	$848	

although the mine reportedly changed hands for $60,000 in 1880. (Northrop, 1959). Small pockets and veinlets of barite are scattered all over Montezuma Mountain, but no workable deposit has yet been found. As recently as 1958, there was a short-lived attempt to mine and mill barite. A few prospects near Tecolote have showings of copper, a small lot of which was shipped in 1920.

SANTA FE COUNTY

CERRILLOS DISTRICT

The Cerrillos district covers Los Cerrillos, a group of low hills fifteen miles southwest of Santa Fe. The main line of the Atchison, Topeka, and Santa Fe Railway skirts the southern edge of the hills and U.S. Highway 85 passes within two miles of the northern edge. The village of Cerrillos is the nearest shipping point on the railroad. The district is best known for its turquoise deposits, but it has also yielded zinc, lead, silver, copper, and gold worth about $620,000.

The geology and ore deposits of the district were described by Disbrow and Stoll (1957). Their work is in print and almost up to date; descriptions of individual mines need not be repeated here. Stearns' (1953) report, with map, includes the Cerrillos district. Among older works, a brief account of the district can be found in Lindgren, Graton, and Gordon. Johnson's geologic study, published in 1903, has been superseded by that of Disbrow and Stoll, but it contains interesting information on the turquoise deposits and on the coal mines of Madrid, three miles southwest of Cerrillos.

The mineralized rocks of the district are the Jurrasic Morrison Formation; the Cretaceous Dakota Sandstone, Mancos Shale, and Mesaverde Group; the Eocene Galisteo Formation; a group of intrusive Oligocene(?) monzonites and their extrusive equivalents, the Espinaso Volcanics. Four distinct phases of monzonite have been recognized: (1) hornblende monzonite porphyry, (2) and (3) hornblende-augite monzonite porphyry, and (4) augite-biotite monzonite. All intrusive phases except the first have volcanic equivalents. All have the form of one or more central plugs and 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. To date, veins carrying lead and zinc sulfides account for most of the production, but at least two small disseminated copper deposits are known. Most of the veins trend northeasterly or northerly. Rocks younger than mineralization include the Cieneguilla Limburgite (Miocene?) and the Santa Fe Group (Miocene to Pleistocene), Cuerbio Basalt (Pleistocene?), and alluvium (Recent).

An angular unconformity between the Mesaverde Group and the Galisteo Formation is evidence for late Cretaceous to early Tertiary deformation. Later, doming, fracturing, and mineralization accompanied the monzonitic intrusions. A major portion of faulting occurred in Pliocene (?) time between deposition of the Abiquiu (= Bishop's Lodge) and Ancha Formations of the Santa Fe Group. The vein of the La Bajada mine, four and one-half miles northwest of the Cerrillos district, was formed at that time. The entire area was tilted eastward by a major north-trending fault that crosses U.S. Highway 85 at La Bajada Hill, about five miles east of Cerrillos.

The major lead-zinc veins are grouped in three distinct areas. Monzonite forms most of the bedrock in all three. The first is in the SE1/$_4$ sec. 5, T. 14 N., R. 8 E. All veins in this area have steep dips and northeasterly strikes. The Grand Central mine lies at the foot of Mount Chalchihuitl, just south of the ancient turquoise mines. The Cash Entry and Franklin mines probably worked the same vein a few hundred yards southeast of the Grand Central mine. The Mina del Tiro, in the NW1/4 sec. 8, T. 14 N., R. 8 E., is on the southwestward continuation of the same vein set.

The second group is in and around the S y$_2$ sec. 30, T. 15 N., R. 8 E. between Santa Rosita Mountain and Luceras Hill. Stoll (Disbrow and Stoll) mapped this area at a scale of 1:2400. It includes the Andrews, Tom Payne, Bottom Dollar, Black Hornet, Armington, and Pennsylvania mines. The veins have steep dips and a northerly trend. The Tom Payne and Armington mines are probably on the same vein. The Pennsylvania mine may be on its southern extension, slightly offset to the right.

The third group is in the northern tip of Los Cerrillos, in secs. 19 and 20, T. 15 N., R. 8 E. It includes the Trio, Evelyn, and Marshall Bonanza mines. The veins in this area have northeasterly strikes. The Evelyn mine, in the SE1/$_4$ sec. 19, T. 15 N., R. 8 E. at the northeastern foot of Santa Rosita Mountain, is the only one in the Cerrillos district to have shipped copper-gold ore rather than zinc-lead-silver ore, most of it from a small disseminated deposit worked by an open pit.

The veins are controlled by shear zones and are usually 1 to 6 feet wide and a few hundred feet long. Some are much larger, up to 16 feet wide and 2500 feet long. Only a fraction of the shear zone is ordinarily filled with vein matter; for this reason, the walls of mine workings are weak and must be supported.

Commercial ore occurs in definite shoots, but their geologic control is not known. The largest shoot in the Pennsylvania mine, mined out in 1945 and 1946, was 370 feet long, 220 feet deep, and from a feather edge to 3 feet wide. A shoot in the Tom Payne mine, mined out during World War I, was 300 feet long, 130 feet deep, and 6 inches to 4 feet wide. These are the largest shoots so far discovered in the district.

Disbrow and Stoll described the veins as follows:

> Several types of ore bodies are present. 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 thick zone of highly sericitized monzonite porphyry. The other ore 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.

To a distance of 1 to 10 feet on either side of the veins, the rocks are usually altered to sericite and smaller amounts of pyrite, carbonates, quartz, and tourmaline. Chlorite has locally formed beyond the sericite zone. Lindgren (Lindgren, Graton, and Gordon) thought that the presence of tourmaline indicated a "rather high" temperature and pressure during mineralization, even though the deposits probably formed within 4000 feet of the surface.

Oxidation has affected all veins down to the water table, 50 to 150 feet below the surface. Smithsonite, cerussite, wulfenite, malachite, azurite, chrysocolla, covellite, limonite, manganese oxides, chalcedony, opal, kaolinite, and gypsum occur in the oxidized zone. 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). Turquoise mining declined sharply between 1904 and 1906, and the district was inactive until 1909. Its subsequent history is summarized in Table 9. During the 56 years from 1904 through 1957, there has been some metal production in 30 of those years, but the output exceeded 1000 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 average grade of ore has been about 0.34 per cent copper, 2.94 per cent lead, 3.61 per cent zinc, 0.03 ounce of gold, and 1.04 ounces of silver a ton.

Since little ore from the Cerrillos area is of shipping grade, one of the attractive features of the district has been proximity to the Cerrillos (Madrid) coal field. Several unsuccessful smelters were built before 1904. At one time, 50 coke ovens were active at Waldo, one mile northeast of Cerrillos. Production of ore has never been sufficiently large or steady to feed a smelter. A zinc oxide plant was operated by Grubnau, Bryant, and Grubnau at Waldo from 1917 to 1921. It used local anthracite, but most of the zinc carbonate ore had to be brought in from Mexico, Colorado, and other parts of New Mexico. Since 1909, sulfide ores from the district have usually been milled near the mines. At different times between 1908 and 1918, three jigmills were active, a 150-ton mill for the Cash Entry mine, a 100-ton mill for the Tom Payne, and a 50-ton mill for the Grand Central. Between 1945 and 1949, two selective flotation mills concentrated ore from, respectively, the Cash Entry and Black Hornet mines.

Since the decline of lead and zinc prices in 1957, the Cerrillos district has seen little mining, but a good deal of effort has gone into exploration for copper. In 1959 and 1960, Bear Creek Mining Company, exploration subsidiary of Kennecott Copper Corporation, conducted an intensive exploration campaign in a disseminated chalcopyrite-bornite deposit within half a mile to the northeast of the Mina del Tiro. Concentrations of more than 2000 parts per million of copper were found as primary sulfides in a zone 600 feet wide surrounding a monzonite porphyry stock about 1200 feet in diameter (Wargo, 1964). The Evelyn mine, at the northern end of the district, formerly produced low-grade oxidized copper carbonate ores disseminated in monzonite.

GLORIETA DISTRICT

The Glorieta district occupies a large area in the vicinity of Glorieta Pass, fifteen miles southeast of Santa Fe. The only recorded shipments have been of iron ore from the rim of Glorieta Mesa. Kelley (1949) described the iron deposit. Copper has been found in several prospects in the district.

The Kennedy iron mine is in the NWIA sec. 23, T. 15 N., R. 11 E. The ore bed is a lens of soft, porous, ochery, impure, supergene limonite about 3 feet thick. Limonite partly replaces fine-grained clastic rocks of the San Andres Formation (Permian) along bedding planes. The rocks strike N. 15° W. and dip 7° W. The deposit has been mined by open cuts and underground workings for 275 feet along the strike and 150 feet updip. About 3500 tons of ore were shipped, mostly before 1905, as flux to lead smelters at Socorro and El Paso. Some ore was shipped to the steel mills at Pueblo, Colorado, during World War I. Kelley estimated that a few thousand tons still remained in the deposit, and Anderson suggested possible utilization as pigment in paints or enamelware.

Lindgren (Lindgren, Graton, and Gordon) described low-grade copper deposits disseminated in gently dipping Pennsylvanian arkose and limestone beds on the sides of La Cueva Creek, two and one-half

TABLE 9. METAL PRODUCTION OF THE CERRILLOS MINING DISTRICT, SANTA FE COUNTY, NEW MEXICO, 1909 to 1957

YEAR	ORE (short tons)	GOLD (ounces)	SILVER[a] (ounces)	COPPER (pounds)	LEAD (pounds)	ZINC (pounds)	TOTAL VALUE ($)	OPERATING MINES
1909	2,821	16	2,285	1,093	213,558	4,426	11,170	Cash Entry
1910	4,617	20	3,300	5,150	262,023	74,759	18,496	Cash Entry
1911	51	17	1,915	4,494	11,178	—	2,423	Tom Payne
1912	752	—	1,040	8,670	12,511	10,565	3,271	Tom Payne
1914	287	3	779	7,575	52,948	89,860	8,146	n.d.
1915	700	6	426	1,766	50,638	14,556	4,837	Tom Payne
1916	2,546	7	2,175	—	166,304	334,321	57,853	Tom Payne and Grand Central
1917	3,118	1	142	2,579	17,779	512,628	54,661	Tom Payne, Bonanza, Grand Central
1918	172	—	—	—	11,000	94,572	9,387	Tom Payne
1922	40	—	—	—	8,800	19,840	1,615	n.d.
1926	807	210	1,011	41,800	24,500	—	12,786	Evelyn, Tom Payne
1927	1,644	304	1,120	71,771	8,635	—	17,153	Evelyn
1928	300	42	205	12,174	2,466	—	2,886	Evelyn
1929	87	6	34	3,552	—	—	759	Evelyn, Ready Cash
1941	42	14	3	—	—	—	492	——
1942	65	1	203	300	11,800	14,000	2,307	Pennsylvania, Mina del Tiro
1943	207	2	543	800	32,000	46,000	6,229	Tom Payne, Pennsylvania
1944	447	3	599	1,200	37,800	57,000	10,215	Tom Payne, Cash Entry, Franklin
1945	1,844	6	1,786	2,000	102,000	120,000	24,322	[b]

1946	2,166	17	1,952	1,800	140,000	79,000	27,362	Franklin, Pennsylvania
1948	1,133	9	1,126	2,000	58,000	38,000	7,204	Cash Entry, Franklin Marshall, Bonanza
1949	643	6	757	—	38,000	14,000	8,635	Cash Entry, Franklin, Tom Payne, Marshall, Bonanza
1951	369	9	789	2,500	58,000	76,000	25,500	Tom Payne, Grand Central
1952	334	3	842	2,000	54,000	72,000	21,997	Pennsylvania
1953	81	—	644	—	26,000	20,000	6,289	Pennsylvania, Cash Entry
1954	75	12	43	4,000	—	—	1,639	Evelyn
1955	586	17	1,038	4,300	60,000	88,000	22,902	Tom Payne, Evelyn, Bottom Dollar
1956	800[c]	[d]	2,890[e]	[d]	105,700	156,200	40,000[c]	Tom Payne, Bottom Dollar
1957	82	3	217	300	12,700	—	2,207	Mina del Tiro
Total 1909-1957	26,816	734+	27,864	181,224	1,578,340	1,935,727	$422,743	

[a]Includes a small amount of placer silver from Old Placers, 1909-1942.
[b]Cash Entry, Chicago, Pennsylvania, and Tom Payne mines.
[c]Estimated.
[d]Included with San Pedro district.
[e]Includes some silver from San Pedro district.
n.d., no data.

to four and one-half miles northeast of Glorieta. The ore occurs in at least three horizons. It consists of chalcocite, azurite, and malachite and is closely associated with organic matter. Soule gave brief descriptions of the Paytiano deposit in sec. 32, T. 16 W., R. 11 E. and the Kunklin (?) deposit, which has signs of recent activity, in or near secs. 14 or 15, T. 16 N., R. 11 E.

