THE MINERAL INDUSTRY OF MISSOURI IN 1946 AND 1947 WITH TOTAL PRODUCTION SUMMARIZED

by

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INTRODUCTION

Missouri is a State noted for its mineral wealth. During 150 years of mining, minerals and metals extracted from mines, quarries, and pits of the State have exceeded the substantial value of $3,540,000,000. Mineral commodities which have contributed most to this income are lead, clays, coal, zinc, cement, and stone and stone products.

Missouri ranks first among the states in annual production of lead and has held that pre-eminent position for 40 consecutive years. At present, 40 per cent of the lead mined in the United States is obtained from the very important "lead-belt" of southeast Missouri. The State ranks first in the value of barite produced annually and is a foremost producer of fireclays, being first in the important refractories, diaspore and burley.

Missouri's mineral resources are remarkable for their diversity. Not only does the State contain metallic ores such as those of lead, zinc, iron, copper, cobalt, nickel, silver, manganese, and tungsten, but it also contains considerable coal, some oil and gas, and immense quantities of clays, limestones, dolomites, glass sand and other stone products, as well as barite, pyrites, and tripoli.

This array of mineral raw materials situated in the heart of a rich agricultural region, deep within the interior of the nation in an area of ample transportation facilities, abundance of fuels, and adequate native-American manpower is a resource of inestimable value to the nation.

This report presents the mineral statistics for 1946 and 1947, summarizes all past mineral production, and gives information on the sources and uses of each raw material. In doing this economic trends are observed, factors causing increases or decreases are recorded, and in some instances inferences as to the future are made.

ACKNOWLEDGMENT

The production data on coal were collected in part by the office of the State Mine Inspector and in part by the United States Bureau of Mines. Practically all other basic data were furnished by the mineral industry of Missouri to the Missouri Division of Geology and Water Resources working cooperatively with the United States Bureau of Mines.

Special acknowledgment is made to Edward L. Clark, State Geologist, and Walter V. Searight, Principal Geologist, each of whom as members of the Geological Survey contributed to the report. Junius A. Van Lieu and Willard E. Davis also contributed.

SUMMARY OF PRODUCTION

In 1946, the mineral industry of Missouri yielded products valued at $109,883,887 as compared to $97,878,225 in 1945. In 1947, the value of Missouri's mineral commodities was $128,457,407. This value is an all-time high.

Table 1 summarizes the amount and value of the mineral products produced in the years 1945, 1946, and 1947 in such a way as to allow direct comparisons of both the amounts and values. In Table 2, the annual value of Missouri mineral production is recorded from 1905 through 1947. Total production prior to 1905 is also shown, and the grand total of the State's production is given.

Figure 1, which is based on data given in Table 3, is a pie chart that shows what part of the grand total value given in Table 2 was contributed by coal, lead, zinc, clays, cement, and the other mineral commodities.

An examination of the production data given in Table 1 shows that production has been maintained or increased in almost all commodities since the end of World War II and that the value per unit of each mineral product has increased. The unit values of non-metallics such as stone, lime, cement, sand and gravel increased from 8 to 18 per cent in 1947 as compared to 1945. During the same period the unit value of lead increased by 68 per cent. During 1948, commodity prices increased further, until by December 1948 lead was quoted in St. Louis at 21.3 cents a pound and zinc, too, was selling at the record price in East St. Louis of 17.5 cents a pound. As of April 1949 zinc sold at 16 cents a pound in East St. Louis and lead was selling for 17.5 cents. By May 10, 1949, the prices had declined to 13.8 cents a pound for lead and 12 cents for zinc.