Anderson mentioned vein deposits in Precambrian rocks north of Glorieta. No commercial ore has yet been found in this area.

LA BAJADA DISTRICT

The La Bajada district consists of only one mine, also called La Bajada, in La Bajada Canyon at the foot of La Bajada Hill about two miles north of U.S. Highway 85. The geology and mineralogy of the deposit have been described by Lustig (1957).

Although the mine never had large production, it has considerable geologic interest. The ore body follows a north-trending fault cutting Miocene (?) Cieneguilla Limburgite and the Miocene Bishop's Lodge (= Abiquiu) Member of the Tesuque Formation in the Santa Fe Group *(see* description of the Cerrillos district). A monzonite body, similar to the last monzonite phase of the Cerrillos district, lies half a mile east of the mine but is older than the mineralized rocks and has no connection with mineralization.

Mineralization occurred in late Cenozoic time under low-temperature and near-surface conditions. Lustig described 23 minerals from the deposit (6 from an oxidized dump, 7 hypogene ore minerals and 6 gangue minerals from the vein, and 4 alteration products from the wall rock). The chief hypogene metallic minerals are pyrite, sphalerite, marcasite, colusite, chalcopyrite, and bornite, formed in that order. Brannerite is reported to be present (though none was seen by Lustig), and its uranium content is said to account for the anomalous radioactivity of the deposit. Colbalt, nickel, and germanium are present in more than ordinary trace-element amounts. Colloform textures characterize the ore minerals and indicate a low temperature of formation.

The mine has a vertical 170-foot shaft and drifts and crosscuts on the 140- and 170-foot levels. Access to the 140-foot level is by a raise. The 170-foot level is below the water table. There is no published information on the size and tenor of the ore body.

The deposit was developed by La Bajada Mining Company in the 1920's. Although the company is said to have sold stock for $2 million (Lustig), the total production came to only 8 tons of ore containing 24 ounces of silver and 2423 pounds of copper, valued at $363. This was shipped in 1928. In the 1950's, the discovery of uranium in the deposit caused a renewal of interest. Lone Star Mining and Development Corporation of Albuquerque is the current operator. A small shipment of uranium was recorded by the 1957 edition of

Minerals Yearbook. The mine shipped uranium worth $16,942 in 1963 and $9,708 in 1964 (State Inspector of Mines). Development work was reported in 1965.

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 between the Rio Quemado and Rio en Medio drainages. The bedrock of this area (Miller, Montgomery, and Sutherland, 1963) consists of Precambrian mica schist, granite gneiss, and migmatite trending northeast and containing many small lenses of granite pegmatite. As far as is known, the largest pegmatite body is on the Rocking Chair claim, which was prospected for feldspar, mica, and beryl. So far, only a few pounds of beryl have been found. The mica deposits of the district are described in the section on industrial nonmetals.

NEW PLACERS (SAN PEDRO, GOLDEN, TUERTO) DISTRICT

The New Placers district is in southern Santa Fe County in T. 12 N., R. 7 and 8 E. 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. The San Pedro copper-goldsilver pyrometasomatic deposit has produced more by value than all other lode deposits in Bernalillo, Sandoval, and Santa Fe counties put together. Between 1924 and 1928, the Carnahan (Lincoln—Lucky) limestone replacement deposit accounted for more lead, zinc, and silver than all the veins of the Cerrillos district from 1904 to the present time. There are many other mines, none of them important. Placers were worked extensively in the early days for gold but yielded only 3011 ounces in the past 56 years. Total production of the district has been about $5,750,000.

Atkinson (1962) described the geology of the district in detail. During World War II, the U.S. Geological Survey examined the San Pedro and Lincoln—Lucky mines; the report (Smith et al., 1945) is on open file. Information on tungsten was summarized by Dale and McKinney (1959). Lindgren (Lindgren, Graton, and Gordon) gave an excellent, though dated, account of the district. The close association of ore bodies, contact metasomatism, and igneous rocks impressed him deeply, and he cited the San Pedro mine as a typical example of the pyrometasomatic class of ore deposits in his classic textbook (Lindgren, p. 718). Many consultants' reports and short articles have been written on the district; Atkinson gave a nearly complete list.

According to Atkinson, the sedimentary rocks of the district include the Madera Limestone (Pennsylvanian); 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 lathe porphyry dikes and sills. **In** addition, a small stock of augite-bearing monzonite crops out apart from other igneous rocks. 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. Atkinson thought that the igneous rocks of the range were differentiated from a single magma and intruded in a relatively short time span. As evidence, he cited some paradoxical field relationships. In dikes associated with the westernmost stock, on the west side of Old Timer Gulch in the NW1 sec. 21, T. 12 N., R. 7 E., monzonite grades marginally into monzonite porphyry and then into latite porphyry. Elsewhere, monzonite and monzonite porphyry were separated in time by a phase of intrusive rhyolite porphyry. Atkinson thought that the stock in Old Timer Gulch was the feeder for the laccoliths.

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 deposits of sphalerite and argentiferous galena in limestone. An example is the Carnahan mine.
3. Iron veins and bedded replacement deposits containing magnetite, specularite, or both. These are economically unimportant, although formerly they were worked for flux; 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. Most of the mines listed in Table 9, other than the San Pedro and Lincoln—Lucky, are of this type, but none is important.
5. Small pockets of auriferous pyrite disseminated in tactite, containing free gold in the oxidized zone. These are economically unimportant.
6. Placers derived by weathering and erosion of types 4 and 5. Before 1880 they probably yielded between $1 and $2 million in gold (and gave the district its name); since 1880 they have been relatively unimportant.

Atkinson demonstrated the existence of hypogene zoning in the lode deposits. Among the nonferrous metals, copper occurs in the contact metamorphosed limestone, not far from igneous rocks. The controlling structure is the "marble line," the highly irregular contact between limestone that has turned into garnet tactite under contact metasomatism and limestone that has undergone only thermal metamorphism (being farther away from igneous contact) and has turned into marble. Lead and zinc are found farther away from igneous rocks, replacing unmetamorphosed limestone. Of the iron minerals, Atkinson 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. San Pedro

Mine

The pyrometasomatic San Pedro deposit is by far the most important in the district. Although thermal metamorphism is widespread throughout the range, having turned shale into hornfels and limestone into marble, pyrometasomatism is more local. It has resulted in a belt of garnet tactite that runs about one and one-half miles along the western side of San Pedro Mountain from the SWIA sec. 15 (unsurveyed), T. 12 N., R. 7 E. to the NW1/4 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. The top of a monzonite porphyry laccolith is about 200 to 300 feet below the rhyolite porphyry sill, but the rocks directly above the laccolith and below the tactite show only slight thermal metamorphism and no metasomatism. The San Pedro ore body is localized by the "marble line" at the southeastern perimeter of the tactite zone. Most ore irregularly replaces a group of marbleized beds, 50 to 100 feet thick, the top of which is 5 to 50 feet, usually 20 feet, below the rhyolite sill. One stope (No. 1) is in the lower 10 feet of the rhyolite sill itself; sheets of chalcopyrite a quarter inch to one foot thick occurred in fractures parallel to the base of the sill (G. R. Griswold, personal communication).

Both Lindgren (Lindgren, Graton, and Gordon) and Atkinson believed that a conspicuous east-trending monzonite porphyry dike 1000 feet north of the San Pedro mine carried the metasomatizing and mineralizing fluids to the San Pedro mine area. The dike is probably an offshoot of the stock in Old Timer Gulch or, possibly, of the stock in Oro Quay Mountain. No metasomatism has occurred directly above the laccolith. Neither Lindgren nor Atkinson seriously considered the possibility that the rhyolite porphyry sill may have brought in the fluids. Atkinson interpreted the conditions favoring formation of the San Pedro ore body as follows: (1) arching of the Madera Limestone by the underlying laccolith, enabling ore-forming fluids to travel updip from either the Old Timer or Oro Quay stocks; the ore body lies near the crest of the arch; (2) thermal metamorphism, which has made the sedimentary rocks sufficiently strong to support open fractures through which the fluids could travel; and (3) the position of the rhyolite sill, which acted as an impermeable barrier to rising solutions.

Mineralization at the San Pedro mine took place in two stages. In the first stage, pyrite, pyrrhotite, chalcopyrite, bornite, calcite, specularite, quartz, chlorite, and scheelite were deposited in small openings in tactite, forming so-called "disseminated ore." In the second stage, quartz, pyrite, chalcopyrite, calcite, siderite, scheelite, and adularia were deposited as coarse crystals in larger openings. The full paragenesis has not yet been worked out.

The mine has miles of workings and was opened by several shafts and tunnels. The main shaft, the two-compartment Richman, is 300 feet deep; the main adit is 1600 feet long. Stopes in tactite stand well without timber. All stopes are within 200 feet of the "marble line." Except at the extreme eastern end, the mine is dry, even though oxidized ore does not go deeper than 100 feet.

The history of the San Pedro mine dates back to the middle of the nineteenth century, although Atkinson cited some circumstantial evidence that it may have been worked 100 years before that. About 1880, control was obtained by the San Pedro and Cafion del Agua Company; but mismanagement, litigation, and technical difficulties prevented successful operations. From 1889 until 1938, the Lewisohn family of New York operated the mine intermittently as the Santa Fe Gold and Copper Company. 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. Coal was obtained from the company's own mine in sec. 32, T. 13 N., R. 9 E. Some coal came from Madrid, and coke was shipped in from Colorado. Matte was hauled fifteen and one-half miles to the railhead at Cerrillos and then shipped to the El Paso smelter.

In 1938 the mine was purchased by Raskob Mining Interests, Inc. and, after an exploratory period, was worked by 70 men at the rate of 110 tons a day in 1940 and 1941. The ore was concentrated by a 150-ton flotation mill on the property, later dismantled. During World War II, the mine was mapped in detail by the U.S. Geological Survey in a search for tungsten as well as for copper. The present owners are Mrs. C. F. Williams of Santa Fe and Mrs. C. L. Bradbury of Socorro. Until recently, Tom B. Scarticcini made a small ore shipment to the

El Paso smelter every year. The mine has been repeatedly leased; the current lessee is Ira Young.

In spite of the relatively high grade of ore, the mine has rarely been profitable. Distance from the railroad and from a smelter or refinery, high operating costs, and financial problems are to blame. The mine was worked on a large scale only in times of unusually favorable copper prices. Production records since 1904 are shown in Table 9. Lindgren (Lindgren, Graton, and Gordon) estimated production from 1889 to 1892 at several million pounds of copper. A total output of 265,525 tons of ore, yielding 20,704,981 pounds of copper, 18,930 ounces of gold, and 284,452 ounces of silver, was quoted by Dale and McKinney. During 1940 and 1941, the ore averaged 3.54 per cent copper, 0.056 ounce of gold, and 0.81 ounce of silver a ton. The work of the U.S. Geological Survey and U.S. Bureau of Mines showed the tungsten content of minable ore bodies between 0.1 and 0.5 per cent $W0_3$, although locally as much as 1 to 2 per cent WO_3 is present. The higher concentrations of tungsten are not necessarily in the same places as the higher concentrations of copper.

Considerable amounts of low-grade copper ore are believed to remain in the mine, and the U.S. Geological Survey estimated low-grade tungsten reserves at more than 20,000 tons. Geologic conditions favor the discovery of additional ore bodies, although exploration and mining costs would be high. The success of the San Pedro mine will depend on high, stable prices as well as on skillful mining and milling techniques.

Carnahan (Lincoln—Lucky) Mine

The Carnahan lead-zinc mine is in the NW1/4 sec. 28, T. 12 N., R. 7 E., about half a mile southwest of the San Pedro copper mine and part of the same property. It is a limestone replacement deposit of pipelike shape, elliptical in cross section, measuring about 60 feet across in the widest places. It follows a particular bed in the Madera Limestone downdip (eastward) for about 3000 feet. Small replacement deposits are common in its vicinity and are usually just a couple of inches to a couple of feet wide, but this particular pipe formed at the intersection of a favorable bed and a steeply dipping, eastward-trending fault. The pipe is said to have widened near north-trending cross faults; in other places it pinched down to a narrow vein. The primary minerals are coarsely crystalline sphalerite and argentiferous galena, a little pyrite, chalcopyrite, and alabandite in a quartz-calcite gangue. A complex manganiferous gossan was found near the surface. Most of the oxidized ore and some of the primary ore was mined out for a length of 2300 feet in the 1880's by the Santa Fe Gold and Copper Company, which shipped ore to the Cerrillos smelter. It contained enough manganese to be excellent fluxing ore (Wells, 1918). A second period of operation was from 1919 to 1928, first by the Collier Mines Company (1919 to 1926) and then by the Carnahan Mines Company (1926 to 1928). Between 1920 and 1924, small amounts of ore were shipped directly; from 1925 to 1928, a 50-ton selective flotation mill milled 27,377 tons of ore, yielding 8552 tons of concentrate, including a high-grade lead concentrate containing a little gold and 20 ounces of silver a ton and a relatively poor zinc concentrate containing 5 per cent lead and 3 ounces of silver a ton. Altogether, the output between 1925 and 1928 was 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 *(Mineral Resources of the United States).* Coal for the power plant was obtained from the Hagan field, and concentrate was hauled to the railroad at Hagan. The main incline was extended along the ore pipe eastward for 3000 feet, where water became troublesome. A vertical 500-foot shaft was used for access. Wells reported exploratory work on a second pipe below the main pipe. Today the incline is caved at a fault 1300 feet from the portal. It is believed that the drop in metal prices discouraged a search for additional ore after 1928. In 1955, Tom B. Scarticcini shipped 50 tons of stope fill as manganese ore (Farnham).

Placers

Placers were important in the early days of the district, but have lately been relatively inactive. 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, just east of Golden. The tenor ranges from 10 cents to $1.75 a yard. Placer gold also occurs in consolidated gravels of the Santa Fe Group (the so-called "cement beds") halfway between Golden and the Uno del Gato coal fields. Up to now, the "cement beds" have defied innumerable attempts at exploitation.

In the middle of the nineteenth century, individual miners were able to make a modest living by panning or sluicing gold with primitive equipment; but all large-scale modern operations have failed. There is insufficient water for wet methods of extraction, and the ground is too wet for dry methods. In recent years most of the output has come from weekend prospectors from Albuquerque, who pan gold as a hobby.

Other Mines

Table 10 lists all mines active since 1904. It shows that none has produced more than about $30,000 worth of ore. Most of them worked narrow quartz veins, containing auriferous pyrite, calcite, and a little barite. Most of the ore was treated locally by amalgamation. A few worked small copper deposits of the San Pedro type. Sporadic shipments of iron and manganese ores have been made over the years. The Glorieta Sandstone (Permian) was prospected in the late 1950's and early 1960's southeast of Oro Quay peak for silica sand by New Mexico Quartz Manufacturing Company, Inc.

Future Exploration

Not only are there possibilities of finding extensions of known ore bodies in the New Placers district, but there are also distinct possibilities of finding entirely new ore bodies. While the more important ore bodies are confined to the western end of the San Pedro Mountains, igneous intrusions and contact metamorphism are much more widespread. The conditions that favored mineralization at the San Pedro mine may well be repeated at the eastern end of the range, where there are no fewer than four stocks. The existence of iron-bearing veins indicates that the stocks were loci of mineralization. Iron minerals are particularly significant in this connection because contact pyrometasomatism is ordinarily characterized by addition of iron, in this case converting limestone into iron-garnet tactite. Here the Madera Limestone lies beneath younger rocks but not necessarily everywhere at depths below economic mining. Also, Atkinson's work showed the existence of a stratigraphically higher limestone horizon, the San Andres Limestone (Permian). He described it as having been recrystallized to marble but did not find evidence of metasomatism in surface exposure.

In the vicinity of Lazarus Gulch, drilling done in 1965 under the supervision of Chapman, Wood, and Griswold of Albuquerque found significant showings of copper and molybdenum mineralization. According to G. R. Griswold, the showings are in a subsurface body of monzonite and its sedimentary wall rock. The sedimentary rocks were part of the Permian Abo Formation, stratigraphically higher than the ore zone at the San Pedro mine.

OLD PLACERS (ORTIZ, DOLORES) DISTRICT

The Old Placers district covers the Ortiz, or Placer, Mountains, seven miles south of Cerrillos and three miles northeast of Golden. The district 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 George W. Potter, Jr., of Kansas City, Missouri.

The geology of the Ortiz Mountains was described in detail by McRae (1958) and Peterson (1958). The mines were visited by Lindgren (Lindgren, Graton, and Gordon). In recent years, G. R. Griswold of Albuquerque, agent for the Potter interests, has been in charge of

TABLE 10. METAL PRODUCTION OF THE NEW PLACERS (SAN PEDRO, GOLDEN, TUERTO) MINING DISTRICT, SANTA FE COUNTY, NEW MEXICO, 1904 to 1959

YEAR	ORE (short tons)	GOLD (ounces) LODE	GOLD (ounces) PLACER	SILVER (ounces)	COPPER (pounds)	LEAD (pounds)	ZINC (pounds)	TOTAL VALUE ($)	OPERATING LODE MINES
1904	170	62	200	—	2,308	—	—	5,722	n.d.
1905	180	108	194	42	—	—	—	6,269	San Lazarus, McKinley
1906	128	345	326	53	—	—	—	13,916	Gold Coin, San Miguel, Old Timer
1907	21,388	810	54	17,635	1,231,260	—	—	275,759	San Pedro, Gold Coin, Gold Queen
1908	7	12	76	6	—	—	—	1,817	n.d.
1909	10	22	59	10	—	—	—	1,673	n.d.
1910	122	163	121	59	—	—	—	5,915	Gold Coin, Gold Standard, others
1911	69	47	109	717	12,150	—	—	5,139	Gold Coin, others
1912	14,583	494	54	13,138	801,893	—	—	151,706	San Pedro
1913	29,800	1,293	6	22,076	1,798,769	794	—	319,053	San Pedro, Candelaria,[a] several others
1914	23,297	434	63	4,944	285,786	—	—	51,036	San Pedro, Candelaria,[a] Morrison
1915	27,013	2,030	76	23,945	1,703,091	—	—	353,721	San Pedro, several others
1916	40,137	3,192	150	29,696	2,153,610	—	—	618,546	San Pedro, several others
1917	7,074	345	104	6,739	396,828	—	—	123,171	San Pedro, several others
1918	3,743	193	15	5,244	220,846	17,479	—	65,328	San Pedro
1919	125	57	—	642	3,414	16,623	—	3,719	Lincoln–Lucky, Copper Basin No. 1, Gold King, Las Vegas
1920	111	55	—	46	2,598	—	37,555	4,700	Lincoln–Lucky, Abeyta, Copper Basin, Gold King, Las Vegas
1921	—	—	119	5	—	—	—	2,471	—
1922	9	1	11	27	2,003	—	—	541	n.d.
1923	105	35	47	298	23,102	—	—	5,328	San Pedro, Golden Cycle, one other
1924	569	123	14	1,788	143,152	5,787	14,400	24,197	Lincoln–Lucky, San Pedro
1925	5,984	257	25	10,275	199,770	249,800	170,000	75,991	Lincoln–Lucky, San Pedro
1926	6,952	196	10	37,651	136,000	1,053,166	1,234,000	223,595	Lincoln–Lucky, San Pedro
1927	15,248	228	143	54,037	46,748	2,199,490	2,446,000	339,554	Lincoln–Lucky, San Pedro
1928	3,252	161	—	6,530	243,042	96,000	145,000	56,557	Lincoln–Lucky, San Pedro dump, San Francisco
1929	1,182	112	31	7,452	179,903	—	—	35,918	San Pedro dump, San Francisco
1930	465	75	—	870	79,100	10,283	—	12,178	San Pedro, Old Timer, Delgado
1931	—	—	107	7	—	—	—	2,209	—
1932	33	14	161	28	—	—	—	3,623	Santa Fe

1933	128	126	149	39	1,000	—	—	5,753	Santa Fe, others
1934	15	23	128	10	—	—	—	5,290	Santa Fe, Delgado, San Pedro
1935	135	59	85	168	11,000	—	—	6,072	Santa Fe, others
1936	44	15	86	49	3,130	—	—	3,847	San Pedro, Santa Fe
1937	1,202	184	57	1,781	87,000	700	—	20,381	San Pedro, Chief No. 1 & No. 2, Delgado, Old Timer
1938	1,342	255	44	2,698	88,500	—	—	22,708	San Pedro, Lincoln–Lucky, Delgado, Old Timer, Captain Davis[a]
1939	2,411	746	29	8,834	671,000	700	—	102,914	San Pedro, Old Timer, Mascot, Candelaria,[a] La Santa Fe, Live Oak[a]
1940	35,212	2,688	47	32,579	2,788,900	—	—	434,038	San Pedro, Candelaria,[a] Shamrock
1941	27,334	1,038	56	17,378	1,437,000	—	—	220,214	San Pedro, Old Timer, Candelaria[b]
1942	450	158	2	38	—	—	—	5,657	Old Timer, Candelaria[a]
1943	110	20	23	14	—	—	—	1,515	Candelaria,[a] St. Paul
1944	—	—	—	—	—	—	—	—	—
1945	—	—	8	3	—	—	—	282	—
1946	108	38	3	64	4,200	—	—	2,167	Padilla
1947	150	23	6	13	500	—	—	1,132	Padilla
1948	205	26	8	13	—	—	—	1,202	Padilla[b]
1949	50	12	3	181	16,000	—	—	3,841	San Pedro
1950	267	63	—	643	46,000	—	—	12,355	San Pedro, Oro Quay
1951	173	41	—	64	5,500	—	—	2,824	San Pedro, Oro Quay
1952[b]	12	5	—	53	4,000	—	—	1,191	San Pedro
1953	38	1	2	41	4,000	—	—	1,290	San Pedro, Parachute
1954	21	4	—	45	4,000	—	—	1,361	San Pedro
1955	139	17	—	223	17,700	—	—	7,399	San Pedro
1956	550[b]	112[c]	—	[d]	45,900	—	—	24,000[b]	San Pedro, Elena Marie
1957	135	11	—	284	19,100	—	—	6,391	San Pedro
1958	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	San Pedro
1959	242	20	—	447	32,000	1,000	—	11,155	San Pedro, one other
Totals	272,129	16,549	3,011	304,625	14,951,803	3,651,291	4,046,955	$3,694,431	

[a]Probably refers to a mine in the Old Placers district.
[b]Estimated.
[c]Includes a small amount from Cerrillos district.
[d]Included with Cerrillos district.

mineral exploration and has made a number of private reports available to Peterson and McRae. Information from several private reports was summarized by Dale and McKinney.