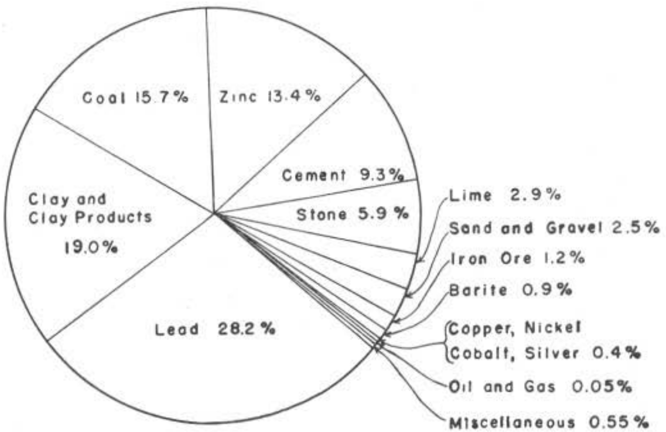

Figure 1 – Value of Mineral Production by Commodity Expressed in Percentage of the Total Production Through 1947

Table 1

Mineral Production in Missouri 1945 Through 1947

PRODUCT	Unit	1945		1946		1947	
		Quantity	Value	Quantity	Value	Quantity	Value
Asphaltic rock	short tons	[1]	[1]	[1]	[1]	[1]	[1]
Barite	do	225,467	$ 1,841,959	270,850	$ 2,168,067	291,619	$ 2,405,249
Cement	barrels	3,681,632	6,134,452	6,887,517	12,142,018	8,030,939	15,066,390
Clay—							
Products, heavy clay, pottery and refractories	....	....	25,000,000 [2]	....	25,500,000 [2]	....	25,600,000 [2]
Raw	short tons	1,355,349 [3]	2,311,660 [3]	1,689,229 [3]	3,257,687 [3]	1,744,411 [3]	4,051,157 [3]
Coal	do	3,982,724	10,322,177	3,732,815	10,432,591	4,020,000	13,226,000 [7]
Cobalt	pounds	[1]	[1]	[1]	[1]	[1]	[1]
Coke	short tons	[1] [4]	[1] [4]	[1] [4]	[1] [4]	[1] [4]	[1] [4]
Copper	pounds	6,798,000	917,730	3,714,000	601,668	3,520,000	739,200
Iron ore	long tons	112,668	[1]	156,350	[1]	171,356	[1]
Lead	short tons	176,575	30,370,900	139,112	30,326,416	132,246	38,086,848
Lime	do	753,932	5,031,222	799,742	5,931,485	889,090	7,006,426
Mineral paints (zinc and lead pigments)	do	[1] [4]	[1] [4]	[1] [4]	[1] [4]	[1] [4]	[1] [4]
Mineral waters	gallons sold	[5]	[5]	[5]	[5]	[5]	[5]
Natural gas	M cubic feet	77,575	8,913	37,863	4,467	30,035	3,907
Nickel	short tons	[1]	[1]	....	....	....	....
Ores (crude), etc.—							
Lead	do	6,509,287	[6]	5,361,694	[6]	5,711,700	[6]
Lead-copper	do	167,485	[6]	141,698	[6]	183,442	[6]
Zinc	do	849,836	[6]	700,849	[6]	606,910	[6]
Zinc-lead	do	1,131,228	[6]	1,297,689	[6]	804,755	[6]
Petroleum	barrels	37,714	40,731	42,728	44,375	31,462	54,326
Sand and gravel	short tons	3,489,775	2,780,467	5,136,904	4,070,448	8,136,657	5,486,811
Sand and sandstone (ground)	do	[1]	[1]	[1]	[1]	[1]	[1]
Silver	troy ounces	94,822	67,429	69,401	56,076	93,600	84,708
Stone	short tons	5,314,160 [8]	6,055,747 [8]	7,258,990	8,996,440	8,438,320 [8]	11,195,993 [8]
Sulfuric acid (60° B.) [9]	do	[1] [4]	[1] [4]	[1] [4]	[1] [4]	[1] [4]	[1] [4]
Tripoli	do	6,542	114,188	12,180	211,244	19,375	469,927
Tungsten concentrates (60 per cent WO_3 basis)	do	....	....	....	....	....	....
Zinc	do	22,175	5,100,250	22,234	5,425,096	17,074	4,131,908
Miscellaneous [10]	do	....	5,164,288	....	4,467,428	....	7,129,888
Total value, eliminating duplications		....	$97,878,225	....	$109,883,887	....	$128,457,407

[1]Value included with "Miscellaneous."
[2]Estimated.
[3]Sold or used.
[4]Value not included in total for State.
[5]No canvass.
[6]Not valued as ore; value of recoverable metal content included with metals.
[7]Value obtained from Missouri State Mine Inspector.
[8]Exclusive of sandstone, value for which is included with "Miscellaneous."
[9]From zinc smelting.
[10]Includes minerals indicated by footnotes 1 and 8 above.