The geology of the Ortiz Mountains has many similarities to the geology of Los Cerrillos and the San Pedro Mountains. All are part of the same porphyry belt. 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; a swarm of laccoliths, sills, and small plugs of latite-andesite porphyry; and a hydrothermally altered body of trachyte-latite with brecciated borders, interpreted as a vent rock. Unfortunately, Peterson and McRae were unable to agree on the sequence of intrusion or on the possible relationship of intrusive rocks to the Espinaso Volcanics (Oligocene?). For example, McRae thought that the vent of trachyte-latite, which occupies both sides of Cunningham Gulch in the western part of the range, was the oldest igneous rock in the district; Peterson thought it was the youngest. This is of practical consequence because the most important lode mines in the district lie in the brecciated margins of the vent.

The district has four types of ore deposits: (1) gold in distinct quartz fissure veins and stringers in the brecciated margins of the Cunningham Gulch vent; (2) gold and scheelite disseminated in the brecciated margins of the Cunningham Gulch vent; (3) contact pyrometasomatic auriferous pyrite, chalcopyrite, and scheelite disseminated in garnet tactite at the southern tip of the Ortiz Mountains; and (4) placers.

Of the first type, the most important example is the Ortiz mine, on the north side of the Cunningham Gulch vent, about one and a quarter miles west of the Dolores Ranch. The vein is about four feet wide but pinches and swells irregularly. It strikes N. 15° E., dips 75° WNW, and can be traced for about half a mile. It is the oldest lode mine in the district, most of the mining having been done between 1832 and 1870. Since then several attempts have been made to reopen the mine, the last in 1935 and 1936. The main shaft is 250 feet deep. Water stands at about 150 feet. Ore above the 200-foot level is oxidized and free-milling; below 200 feet, pyrite and chalcopyrite appear. Production has probably been worth a couple of hundred thousand dollars. A number of mills were supplied by the mine at different periods.

The Benton and Live Oak mines are on the southeastern side of the Cunningham Gulch vent, about a half a mile east of the Ortiz mine. Both are on the same vein, a nearly vertical zone of quartz stringers that strikes N. 50° E. Lindgren (Lindgren, Graton, and Gordon) reported a trace of molybdenite from the Live Oak mine. The Benton mine was last worked from 1933 to 1936 (table 11).

Gold and scheelite are disseminated through the brecciated contact zone at the southeastern end of the Cunningham Gulch vent. At the Cunningham mine, about 1800 feet northeast of the Benton mine, the breccia zone is 600 feet wide (Jones). Dale and McKinney quoted two reserve estimates, one by D. R. Stewart, who calculated reserves at 5 million tons carrying $1.56 in gold and $3.10 in tungsten a ton (based on 85 per cent recovery and 1953 prices), and the other by G. R. Griswold, who estimated reserves at 3 million tons carrying 0.0711 ounce of gold a ton and 0.0682 per cent WO_3.

Pyrometasomatic deposits occur in a wide band of garnet tactite near the southern end of the range. The Greenhorn Limestone Member and adjacent shale beds of the Mancos Shale have been garnetized (Peterson). Low values in gold and tungsten can be obtained from pyrite and chalcopyrite, disseminated in garnet; oxidized ore is free-milling. According to Lindgren (Lindgren, Graton, and Gordon), the best values were obtained in a place where a north-trending seam of oxidized pyrite cut across the garnet bed. The Lucas (or Old Reliable or Pat Collins) mine has had some production in this area. It supplied ore to a 5-stamp mill when Lindgren visited it in 1905. The Candelaria mine, southeast of the Lucas, has a 300-foot shaft sunk between 1934 and 1939 on a north-trending vein but has shipped no ore (McRae). Other lode mines and prospects in this area are the Alpine, Buckeye No. 1 and Buckeye No. 2, Captain Davis, Gold Leaf, Gypsy Queen, Pat Collins, and Patagonia. All are in the southern part of the district and none has had significant production. Most ore samples assay between 0.01 and 0.07 per cent WO_3, but no tungsten mineral was identified by Dale and McKinney.

The most important placers are at the west side of the mountain at the mouth of Cunningham Gulch near the Dolores Ranch, which occupies the site of the abandoned village of Dolores. Lindgren (Lindgren, Graton, and Gordon) described them as follows:

> The gravels form a mesa, the upper part of the old debris fan from the gulch, and this is dotted with shafts and pits. A considerable area is occupied by the gravels and it is stated that much profitable ground remains. The depth of the angular wash increases with distance from the mountains and in some places has been found to be more than 100 feet . . . Dolores Gulch, which lies to the west of Cunningham Gulch, was less rich. Arroyo Viejo, between the two, also carried some good values in gold. . . . The fineness of the gold is said to be 918; in part it is coarse, many nuggets being reported. Placer gold is also found at the south side of the mountains, but the gravels are less rich.

TABLE 11. METAL PRODUCTION OF OLD PLACERS (ORTIZ, DOLORES) MINING DISTRICT, SANTA FE COUNTY, NEW MEXICO, 1907 to 1940

YEAR	LODE ORE (short tons)	GOLD (ounces)		SILVER (ounces)		COPPER (pounds)	LEAD (pounds)	VALUE (dollars)	OPERATING LODE MINES
		LODE	PLACER	LODE	PLACER				
1907	—	—	5	—	a	—	—	111	—
1908	—	—	11	—	a	—	—	217	—
1909	—	—	29	—	a	—	—	602	—
1910	—	—	85	—	a	—	—	1,757	—
1911	—	—	5	—	a	—	—	101	—
1912	—	—	9	—	a	—	—	195	—
1932	—	—	13	—	—	—	—	270	—
1933	40	28	31	7	3	—	—	1,232	Benton
1934	68	32	51	89	—	700	5000	3,208	Benton, one other
1935	9	32	25	14	—	—	100	2,011	Granito
1936	110	82	—	13	—	370	—	2,921	Ortiz, Benton
1937	—	—	6	—	—	—	—	224	—
1938	32	17	5	20	—	300	—	805	Chord
1939	19	9	736	13	34	200	—	26,128	n.d.
1940	13	28	363	1	17	—	—	13,359	n.d.
Totals	291	228	1374	157	54	1570	5100	$53,141	

[a]Included with Cerrillos district.

NOTE: This table is probably incomplete because a little production from the Old Placers is included with the Cerrillos and New Placers districts.

The placers are said to have yielded gold worth nearly $2 million during the nineteenth century. The peak years were between 1832 and 1835, when the annual output was between $30,000 and $80,000. Modern attempts at exploitation have been frustrated by the same difficulties as at the New Placers. The last attempt to work the gravels was in 1939 and 1940 by the Universal Placer Mining Corporation. This operation accounted for most of the production of the district in this century, but it was not a financial success.

SANTA FE DISTRICT (ADJOINING WILLOW CREEK DISTRICT)

The Santa Fe district covers a large area of Precambrian granite, schist, and diabase in the southern end of the Sangre de Cristo Mountains, east of Santa Fe. It merges southward into the Glorieta district, northward into the Nambe district, and eastward into the Willow Creek (Cooper, Pecos) district. The district has showings of placer gold and base-metal sulfides but has never produced ore commercially. Its proximity to the Willow Creek district in San Miguel County has stimulated intensive prospecting. The Pecos mine at Tererro, San Miguel County, only a few miles east of the Santa Fe county line, produced zinc, lead, copper, gold, and silver worth $7 million at Depression prices between 1927 and 1939. It was described by Krieger (1932).

Anderson described the Santa Fe district as follows:

> A small amount of placer gold is reported along the upper reaches of the Santa Fe River and its tributaries, but no production has been reported. In the Mikado subdistrict, on the south side of the Santa Fe River, gold-silver and copper mineralization occurs in fissures in aplitic gneiss and in schists. Galena and sphalerite are present locally. Small deposits of copper, carrying some gold, occur on Penacho Peak.
>
> In the area on the east side of the range, around the head of Dalton, Macho, and Indian Creeks, strong mineralization occurs in the shear zones in the diabase and along the diabase granite contacts. No ore bodies of importance have been developed, but much interest has been shown in the district because of its geologic similarity to the Pecos mines area, a few miles away. A few small pegmatite dikes in the Dalton Creek area contain columbite and monazite in small amounts.

In 1956 and 1957, the Kingdom—Moya No. 1 mine, listed by the *Minerals Yearbooks* as being in the Santa Fe County part of the Pecos (Cooper) district, shipped 193 tons of ore containing 96 ounces of silver and 11,400 pounds of copper, valued at $4573. This is the only record of production in recent decades.

SANTA FE MANGANESE DISTRICT

The Santa Fe manganese district, first described by Wells, is three miles northeast of Santa Fe in the SW corner sec. 9, 17 N., R. 10 E.

(Kottlowski *in* Spiegel and Baldwin, 1963, p. 80). Pyrolusite and psilomelane partly replace Pennsylvanian shale along bedding planes as well as fragments of limestone in fault breccia; the ore occurred in nodules and small irregular pockets. The district was worked on a very small scale during World War I and has been unproductive since then despite sporadic prospecting. 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. Manganese mining ceased entirely with the termination of the U.S. Government Carlot-Load Purchasing Program in August 1959. Recent shipments are listed in Table 12.

TABLE 12. MANGANESE PRODUCTION OF SANDOVAL AND SANTA FE COUNTIES, FISCAL YEARS 1954 to 1959

YEAR	SHIPMENT (short tons)	VALUE (dollars)	NAME OF MINE	COUNTY
1954	n.d.	n.d.	Lander	Sandoval
1955	40	2893	Lander	Sandoval
1956	62	6528	Lander	Sandoval
1956	22	3104	n.d.	Santa Fe
1957	348	7273	Jicarilla, Lander	Sandoval
1958	n.d.	n.d.	Jicarilla No. 1, Lander	Sandoval
1959	n.d.	n.d.	Lander	Sandoval
1959	n.d.	n.d.	San Pedro, McDuff Lease	Santa Fe

n.d., no data.

SOURCE: State Inspector of Mines, *Annual Reports*.

SOUTH MOUNTAIN AREA *(by Tommy B. Thompson)*

South Mountain, directly south of the New Placers district, is formed by an asymmetrical, doubly convex, monzonite laccolith that intrudes a syncline formed by the Permian Abo and Yeso Formations and, in places, the Glorieta Sandstone. The area has showings of mineralization but no recorded production.

In several places, small contact-metasomatic magnetite deposits replace Glorieta Sandstone. One of these, the Fuzzy Jim claim, is in the SEIASWIA sec. 34, T. 12 N., R. 7 E. Mineralization occurs in a lens about 300 feet long and up to 10 feet wide. Granular magnetite is associated with abundant asbestiform or leathery tremolite that formed prior to the magnetite. There were two periods of development but no record of production.

South Mountain contains many small, supergene iron deposits. The largest is in the NEN sec. 2, T. 11 N., R. 7 E. Goethite, hematite, and limonite replace shale and siltstone of the Yeso Formation, directly beneath the Glorieta Sandstone. The deposit probably was formed by ground water seeping downdip and leaching small contact-metasomatic iron deposits. The supergene iron ore was deposited at the discharge area. The ore is up to 2.5 feet thick and covers about 8 acres. Five prospect pits and a loading stand show that there probably was some production, but no records are available.

Two fissure veins occur in the south-central part of sec. 28, T. 12 N., R. 7 E. One is about three quarters of a mile south of State Highway 344. Primary magnetite and specularite replace a rhyolite sill and underlying Madera Limestone along an east-trending fault. Much of the magnetite and specularite has oxidized to goethite, limonite, and hematite. Pockets of ore are exposed in a 20-foot shaft. The other vein is approximately three eighths of a mile south of State Highway 344. It is controlled by a southeast-trending fault. Small pockets of galena and sphalerite replace Madera Limestone faulted against a rhyolite sill. Lesser minerals include chalcopyrite, pyrite, covellite, and angle-site; the gangue is quartz and calcite. Mineralization is exposed in two shafts and one ad it.

Small reserves and discontinuity of mineralization indicate that production from the ore deposits of the South Mountain area is unlikely.

Industrial Nonmetals

Industrial nonmetals are discussed by commodities, not by counties, since the deposits commonly cross county lines. The standard reference on the subject, Talmage and Wootton (1937), is now out of date but still useful. Since World War II, the outstanding developments in the mineral industries of Bernalillo, Sandoval, and Santa Fe counties have been in the field of industrial nonmetals. Most of them are bulk commodities of low unit value produced in large volume.

ALUM

Talmage and Wootton reported alum in sandstone in the northeastern part of Sandoval County but gave no details.

BARITE

Barite deposits are discussed under *Bernalillo County, Tijeras Canyon district,* and *Sandoval County, Placitas district.* The deposits are small.

CEMENT

The Ideal Cement Company plant at Tijeras, eight miles east of Albuquerque, is the largest single operation in the mineral industries of the three-county area. It is the only cement plant in New Mexico (1966). Limestone and shale of the Madera Formation (Pennsylvanian) are quarried on a large scale next to the plant. The plant annually consumes about half a million tons of limestone and dolomite and smaller amounts of shale and gypsum. Natural gas, brought in from Albuquerque by the Southern Union Gas Company, is used as fuel. The plant cost $19 million and has a capacity of 2,500,000 barrels a year. The cement mill began operations on May 6, 1959, and completed a major expansion program in December 1960. It has two kilns, two raw mills, and two finish mills. It employs 99 men, including 10 in the quarry. The product is a complete line of Portland and masonry cements, sold in New Mexico and southern Colorado. At times, shipments are made to Arizona, Oklahoma, Texas, and Utah. The annual output is worth between $5 and $10 million.

The Pennsylvanian rocks that supply the bulk of the raw materials for cement cover a wide area (pl. 2); much of their outcrop is at high elevations. No place in the three-country area can match Tijeras Canyon as the site for a cement plant with respect to the availability of labor, transportation, fuel, and markets.

COMMON CLAY

Kinney Brick Company of Albuquerque is at present the only large producer and consumer of common clay in the area. The company's plant on South Second Street, three miles south of the city limits, has a capacity of one million bricks a month. A pit in the Manzano Mountains, just west of State Highway 10, about eight miles south of Tijeras, supplies the plant with 90 to 95 per cent of its raw material, Pennsylvanian fresh-water shale from beds transitional between the Abo Formation and the Magdalena Group (Pennsylvanian). The rest is Mancos Shale (Cretaceous) from a small pit just west of Cerrillos, on the north side of the Atchison, Topeka, and Santa Fe Railway 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 proved a superior material. The company employs 37 men. Its plant has five skoves with a capacity of 450,000 bricks each, which take one month for a complete run. In addition, there is an envelope kiln with a capacity of 20,000 bricks, which takes about ten days for one run. Natural gas is used for fuel. The plant turns out a complete line of brick and tile. In recent years, it has run at 60 to 95 per cent of capacity. The average consumption is 4000 tons of clay a month. The main clay pit is operated for about one month of the year by a contractor. The deposit has 2 to 8 feet of overburden that is stripped off by bulldozer. Brick and tiles 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 (Kottlowski *in* Spiegel and Baldwin, p. 82). The raw material was shale of the Magdalena Group (Pennsylvanian) obtained from several pits north and east of Santa Fe. In fiscal year 1934-1935, 225,000 pieces of tile and 900,000 bricks were made. A small brick plant was formerly located near Tongue, north of Hagan, Sandoval County. It used Mancos Shale (Cretaceous).

FLUORSPAR

Fluorspar deposits are discussed under *Bernalillo County, Tijeras Canyon district,* and *Sandoval County, Placitas district.* The deposits were described in detail by Rothrock, Johnson, and Hahn.

GEM STONES

Turquoise is the outstanding gem stone produced in the area. It has probably been mined since at least the eighth century A.D. (Northrop, 1959) in two localities in the Cerrillos mining district, Santa Fe County: Mount Chalchihuitl, near the center of sec. 5, T. 14 N., R. 8 E., and Turquoise Hill, near the center of sec. 31, T. 15 N., R. 8 E. In modern times, the most important operation was by the American Turquoise Company, which worked the Turquoise Hill deposits from 1890 to about 1904. Estimates of production vary greatly. A conservative figure of $2 million is usually quoted, but some estimates are as high as $9 million. The value of the material as mined is, of course, far below the retail price, which may partly account for the different estimates. George F. Kunz, the famous gemologist, described the turquoise in 1893 as sky blue, resistant to fading, and equal or superior to Persian material. In view of the new operations by the American Turquoise Company, he wrote that "it is now possible, for the first time in the past half-century, to match a perfect turquoise necklace." Stones up to 60 carats were found, which sold for as much as $4000.

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. Recently, Gustafson found good field evidence for supergene origin.

Mining has been by surface and underground workings. In recent years the production has been negligible.

Few gem stones other than turquoise have been found. Precious opal has been reported from the Cochiti mining district (Wynkoop). Petrified wood is abundant in the Galisteo Formation on Sweet's Ranch, three miles east of Cerrillos.

GRAPHITE

Herrick (1900) and Ellis (1922) mentioned a band of impure amorphous graphite 1 to 3 feet thick in the eastern part of Tijeras Canyon, near Whitcomb's Spring, Bernalillo County. Early reports of graphite in Santa Fe County probably refer to the anthracite at Cerrillos.

GRAVEL AND SAND

Gravel and sand have been most important products in recent years, especially in Bernalillo County (table 1). In 1965, fourteen sand and gravel companies were active in the Albuquerque area, employing about 138 men. The largest operations are by the Springer Transfer Company and the Albuquerque Gravel Company. The largest sand and gravel producer in the three-county area outside greater Albuquerque is the Kauffman Trucking Company at Santa Fe. In 1965, there were seven gravel and sand operations, employing 46 men, in Sandoval County and five operations, employing 29 men, in Santa Fe County. Much sand and gravel is produced by government contractors.

All the sand and gravel in Bernalillo County comes from Quaternary terrace deposits of the Rio Grande, especially the lowest and youngest terrace deposit above the present flood plain. Most pits are on the east side of the Rio Grande between Tijeras Canyon and Bernalillo, where this terrace material is well-sorted and well-rounded stream gravels. Older gravels from alluvial fans are unsuited for most commercial uses. Plate 2 shows that terrace gravels are scarce north of Bernalillo, although small deposits have been used locally in construction work. Large reserves of sand and gravel remain in the ground, but the growth of the Albuquerque urban area has restricted the amount of open land available for pit development.

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 sizable gypsum products industry. Production rose from 5000 tons in 1960 to 105,000 tons valued at $386,000 in 1961, 151,000 tons valued at $564,000 in 1962, and 179,000 tons valued at $656,000 in 1963 *(Minerals Yearbooks).* The figures in Table 1 tell only a fraction of the story because they list only the value of raw gypsum, not of the manufactured product. Three quarries and two manufacturing plants are now active.

The gypsum resources of New Mexico were recently described by Weber and Kottlowski (1959). Virtually all the gypsum in Bernalillo, Sandoval, and Santa Fe counties occurs in the Todilto Formation (Jurassic). The base of the Todilto Formation consists of thinly laminated limestone, 2 to 10 feet thick, overlain by 50 to 100 feet of nearly pure gypsum alternating with thin laminae of calcareous shale. Anderson and Kirkland (1960) interpreted the Todilto Formation as a saline lake deposit and the laminae as annual layers that reflect seasonal changes in conditions of depositions. The gypsum was formed near and at the surface by hydration of anhydrite; in the subsurface, only anhydrite is encountered. The gypsum is of good quality, usually 95 to 99 per cent pure, but a little anhydrite may remain near the base of the deposit. Its outcrops are shown on Plate 2.

In June 1960, the Kaiser Gypsum Company began production at its quarry and plant at Rosario, Santa Fe County. Here the main line of the Atchison, Topeka, and Santa Fe Railway crosses the outcrop of the Todilto gypsum on the western side of the Galisteo monocline, five miles northwest of Cerrillos. At present, the plant turns out plaster board, a fireproof, 5/8-inch board made of plaster and fiberglass and sold under the trade name *Null-a-fire,* as well as plain and impregnated gypsum sheathing and gypsum lath. Raw gypsum is treated in three Raymond imp mills, using natural gas as fuel. The company plans to install additional equipment to bring its capacity to the equivalent of 120 million square feet of 1/2-inch plaster board a year, and to produce plaster and stucco in addition. When operating at full capacity, the plant will require a little more than 100,000 tons of gypsum annually. The company currently has 71 employees at the plant site, including one man 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.

The American Gypsum Company now quarries gypsum from the deposit at White Mesa, south of San Ysidro, Sandoval County, and trucks it to its plant near the Santa Fe railroad north of Albuquerque. The plant began production on November 2, 1960, and operates four 24-hour days a week. In 1963, capacity of the plant was expanded from 100 to 150 million square feet of gypsum plaster board a year. The company employs 85 to 90 men (other than sales staff), including four men at the open-pit quarry. The average purity of the raw gypsum is 98.1 per cent; the purest material comes from a depth between 17 and 40 feet in the quarry. The largest markets for the company's products are in Phoenix and Los Angeles, but shipments are also made to Denver, Oklahoma City, El Paso, Lubbock, and Amarillo.

A small quarry formerly supplied gypsum to the Ideal Cement Company plant for use as a retarder. This quarry is five miles north 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 was operated by the Duke City Gravel Products Company. Between 1959 and 1962, it quarried 29,329 tons of gypsum, valued at $50,895 (State Inspector of Mines), but it is now inactive. The Todilto gypsum is discontinuous in the Tijeras Basin, probably because of faulting. The Duke City Gravel Products Company started a new gypsum pit, the San Felipe pit, in Tongue Arroyo, Sandoval County, in 1963.

The reserves of gypsum in the three-county area are virtually inexhaustible. Weber and Kottlowski estimated that the 1180-acre site owned by the American Gypsum Company on White Mesa alone contains 98 million tons under a five- to eight-foot overburden of unusable gypsite and that an additional 123 million tons are present under a thin overburden of Morrison sandstone. The Kaiser quarry has reserves sufficient for at least 50 years, and large additional reserves could be developed within a few miles. In the prevailing semiarid climate, gypsum is resistant to weathering and erosion. It crops out in steep cliffs and broad benches, amenable to cheap stripping by bulldozer.

Although large-scale commercial exploitation of gypsum began only in 1959, the industry is not really new to the area. In the 1882 edition of *Mineral Resources of the United States,* we read (p. 529):

> In the Sandia Mountains, at the towns of Tejon and Una de Gato, quite a business is carried on by the native Mexicans, who make plaster and sell it at Santa Fe and along the upper Rio Grande at $1 a bushel.

MARBLE

Ultra Marbles, Inc., of Albuquerque is exploiting a deposit of banded travertine on the Laguna Indian Reservation in Valencia County. Similar deposits, formed by Pleistocene to Recent 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. Travertine is considered marble by the building trade, and slabs can be polished into attractive facings.

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

Granite pegmatites and micaceous Precambrian metamorphic rocks of the Nambe district, in the Sangre de Cristo Mountains north of Santa Fe, have been prospected for mica for many years, but production has been small. Sheets of muscovite mica have been used as window glass by Pueblo Indians for centuries, and attempts at commercial mining go back to at least 1887 *(Mineral Resources of the United States).* However, most mica produced in New Mexico has come from farther north, in Rio Arriba and Taos counties.