Table 2

Annual Value of Missouri Mineral Production

Year	Value	Year	Value
Prior to 1905	$614,514,903[1]	1926	$90,003,537
1905	37,506,479	1927	75,890,415
1906	55,496,317	1928	74,981,382
1907	53,129,431	1929	78,948,484
1908	41,499,835	1930	69,074,500
1909	50,416,043	1931	41,805,772
1910	51,857,640	1932	29,245,055
1911	51,932,906	1933	30,588,018
1912	58,332,550	1934	32,954,534
1913	54,001,088	1935	35,800,213
1914	48,597,593	1936	49,719,922
1915	74,953,623	1937	64,286,903
1916	103,526,424	1938	47,019,792
1917	105,342,678	1939	54,898,019
1918	76,663,995	1940	62,019,300
1919	61,862,232	1941	74,991,972
1920	90,994,479	1942	96,887,410
1921	56,375,543	1943	96,009,652
1922	62,402,642	1944	96,560,000
1923	79,201,473	1945	97,878,225
1924	81,054,122	1946	109,883,887
1925	92,548,473	1947	128,457,407
Total value of mineral production..........................			$3,540,114,868

[1]In part estimated.

The summary of production by minerals (Table 3) shows the metallic ores and metals produced through 1947 to have been worth $1,533,079,565 and the non-metallic or industrial minerals were but slightly less, with a value of $1,454,913,185. Total fuel production through 1947 is valued at $552,122,118.

BARITE

Barite mining in Missouri was begun in pre-Civil War days. Since 1872 production has been continuous.

The mineral barite is a naturally occurring crystalline form of barium sulfate mined in Washington, Jefferson, Franklin, Benton, Morgan, and Cole counties. At various times it has also been mined in Miller, Moniteau, Dallas, Camden, Hickory, Boone, Pettis, Maries, Texas, Crawford, St. Francois, and Ste. Genevieve counties. The deposits in the residual clays in Washington and Jefferson counties have produced not only the greater amount of the barite mined in Missouri, but have made Missouri one of the principal producing states of this country; in fact, Missouri has produced more barite than any other state. It now

Table 3

Total Production of Minerals in Missouri Through 1947, Except as Noted Differently

Product	Amount		Value	Total Value
Fuels—				
Coal	246,313,001	short tons	$550,274,036	
Oil	581,621	bbls.	607,002	
Gas	11,430,115	thousand cubic feet	1,241,080	
Total value of fuels				$552,122,118
Metals or metallic ores—				
Lead	8,518,943	short tons	993,788,452	
Zinc	3,634,431	short tons	471,841,701	
Copper	46,174,162	pounds	6,842,145	
Silver (1905-1947)	4,582,368	troy ounces	3,234,976	
Nickel [1]	1,410,647+	pounds	705,575+	
Cobalt [1]	587,200+	pounds	1,176,200+	
Manganese ore	2,750	long tons	51,010	
Tungsten concentrate	124.5	short tons	160,077	
Pyrites concentrate	256,745	long tons	793,088	
Iron ore	11,374,792	long tons	41,111,341	
Miscellaneous metallics			13,375,000	
Total value of metals and metallic ores				$1,533,079,565
Industrial minerals (clays, stone and rock products)—				
Raw clay shipped out of State [3]			7,500,000	
Clay products [3]			662,375,000	
Dimension limestone (1860-1947) [3]	14,155,950	short tons	31,628,342	
Crushed limestone (1899-1947)	126,262,750	short tons	143,007,409	
Marble (1902-1947)	1,113,070	short tons	22,422,918	
Granite (1894-1947) [3]	532,270	short tons	5,378,845	
Sandstone (1889-1947) [3]	1,829,890	short tons	2,685,811	
Chats (coarse mill tailings) (1915-1947)	52,609,658	short tons	12,010,978	
Sand, including 8,349,062 tons glass sand (1902-1947)	86,035,982	short tons	49,848,429	
Gravel (1905-1947)	79,725,159	short tons	38,751,474	
Asphaltic sandstone [2]	37,000	short tons	194,000	
Tripoli [3]	308,000	short tons	4,105,000	
Barite (1872-1947)	4,765,125	short tons	31,774,237	
Lime (1897-1947	15,829,374	short tons	100,254,252	
Portland cement (1903-1947)	227,230,267	bbls.	327,721,490	
Miscellaneous non-metallics (mineral wool, mineral water, etc.) [4]			15,255,000	
Total value of industrial minerals				$1,454,913,185
Grand total value				$3,540,114,868

[1]Production not reported here is included under miscellaneous metallics.
[2]Production not reported here is included under miscellaneous industrial minerals.
[3]Production data are incomplete and figures presented are in part estimated.
[4]This production does not include sulfur and coke and coke-oven by-products which are recovered in processing out-of-state coal.

ranks second to Arkansas in tons produced, but exceeds Arkansas in the annual total dollar value because of the higher grade of the barite produced.

Table 4 gives the annual as well as the total production of barite since 1872. All of the production prior to 1885 was not recorded, but that through 1947 which is known amounts to 4,765,125 tons which were sold for $31,774,237. The records show

Table 4

Annual Production and Value of Barite in Missouri[1]

Year	Short Tons	Value	Year	Short Tons	Value
1872	5,218 [3]	$26,090 [5]			
1873-1879	....	....	1914	33,317	$112,231
1880	8,000 [4]	28,000 [5]	1915	39,113	158,597
1881	....	....	1916	58,223	365,111
1882	8,896 [3]	31,847 [5]	1917	59,046	391,363
1883-1884	....	....	1918	49,094	393,738
1885	4,448 [3]	19,838 [5]	1919	73,247	640,398
1886	5,337 [3]	23,803 [5]	1920	99,654	1,013,570
1887	5,560 [3]	36,974 [5]	1921	25,200	217,913
1888	7,280 [3]	24,388 [5]	1922	66,421	421,568
1889	7,558 [4]	36,412 [5]	1923	81,701	629,097
1890	9,883 [4]	39,037 [5]	1924	77,189	604,390
1891	12,000 [4]	60,000	1925	101,056	794,927
1892	16,000 [4]	65,000	1926	118,919	946,595
1893	15,000 [4]	44,000	1927	111,456	797,465
1894	....	....	1928	114,274	810,203
1895	11,670 [3]	37,003 [5]	1929	118,679	880,319
1896	8,820 [3]	50,000 [5]	1930	132,640	938,812
1897	8,100 [3]	50,000 [5]	1931	93,417	539,152
1898 [6]	8,360 [2]	29,360 [5]	1932	85,458	463,347
1899 [6]	21,808 [2]	72,620 [5]	1933	112,335	510,551
1900 [6]	23,632 [2]	65,696 [5]	1934	118,836	581,889
1901	32,388 [2]	104,239	1935	131,921	727,888
1902	31,334	104,677	1936	160,866	1,008,528
1903	26,069 [2]	102,822	1937	198,101	1,430,397
1904	25,498	75,552	1938	156,539	1,150,630
1905	26,761	84,095	1939	171,642	1,163,870
1906	28,869	93,479	1940	179,455	1,216,069
1907	60,370 [2]	292,540	1941	212,718	1,337,756
1908	16,319	56,768	1942	146,270	943,131
1909	34,815	119,818	1943	124,147	872,044
1910	25,431 [2]	85,624	1944	150,748	1,121,678
1911	21,500 [2]	81,380	1945	225,467	1,841,959
1912	24,530	117,035	1946	273,772	2,168,067
1913	31,131	117,638	1947	291,619	2,405,249
Totals from 1872 through 1947......................				4,765,125	$31,774,237

[1]All production data unless otherwise credited were obtained from U. S. Bur. Mines Inf. Circ. no. 7345 and U. S. Bur. Mines Minerals Yearbooks.