With few exceptions, the pegmatites of the Nambe district are small and show little evidence of zoning. Concentrations of scrap mica, usually only a few inches wide, occur around the contacts of pegmatites and mica schist and in small irregular albite-quartz-muscovite replacement veins that cut across the earlier microcline-quartz phase of the pegmatites. The concentrations of mica are generally small and irregular, the mica content rarely exceeding 20 per cent. Books of sheet mica are present here and there but only in small amounts. Microcline and quartz are intimately associated in graphic intergrowths, so that the recovery of commercial feldspar would require froth flotation. Production of mica in recent years has been confined to scrap mica and sericite.

According to the *Annual Reports* of the State Mine Inspector, Santa Fe County has produced scrap mica worth $550 in fiscal 1956, 850 tons valued at $29,750 in 1961, 2933 tons valued at $117,706 in 1962, none in 1963, 5 tons valued at $250 in 1964, and none in 1965. Most of the production is credited to the B.A.T. mine of the Clute Corporation. In recent years most of the scrap mica produced in Rio Arriba, Santa Fe, and Taos counties has been purchased and processed by the Mineral Industrial Commodities of America, Inc. (M.I.C.A.), of Pojoaque, Santa Fe County. The ground scrap mica is used in paints and building materials *(Minerals Yearbook,* 1964).

MONTMORILLONITE CLAY (BENTONITE)

Montmorillonite clay (including bentonite) has never been produced in the three-county area, but at least two occurrences have been reported. One deposit lies just south of Santa Ana Pueblo, west and south of State Highway 44, in secs. 30 and 31, T. 15 N., R. 3 E., Sandoval County. The deposit was explored by the New Mexico Quartz Manufacturing Company, Inc. Talmage and Wootton 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.

OCHER

Ocher, a mineral paint consisting of iron oxides and hydroxides, has been used by Indians since prehistoric days, but there has been no recent production. The ore of the Kennedy iron mine, Glorieta district, and in nearby claims could be utilized as mineral brown (Talmage and Wootton). Jones mentioned a bed of red and yellow ocher several feet thick near Coyote Springs, Tijeras Canyon mining district, Bernalillo County. Kelley thought it was probably a local spring deposit.

PERLITE

Perlite, a water-rich siliceous volcanic glass that can be expanded to form artificial pumice for use in lightweight aggregates and for other purposes, is abundant in the Pleistocene volcanic rocks of the Jemez Mountains. Small shipments have been made from the area of Peralta Canyon, on the east side of the Jemez Mountains, in Sandoval County. The deposits there were described by Mills (1952). They have not been exploited in recent years.

PUMICE AND SCORIA

Pumice and scoria are both used in lightweight aggregates, especially in the manufacture of building blocks. The manufacture of pumice and scoria blocks has become a major industry in Bernalillo, Sandoval, and Santa Fe counties in the past fifteen years (table 2). The largest producer is the Big Chief pumice mine near Jemez Springs, Sandoval County. The *Annual Report* of the State Inspector of Mines for 1963 lists four producing companies, one each in Bernalillo and Sandoval counties, and two in Santa Fe County, which produced 84,635 cubic yards of raw pumice and 30,143 cubic yards of scoria. They employed eight men, not counting those engaged in manufacturing blocks.

Scoria is obtained from a swarm of small Quaternary basalt volcanoes on the western side of the Rio Grande (pl. 2). 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 middle Pleistocene Bandelier Rhyolite Tuff in the Jemez Mountains. Much of the Bandelier Rhyolite Tuff is a cliff-forming welded rhyolite tuff, unsuitable for use as aggregate, but the welded tuffs interlayer with unconsolidated slope-forming pumiceous lapilli tuff. Many active and abandoned pumice quarries lie on the edge of the outcrop area of the Bandelier Tuff (pl. 2).

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

SAND AND SANDSTONE

Ordinary sand for aggregate, paving, plaster, and similar purposes is produced by gravel pits, along with gravel. A few deposits have special uses. Wind-blown dune sand occurs along the Jemez River near Santa Ana Pueblo in secs. 21 and 22, T. 14 N., R. 3 E., Sandoval County. It is sold to the Marvel Roofing Company in Albuquerque for use as roofing sand.

In the late 1950's, the New Mexico Quartz Manufacturing Company of Albuquerque explored the outcrop of the Glorieta Sandstone (Permian) in secs. 23 and 26, T. 12 W., R. 7 E. in the eastern end of the San Pedro Mountains, Santa Fe County, as a possible source of glass sand. The Glorieta Sandstone here is a nearly pure quartz sand, poorly aggregated. Elsewhere it has a calcareous or ferruginous cement.

SELENIUM

Selenium is said to be associated with uranium in sandstones of the Mesaverde Group (Cretaceous) and Galisteo Formation (Tertiary) in the Hagan Basin, Sandoval County.

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 talus blocks of Precambrian quartzite, obtained from the Great Combination gold mining claim in the NE1/4 sec. 12, T. 9 N., R. 41$_2$ E., Tijeras Canyon district, have become popular in Albuquerque.

Crushed stone of many types, especially basalt, has been used for construction work. An attempt has been made to develop a large vein of white bull quartz on Sandia Pueblo land, in the Sandia Mountains near Juan Tabo Canyon, for use as roofing granules. In recent years, the pit has been inactive. 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 have been described by Mansfield (1921), Talmage and Wootton, and Northrop (1959). They were discovered by the Spaniards in the sixteenth century and worked on a small scale into the twentieth century. The larger locality, called Jemez Sulphur Springs, covers about ten acres, eleven miles north-northwest of Jemez Springs. About 1902, M. S. Otero produced about 100 tons of sulfur here, operating a 5-ton plant. The second locality covers about one acre between Soda Dam and Battleship Rock, four and one-half miles north-northeast of Jemez Springs. It contains 15 to 39 per cent free sulfur and 6 to 8 per cent sulfur combined as sulfate. In 1933, the New Mexico Acid Company built a 150-ton plant at this deposit, designed to use carbon disulfide as a recovery agent. A year later, two retorts were added. The plant was never operated successfully.

The solfatara, hot springs, and fumarole activity of the Jemez Mountains probably represent the dying embers of activity of the great Valles volcano, active here in Pleistocene time. Though of geologic interest, the sulfur deposits are unlikely to be competitive with sulfur from the Gulf Coast.

Coal

Bernalillo, Sandoval, and Santa Fe counties contain measured, indicated, and inferred reserves of coal amounting to more than 5 billion tons (table 13), or 8.6 per cent of the estimated reserves of New Mexico (Read et al., 1950). Most of the reserves are in relatively remote parts of Sandoval County, but the bulk of production has come from the Cerrillos district, Santa Fe County, where anthracite and bituminous coking coal occur near the main line of the Atchison, Topeka and Santa Fe Railway. Total past production in the three counties has been more than 7 million 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 known 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 varies from a feather edge to more than 5 feet. Commercial beds are 3 or more feet thick, although thinner beds have been worked from time to time for local markets. Cretaceous coal beds are notoriously lenticular. They pinch out laterally because of nondeposition, erosion beneath minor unconformities, or facies changes. For example, the Cook and White coal bed in the Cerrillos district, one of the most important commercial coal beds in the three counties, disappears north of Madrid because of a facies change from coal to carbonaceous shale (Turnbull et al., 1951).

Coal mining began in the Cerrillos region about 1835 (Lee, 1913), but only about 10,000 tons were 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 Depression in 1929, when the annual output was about 250,000 tons, valued at $1 million. Coal was by far the most important product of mining in the three counties during this period. The decline that began in 1929 became precipitous after World War II and finally led

TABLE 13. TOTAL ORIGINAL COAL RESERVES OF BERNALILLO, SANDOVAL, AND SANTA FE COUNTIES, NEW MEXICO

		Reserves in Millions of Short Tons					
County and Field	Geologic Formation	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	2399.1	3335.2	Subbituminous
San Juan River	Fruitland	0.2	0.5	—	1609.6	1610.3	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	4008.7	5018.6	

This table includes all anthracite and bituminous coal beds more than 14 inches thick, less than 3000 feet deep, and all subbituminous coal beds more than 30 inches thick, less than 3000 feet deep.

Source: Read et al. (1950).

to the virtual extinction of the industry by 1960 (table 1). Although coal from the Cerrillos field was formerly shipped far afield, other fields supplied only local markets and were worked on a much smaller scale.

The *Annual Report* of the State Inspector of Mines for 1965 lists only one small coal mine as active in the entire three-county area, the Padilla No. 2 mine near La Ventana, Sandoval County. In 1963, it employed six men who produced 1903 tons of coal valued at $11,768.

BERNALILLO COUNTY

Bernalillo County has two coal fields, neither of which has had important production in the past. The small Tijeras field is about ten miles east of Albuquerque, just north of U.S. Highway 66. The coal beds of the Mesaverde Group are preserved over an area of two and one-half 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) described the Holmes mine in the SE1/4 /SE1A sec. 1, T. 10 N., R. 5 E., which worked a bed 12 to 30 inches thick, and the Tocco mine in the center of *sec.* 31, T. 11 W., R. 6 E., which mined a bed 18 inches thick. A 30-inch bed was said to be present in the Tocco mine 25 feet below the 18-inch bed. Not only are the beds thin, but they are also badly fractured.

Subbituminous coal occurs in the Rio Puerco Valley of western Bernalillo County. Small coal mines and prospects were formerly worked on the Cañoncito Navajo Indian Reservation but have never had much commercial importance. This field is a southeasterly extension of the large San Juan Basin field on the east side of the Rio Puerco fault zone and runs northward into Sandoval County.

SANDOVAL COUNTY

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

The San Juan Basin field, which includes parts of Bernalillo, Sandoval, Rio Arriba, San Juan, McKinley, and Valencia counties, contains 89 per cent 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 in two stratigraphic levels, the Cleary Coal Member of the Menefee Formation of the Mesaverde Group (Beaumont, Dane, and Sears) and the Fruitland Formation. The geology has been described in detail by

Dane (1937). The field is far from rail transportation and has never been exploited on a large scale. One small mine, the Padilla No. 2, is now active north of La Ventana. It works a 108-inch coal seam in the Cleary Member. 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 thirty square miles (Read et al.; 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, is a constant 48 to 52 inches thick, is folded but not faulted, has a strong sandstone roof and floor, and dips from 15° N to 15° E. Campbell (1907) traced the coal northward into the SE1/4 NW1/4 sec. 32, T. 14 N., R. 6 E. In discontinuous outcrop and prospect pits, the thickness of the most prominent bed, probably equivalent to the Hopewell bed at the Hagan mine, ranges from 3 to 4 feet.

The Una del Gato field lies farther from the railroad than the Cerrillos field and has not been worked on so large a scale. Mining conditions are not everywhere so favorable as at the Hagan mine; locally, the coal is faulted or contains shaly partings.

A coal bed north of Placitas has a number of prospect pits on it but has never produced coal commercially. The bed is nearly vertical and has a roof of weak carbonaceous shale.

SANTA FE COUNTY

Santa Fe County has only one coal field, the Cerrillos, about twenty-five miles southeast of Santa Fe. The main line of the Atchison, Topeka, and Santa Fe Railway, which here follows Galisteo Creek, skirts the northern edge of the field. Cerrillos is now the nearest shipping point, although there formerly was a spur to the mines at Madrid. The Cerrillos coal field has produced approximately 7 million tons, far more than any other field in Bernalillo, Sandoval, and Santa Fe counties.

The Cerrillos coal field has synclinal structure and is bordered on the northwestern and southwestern edges by the igneous rocks of Los Cerrillos and the Ortiz Mountains. Almost all production has come from the western edge of the syncline, where the beds dip 7° to 15° E. The exact extent of the field has been estimated at between thirty (Lee, 1913) and eighty square miles (Read et al.). The variations in these estimates have arisen because of poor exposure, facies changes, igneous intrusions, and cover by younger rocks. It is known, for example, that on the northern and northeastern sides of the syncline, all or part of the Mesaverde Group was removed by erosion prior to deposition of the early Tertiary Galisteo Formation (Lee, 1913; Stearns), 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 east of the outcrop at Madrid. Read et al. 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 mined between 1892 and 1897 in an area about two miles west of Cerrillos and two miles southwest of Waldo. Up to 15,000 tons of bituminous coking coal were produced from a bed 3 feet thick. Turnbull et al. described it as high-volatile, bright-banded, bituminous coal, producing coke not quite so good as that 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, where a thick monzonite sill intervenes between its possible extension and the higher Cook and White bed.

The Cook and White bed and its northward continuation, the Waldo bed, have yielded large quantities of bituminous coal in the Madrid area. The bed is 3 to 41/2 feet thick but locally has shaly partings. Turnbull et al. classified it as high-volatile, bright-banded, bituminous coal, producing coke definitely stronger than that from the Sunnyside bed in Utah. Mine workings and a drill hole have shown that the coal changes laterally into carbonaceous shale one and one-half to two miles north of Madrid. At its northernmost surface exposure, one 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 limits of the Cook and White bed have not been determined, but the bed seems to be disturbed by faulting one and one-half miles south of Madrid, on the edge of the Ortiz intrusive center. It has been mined downdip for distances up to one mile, but its eastward extent is not known. The Jones and the Cook and 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 mile northeast of Madrid. Farther south, it changes into anthracite and thins from about 51/2 feet to about 3 feet. The change from bituminous coal to anthracite via semianthracite takes place within a few hundre 1 feet opposite the town of Madrid, within the No. 1 Anthr icite mine. The rank of coal probably depends on the interval 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 Anthracite No. 4 mine, a quarter mile south of Madrid, only a few feet of shale separate the sill from the coal.

The White Ash bed can be traced from a locality about three quarters of a mile north of Madrid into a faulted area three quarters of a mile south of Madrid. Its ultimate southward extent is unknown. A drill hole east of Madrid, 6800 feet east of the outcrop of the White Ash bed, encountered a 4-foot bed of anthracite 690 feet below the surface. The unconformable contact with the Galisteo Formation seemed to be only 51 feet above the anthracite bed, and the lower contact of a 497-foot sill was 89 feet above the anthracite bed (E. C. Beaumont, personal communication).

Several other coal beds are known in the Madrid area. The Peacock noncoking bituminous coal bed is 22 feet below the White Ash bed but is thinner, higher in ash and volatile matter, and badly crushed. The following account of the Ortiz Arroyo "B" anthracite bed was written by Edward C. Beaumont, consultant geologist of Albuquerque:

> The "B" anthracite bed was first prospected in the Ortiz Arroyo area, about 1/2 mile east of Madrid. Positioned above the thick sill that overlies the White Ash bed, this bed is also known as the "upper anthracite" or the "Ortiz Arroyo" bed. Although records are missing, it would appear that the first anthracite mined in the district came from the early Government mine which exploited this bed in the Ortiz Arroyo area. About 1900 the "B" bed was opened in the "B" mine close to the site of the abandoned Government mine. While the quality of the coal was good and the thickness sufficient (up to 50 inches), the operation proved disappointing when it was found that the coal was destroyed by igneous intrusion only a short distance from the outcrop. Only about 24,000 tons of coal were removed before this operation was abandoned in about 1904 (Johnson, 1904; Lee, 1913).
>
> In the late 1920's prospecting in the area south of the "B" mine disclosed the presence of anthracite which led to the opening of the Nos. 32 and 33 anthracite mines. This area was operated quite effectively for about 10 years. The anthracite taken from these mines was somewhat cleaner than the White Ash anthracite, and the thickness of the bed ranged from about 3 to 4 feet. The bed exploited at this locality is presumed to be correlative with the "B" bed of the Ortiz Arroyo area. The amount of coal taken from these mines is not known, but it can be roughly calculated from the area known to have been mined that the total probably did not exceed 300,000 tons.

Outside the Madrid and Waldo areas, the Cerrillos field has produced coal in only one spot, 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. It 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 directly and unconformably overlain by the Galisteo Formation.

Elsewhere in the Cerrillos field, there are isolated exposures of coal measures in the Ortiz Mountains and between Galisteo and Cerrillos, but little is known about them.

Outside the Cerrillos field, Santa Fe County has only thin and impure Pennsylvanian coals at the southern end of the Sangre de Cristo Mountains (Kottlowski *in* Spiegel and Baldwin, p. 83).

References

Anderson, E. C. (1957) *The metal resources of New Mexico and their economic features through 1954, N.* Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 39, 183 p., 5 pls., 3 figs.

Anderson, R. Y., and Kirkland, D. W. (1960) *Origin, varves, and cycles of Jurassic Todilto Formation, New Mexico,* Am. Assoc. Petrol. Geol. Bull., v. 44, p. 37-52.

Atkinson, W. W., Jr., (1962) *Geology of the San Pedro Mountains, Santa Fe County, New Mexico, N.* Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 77, 50 p., 10 pls., 2 figs.

Bachman, G. 0., Vine, J. D., Read, C. B., and Moore, G. W. (1959) *Uranium-bearing coal and carbonaceous shale in the La Ventana Mesa area, Sandoval County, New Mexico,* U.S. Geol. Surv., Bull. 1055J, p. 295-307.

Barbour, P. E. (1908) *The Cochiti mining district, New Mexico,* Eng. Min. Jour., v. 86, p. 175-177.

Beaumont, E. C., Dane, C. H., and Sears, J. D. (1956) *Revised nomenclature of Mesaverde Group, San Juan Basin, New Mexico, Am.* Assoc. Petrol. Geol. Bull., v. 40, p. 2149-4162.

Brown, B. *N.* (1962) *Geology of the Sedillo—Cedro Canyon area, Bernalillo County, New Mexico,* unpub. master's thesis, Univ. *N.* Mex., 64 p.

Bundy, W. M. (1958) *Wall-rock alteration in the Cochiti mining district, New Mexico, N.* Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 59, 71 p., 2 pls., 34 figs.

Campbell, M. R. (1907) *Una del Gato coal field, Sandoval County, New Mexico,* U.S. Geol. Surv., Bull 316-F, p. 427-430.

Cannon, H. L., and Sterrett, W. H. (1956) *Botanical prospecting for uranium on La Ventana Mesa, Sandoval County, New Mexico,* U.S. Geol. Surv., Bull. 1009-M, p. 391-407.

Dale, V. B., and McKinney, W. A. (1959) *Tungsten deposits of New Mexico,* U.S. Bur. Mines, Rpt. Inv. 5517, 72 p.

Dane, C. H. (1937) *Geology and fuel resources of the southern part of the San Juan basin; pt. 3, the La Ventana—Chacra Mesa coal field,* U.S. Geol. Surv., Bull. 860-C, p. 81-161.

Disbrow, A. E., and Stoll, W. C. (1957) *Geology of the Cerrillos area, Santa Fe County, New Mexico, N.* Mex. Inst. Min. and Tech., Stat Bur. Mines and Mineral Res., Bull. 48, 73 p., 5 pls., 3 figs.

Ellis, R. W. (1922) *Geology of the Sandia Mountains,* Univ. N. Mex., Bull. 108, geol. ser.; v. 3, n. 4, 45 p., 4 pls., 2 figs.

Farnham, L. L. (1961) *Manganese deposits of New Mexico,* U.S. Bur. Mines, Inf. Circ. 8030, 176 p.

Gabelman, J. W. (1956) *Uranium deposits in paludal sandstone, San Juan Basin, New Mexico,* U.S. Geol. Surv., Prof. Paper 300, p. 303-319.

Gardner, J. H. (1910) *Isolated coal fields in Santa Fe and San Miguel counties, New Mexico,* U.S. Geol. Surv., Bull. 381, p. 447-451.

Gustafson, W. G. (1965) *Geology of the copper-lead-zinc-turquoise deposits, southwestern part of the Cerrillos mining district, Santa Fe County, New Mexico,* unpub. master's thesis, Univ. N. Mex., 58 p.

Harrison, E. P. (1949) *Geology of the Hagan coal basin,* unpub. master's thesis, Univ. N. Mex, 177 p., 1 pl., 5 figs.

Hayden, F. V. (1869) *Santa Fe to Placiere Mountain and return,* U.S. Geol. and Geog. Surv. Terr., 3rd Ann. Rpt., p. 166-168.

Herrick, C. L. (1900) *The geology of the Albuquerque sheet,* Univ. N. Mex., Bull. 23, geol. ser., v. 2, pt. 1, n. 1, 67 p., 32 pls.

Johnson, D. W. (1903) *The geology of the Cerrillos Hills, New Mexico,* School of Mines Quart. (Columbia Univ.), v. 24, p. 173-246, 303-350, 456-500; v. 25, p. 69-98, illus.

Jones, F. A. (1904) *New Mexico Mines and Minerals,* Santa Fe: New Mexican Printing Co., 349 p.

Kelley, V. C. (1949) *Geology and economics of New Mexico iron-ore deposits,* Univ. N. Mex. Publ. in Geol. No. 2, 246 p. 16 pls., 46 figs.

Krieger, Philip (1932) *Geology of the lead-zinc deposit at Pecos, New Mexico,* Econ. Geol., v. 27, p. 344-364, 8 figs.; p. 450-470, 7 figs.

Ladoo, R. B. (1927) *Fluorspar, its mining, milling, and utilization, with a chapter on cryolite,* U.S. Bur. Mines, Bull. 244, 185 p., 26 figs.

Lasky, S. G., and Wootton, T. P. (1933) *The metal resources of New Mexico and their economic features,* N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 7, 178 p., 2 pls.

Lee, W. T. (1912) *The Tijeras coal field, Bernalillo County, New Mexico,* U.S. Geol. Surv., Bull. 471-H, p. 575-578.

---- (1913) *The Cerrillos coal field, Santa Fe County, New Mexico,* U.S. Geol. Surv., Bull. 531-J, p. 285-312.

Lindgren, Waldemar (1933) *Mineral deposits,* New York: McGraw-Hill Book Co., 4th ed., 930 p.

– Graton, L. C., and Gordon, C. H. (1910) *The ore deposits of New Mexico,* U.S. Geol. Surv., Prof. Paper 68, 361 p., 22 pls., 33 figs.

Lustig, L. K. (1957) *The mineralogy and paragenesis of the Lone Star deposit, Santa Fe County, New Mexico,* unpub. master's thesis, Univ. N. Mex., 55 p., 13 figs.

Mansfield, G. R. (1921) *New Mexico: Sulphur in Jemez Canyon, Sandoval County,* U.S. Geol. Surv., Mineral Resources U.S. 1918, pt. 2, p. 367-369.

McRae, 0. M. (1958) *Geology of the northern part of the Ortiz Mountains, Santa Fe County, New Mexico,* unpub. master's thesis, Univ. N. Mex., 112 p., 13 figs.

Miller, J. P., Montgomery, Arthur, Sutherland, P. K. (1963) *Geology of part of the southern Sangre de Cristo Mountains, New Mexico, N.* Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Mem. 11.

Mills, D. E. (1952) *Petrogenesis of some perlite in Peralta Canyon, Sandoval County New Mexico,* unpub. master's thesis, Univ. N. Mex., 50 p.

Mineral Resources of the United States (1882 to 1931) U.S. Dept. Interior. *Minerals Yearbooks* (1932 to 1959) U.S. Dept Interior.

Newberry, J. S. (1876) *Geological report* (in Macomb, J. N., Report of the exploring expedition from Santa Fe, New Mexico, to the junction of the Grand and Green rivers of the great Colorado of the West, in 1859), U.S. Army Eng. Dept., p. 9-118.

Northrop, S. A. (1959) *Minerals of New Mexico,* Albuquerque: Univ. N. Mex. Press, rev. ed., 665 p.