[2]1898, 1899, 1900, 1901, 1903, 1907, 1910, and 1911 production data are from Annual Reports of the Missouri State Mine Inspector.

[3]1872, 1882, 1885, 1886, 1887, 1888, 1895, 1896, and 1897 production data obtained from G. A. Muilenburg who collected it from various sources.

[4]1880, 1889, 1890, 1891, 1892, and 1893 from U. S. Geol. Surv. Mineral Resources.

[5]Estimated.

[6]Based on fiscal year ending June 1. There may be some overlap in reported production for years 1897 and 1900.

that the production of 273,772 short tons in 1946 was greater than that of any previous year. This record figure was exceeded in 1947 when 291,619 tons were produced.

Types of Occurrences. The mines in southeastern Missouri are in residual clay derived from the weathering of the Eminence and Potosi dolomites. A replacement vein deposit is found southwest of Steelville in Crawford County, and replacement bedded deposits are known in Boone, Moniteau, and Pettis counties, where the Burlington limestone has been replaced. The Chouteau limestone in Hickory County has also been replaced locally by barite. In the Central Missouri mineral district, the barite occurs primarily in fissures, sinks, circles, and bedding plane breccias, and secondarily in the residual soils derived from the primary deposits. Some of the circle deposits in Morgan, Cole, and Benton counties have been mined to depths of nearly one hundred feet. The barite deposits of Morgan County were recently described by Mather[1].

The mines and mills in Washington County have kept pace with industrial demands through mechanization of the mines and by the introduction of new milling methods. The adoption of mechanical loading, the rotating grizzly, 30-foot double log washers, and other improvements have permitted the continued mining of lower and lower grade deposits. The use of decrepitation and magnetic separators has made possible the production of barite which meets market specifications from crude barite ore containing limonite. Flotation has not been introduced in the mill flow sheets, although laboratory tests have been made on the mud slimes from the washers to determine the feasibility of recovering fine fractions now being lost.

Uses of Barite. The chief uses of barite in sequence of importance are in making drilling muds, lithopone, chemicals, fillers, and glass[2].

In drilling wells for either oil, gas, or water, with a rotary drill, mud slurry must be pumped into the hole to wash or carry the cuttings to the surface and to keep the face of the bit on fresh rock surfaces. The slurry must have a specific gravity greater than the cuttings, otherwise the cuttings would tend to remain at the bottom of the hole. The high specific gravity, relatively low cost, cleanness, freedom from detrimental impurities, and inertness of barite make it a most desirable weighting agent for drill muds. In addition to "floating" the cuttings

[1]Mather, W. B., The Mineral Deposits of Morgan County, Missouri: Missouri Geol. Survey & Water Resources, Rept. Inv. no. 2, 1946.

[2]Harness, C. L., and Barsigian, F. M., Mining and Marketing of Barite: U. S. Bur. Mines Inf. Circ. no. 7345, 1946. This reference has been the principal source of the information which follows.

in the slurry, the barite drill mud acts as a cooling lubricant to the bit, "plasters" or seals the wall of the drill hole preventing caving, and restrains abnormal gas, oil, or water pressures from "blowing" the drill hole.

Lithopone, an intimate mixture of zinc sulfide and barium sulfate, is the second largest use for barite. Barite is crushed and mixed with some form of carbon and fired in furnaces to produce black ash (barium monosulfide). The black ash is then leached in water, and the leach liquor is mixed with a solution of zinc sulfate to produce a lithopone precipitate. This precipitate is washed, dried, calcined, quenched in water, wet-ground, dried, and bagged as lithopone. The high refractive index of lithopone produces a high hiding power that makes it useful as a paint pigment.