___________ (ed.) (1961) *Guidebook of the Albuquerque Country,* N. Mex. Geol. Soc., Twelfth field conference, 199 p.

Peterson, J. W. (1958) *Geology of the southern part of the Ortiz Mountains, Santa Fe County, New Mexico,* unpub. master's thesis, Univ. N. Mex., 115 p., 11 figs.

Read, C. B., Duffner, R. T., Wood, G. H., Jr., and Zapp, A. D. (1950) *Coal resources of New Mexico,* U.S. Geol. Surv., Circ. 89, 24 p., 1 pl.

Reiche, Parry (1949) *Geology of the Manzanita and North Manzano mountains, New Mexico,* Geol. Soc. Am. Bull., v. 60, p. 1183-1212, 5 pls.

Ross, C. S., Smith, R. L., and Bailey, R. A. (1961) *Outline of the geology of the Jemez Mountains, New Mexico,* N. Mex. Geol. Soc., Guidebook, Twelfth field conference, p. 139-143.

Ross, Edmund (1909) *A report on a portion of the Soda Springs mining district in Bernalillo County, New Mexico,* unpub. senior thesis, Univ. N. Mex., 20 p., illus.

Rothrock, H. E., Johnson, C. H., and Hahn, A. D. (1946) *Fluorspar resources of New Mexico,* N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 21, 239 p., 23 pls., 15 figs.

Schmitt, Harrison (1950) *The genetic classification of the bed rock hypogene mineral deposits,* Econ. Geol., v. 45, p. 671-680.

Smith, J. F., Jr., Wadsworth, A. H., Cooper, J. R., Farwell, F. W., and Weissenborn, A. E. (1945) *San Pedro and Carnahan mines, New Placers mining district, Santa Fe County, New Mexico,* U.S. Geol. Surv., Open-file Rpt., 49 p., 12 pls., 2 figs.

Soule, J. H. (1956) *Reconnaissance of the "red bed" copper deposits in New Mexico,* U.S. Bur. Mines, Inf. Circ. 7740, 74 p.

Spiegel, Zane, and Baldwin, Brewster (1963) *Geology and water resources of the Santa Fe area, New Mexico,* U.S. Geol. Surv., Water-Supply Paper 1525, 258 p., 7 pls., 56 figs.

State Inspector of Mines (New Mexico) (1912 to 1965) *Annual Reports.*

Statz, B. A. (1912) *Geology of the Cochiti mining district, New Mexico,* Min. Sci., v. 66, p. 726-727.

Stearns, C. E. (1953) *Tertiary geology of the Galisteo—Tonque area, New Mexico,* Geol. Soc. Am. Bull., v. 64, p. 459-507, 3 pls., 10 figs.

Talmage, S. B., and Wootton, T. P. (1937) *The non-metallic mineral resources of New Mexico and their economic features (exclusive of fuels),* N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 12, 159 p., 2 pls., 4 figs.

Turnbull, L. A., Toenges, A. L., Davis, J. D., Reynolds, D. A., and Parks, B. C. (1951) *Miller Gulch and Cook & White coal beds near Cerrillos, Santa Fe County, New Mexico,* U.S. Bur. Mines., Rpt. Inv. 4814, 29 p., 5 figs.

Vieth, F. E. (1950) *The rise and decline of the Cochiti (Bland) mining district,* unpub. master's thesis, Univ. N. Mex., illus.

Wargo, J. G. (1964) *Geology of a disseminated copper deposit near Cerrillos, New Mexico,* Econ. Geol., v. 59, n. 8, p. 1525-1538.

Weber, R. H., and Kottlowski, F. E. (1959) Gypsum *resources of New Mexico,* N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 68, 6 pls., 5 figs.

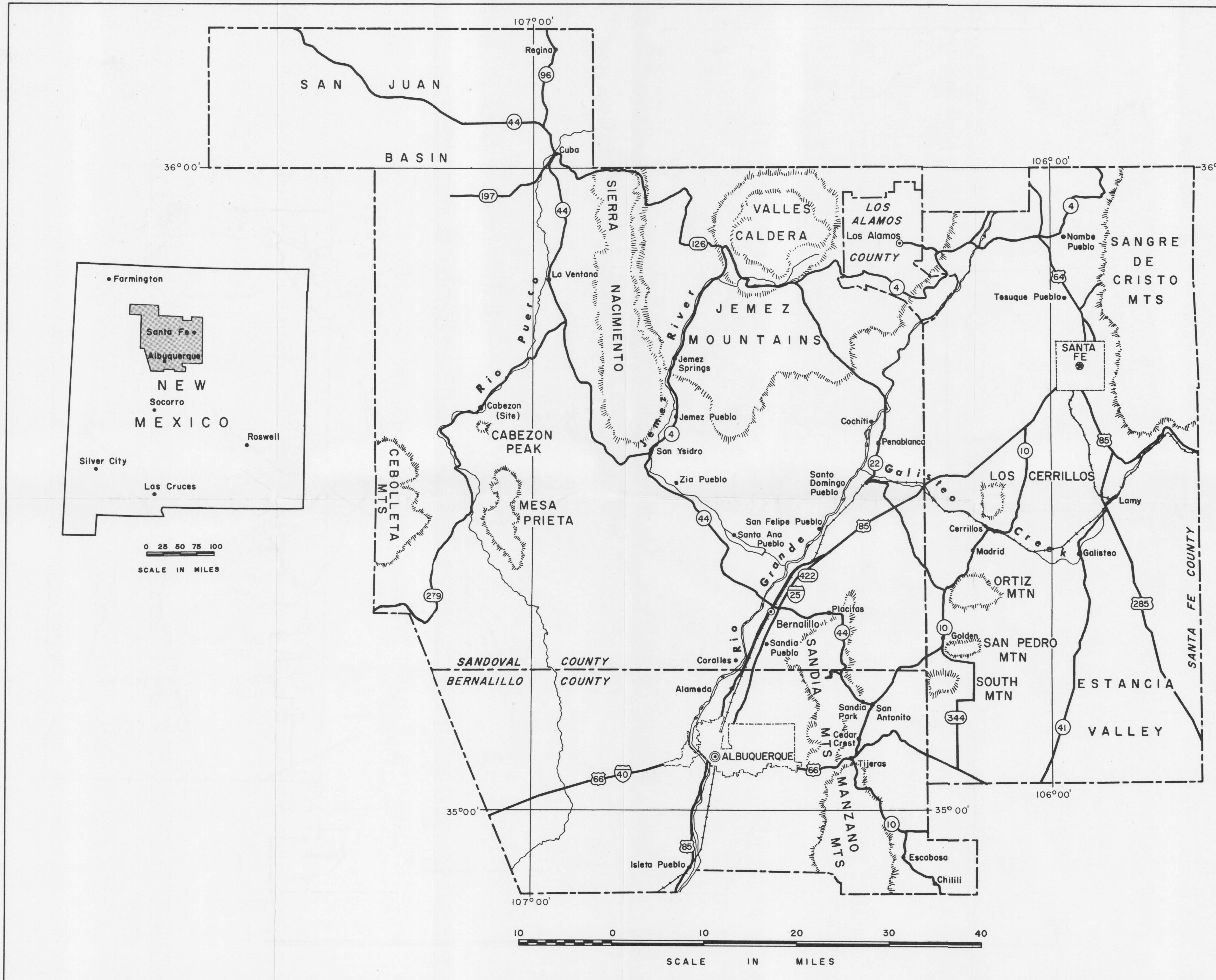
Wells, E. H. (1918) *Manganese in New Mexico,* N. Mex. Min. Res. Surv., Bull. 2, 85 p.

Wood, G. H., Jr., and Northrop, S. A. (1946) *Geology of the Nacimiento Mountains, San Pedro Mountain, and adjacent plateaus in parts of Sandoval and Rio Arriba counties, New Mexico,* U.S. Geol. Surv., Oil and Gas Inv. Prelim. Map 57.

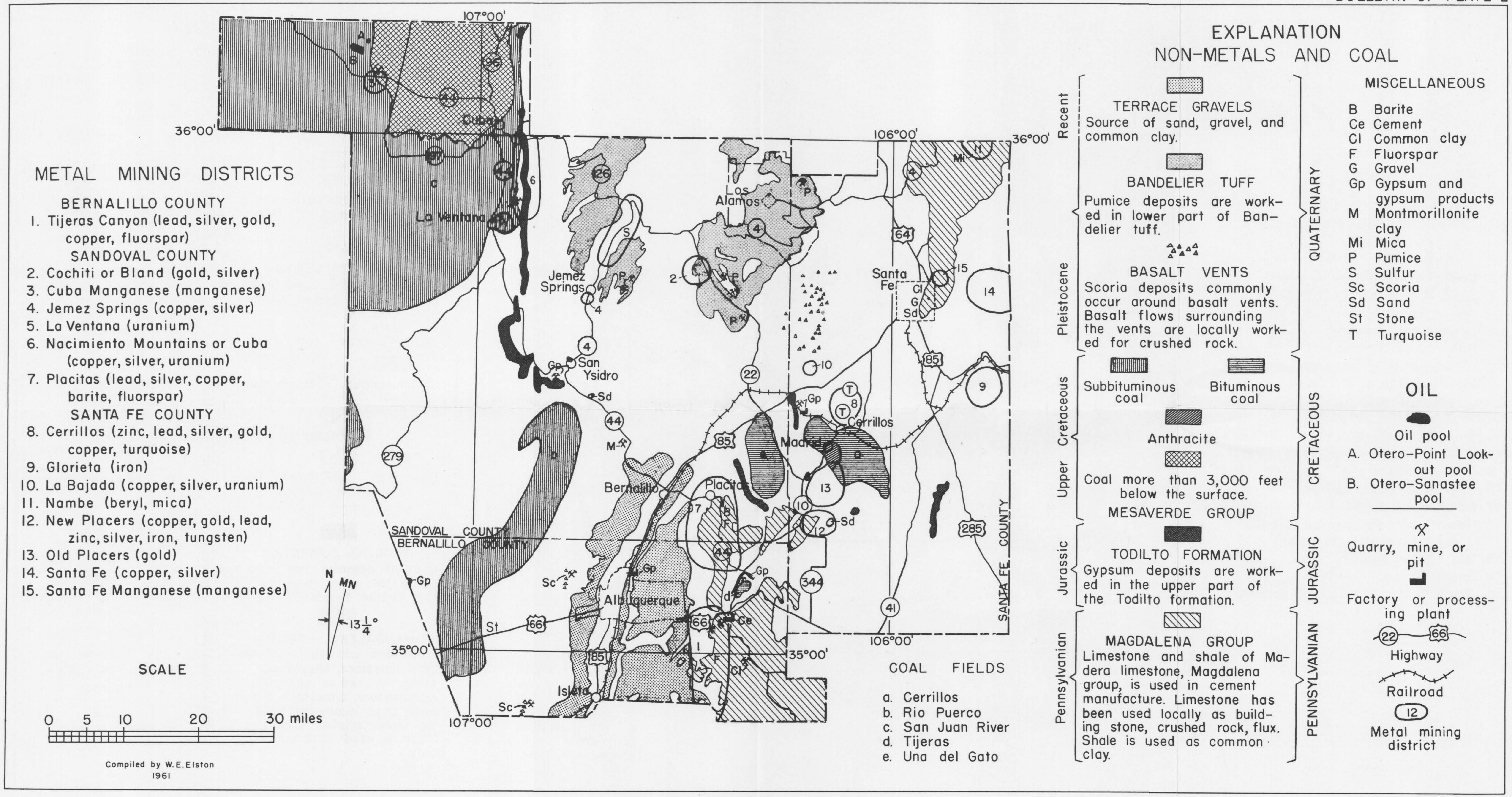
Wynkoop, W. C. (1900) *The Cochiti mining district, New Mexico:* Eng. Min. Jour., v. 70, p. 215-217, 4 figs.

Index

Numbers in **boldface** indicate main sections



Map of Bernalillo, Los Alamos, Sandoval, and Santa Fe Counties, New Mexico



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