Barium chemicals have varied properties which make them of value. Blanc fixe, precipitated barium sulfate, is difficult to redisperse in water and has a high refractive index. As a pulp it is used mostly as a paper filler, it decreases the time required for rubber-sulfur mixtures to reach their maximum strength, and to a certain degree it reinforces rubber. Blanc fixe is often formed in place in leather, rubber and cloth.

Barium chloride removes the sulfate ions from water, acts as a carbon carrier with cyanide salts to caseharden steels, aids in forming blanc fixe, and acts as a flux in making magnesium metal. Barium carbonate in a ceramic batch interchanges its carbonate with the sulfate of calcium, forming insoluble barium sulfate and thus prevents the formation of a calcium sulfate scum when the ceramic product is exposed to moisture.

Barium chloride adds weight, greater refraction, high luster, and a full ringing tone to soda glass, although it reduces the toughness of the glass. Barium salts are also used in making crown and flint glasses for optical purposes. Barium carbonate is sometimes added to drill muds to prevent their flocculation when the drill is cutting gypsum-bearing formations. A mixture of barium oxide and witherite (barium carbonate mineral) increases the life of the acid lining of electric furnaces, produces a quieter and steadier arc, and reduces the sulfur content of the steel made in the furnace. It also reduces slag viscosity. Barium oxide increases the refractive index, density, and elasticity of glass. Barium peroxide was used exclusively in the production of hydrogen peroxide prior to the development of electrolytic processes, but its future use will most likely depend on its use as a bleach in the dry powdered form. Barium hydroxide may be used to break down the calcium sulfate formed by efflorescense on bricks, and in recovering sugar from beet sugar molasses. Barium nitrate, when it is ignited, readily releases the typical green barium flash color and is therefore used in signal flares. It is less soluble and has a better decolorizing action than nitrates of the alkali metals, and therefore it is used in enamel frits. Barium tungstate, manganate, molybdate, and chromate are used as paint pigments. Barium silicofluoride is an effective insecticide. Other barium salts with properties desirable in industry are barium aluminate, sodium barium aluminate, barium nitrophthalate, barium acetate, barium chlorate, barium cyanide, barium ethyl sulfate, barium fluoride, and barium sulfide. Barium chemicals may be used in the refining of animal and vegetable oils. They are also used in the manufacture of designs on Wedgewood ware, rat poison, antiseptics, embalming fluids, safety matches, thermate incendiary bombs, primers and detonators, iron rust resisters, depilatories, and specialized coatings on photographic papers.

The high specific gravity of barite makes it highly useful as a filler in many products to which it is desired to give added weight. Often it gives additional desirable properties. This is particularly true of blanc fixe, the chemically precipitated barium sulfate which has a high refractive index and readily and uniformly takes color stains or pigments. The inertness of barium sulfate adds to the value of barite as a filler where corrosion is apt to exist. Barite and barium chemicals are used as fillers in pigments, oilcloth, linoleum, putty, roofing compounds, rubber, X-ray proof fabricated walls, asbestos brake linings, asbestos cements, paper, sealing wax, printing inks, phonograph records, plastics, poker chips, and fertilizers.

Barium metal is a satisfactory deoxidizer of copper. The high rate of electron emission of barium when subjected to an electrical potential is utilized in alloys for spark plugs. Barium metal has been found to be the best all-around metal for use as a "getter" for the removal of residual gases in and those evolved during service in vacuum, radio, radionic, thermionic, and electron tubes, but for such uses it is ordinarily used in the alloyed form with aluminum and magnesium[1]. Lead hardened with barium may be used as a bearing metal, which has a high compression strength and hardness but a lower load-carrying capacity under high speeds than tin-base alloys.[2].

[1]U. S. Bur. Mines Minerals Yearbook, 1944, p. 807, 1946.

[2]Op. cit. (U. S. Bur. of Mines Inf. Circ. No. 7345), p. 42.

CADMIUM

Cadmium is a silver-white metal which is found associated with the lead and zinc ores of Missouri in relatively small quantity. It is recovered as a by-product in the smelting of those ores at the Herculaneum smelter of the St. Joseph Lead Company, Herculaneum, Missouri, and at the Eagle-Picher Mining and Smelting Company zinc smelter at Henryetta, Oklahoma. About 14 pounds of metallic cadmium are recovered for each ton of zinc smelted from Tri-State zinc ores.

Although no statistics are kept on cadmium production in the State, it is likely that Missouri produced about 300,000 pounds of the metal in 1946 which, at $0.99 a pound, was worth $297,000. Since 1946 the price has increased so that by the end of 1948 it was priced at $2.00 a pound. Total cadmium production has probably been about 20,000,000 pounds.

Uses of Cadmium. Cadmium is principally used as a plating metal to protect steel, particularly steel parts that will be subject to salt-water corrosion. High-speed, high-pressure bearings, such as are used in light weight gasoline engines of the automotive type, are often made of cadmium-base alloys. Other special uses include cadmium solders in fire-detector and sprinkling devices, and cadmium salts as yellow and red colors in paints, ceramics, ink, rubber, and leather.

It will also be remembered that cadmium barriers are used to control the speed of atomic fission.

CEMENT

The production and demand for cement increased rapidly in 1946 and 1947. Indeed, the plants were at a capacity rate in 1947 that was only exceeded in 1925. The five Missouri cement plants, as in former years, produced more cement than was required within the State. Thus in 1945 Missouri plants shipped 2,579,047 barrels of Portland cement for use within the State and 1,102,585 barrels for use outside the State. In 1946 the figures had approximately the same ratio, being respectively 4,885,365 and 2,002,152. In 1948 the plants sold 8,030,939 barrels of cement. Production figures on cement are always given in terms of barrels, although it is now shipped only in sacks holding 94 pounds (1 cubic foot) or in unpackaged bulk shipments.

History of Portland Cement Manufacture in Missouri. It was not until 1903 that Portland cement was manufactured in Missouri. The first plant erected, that of the Atlas Cement Company at Hannibal, was built in 1902 with a capacity of 7,000 barrels a day. The Prospect Hill plant of the St. Louis Portland Cement Company, St. Louis, was built shortly thereafter. By 1913 five plants were producing cement in Missouri. These same plants are still operating. They are:

Universal Atlas Cement Co., Ilasco station in Ralls County, south of Hannibal.
Missouri Portland Cement Co., Prospect Hill, St. Louis County.
Marquette Cement Manufacturing Co., Cape Girardeau, Cape Girardeau County.
Alpha Portland Cement Co., Alpha, St. Louis County.
Missouri Portland Cement Co., Sugar Creek, Jackson County.

In 1917 and 1918 when potassium salts were not available from Germany, the cement plant near Hannibal recovered potassium as a by-product of the clinkering process. During that same period the government built numerous concrete ships using light weight aggregate. The Atlas Cement Company at Hannibal, Missouri, and the Los Angeles Pressed Brick Company of California manufactured all the Haydite used for that purpose.

Table 5

Annual Production and Value of Portland Cement in Missouri

Year	Bbls.	Value	Year	Bbls.	Value
Prior to 1903	No Pro	duction	1925	8,168,165	$14,155,795
1903	600,000[1]	$ 800,000[1]	1926	7,639,966	12,917,342
1904	1,300,000[1]	1,065,000[1]	1927	6,929,229	11,117,047
1905	3,879,542	4,164,974	1928	7,943,367	12,367,018
1906	2,235,000[1]	2,175,000[1]	1929	7,984,337	11,557,905
1907	2,125,000[1]	2,215,000[1]	1930	8,030,528	11,470,751
1908	2,929,504	2,571,236	1931	5,103,287	5,052,840
1909	3,445,076	2,808,916	1932	4,846,871	3,666,220
1910	4,455,589	3,858,088	1933	3,994,690	4,722,441
1911	4,114,859	3,349,312	1934	3,779,125	5,449,606
1912	4,614,547	3,700,776	1935	3,291,332	4,940,713
1913	4,485,820	4,556,822	1936	4,632,191	7,134,240
1914	4,706,389	4,485,744	1937	4,565,448	7,041,016
1915	4,628,484	4,007,679	1938	4,570,389	6,871,120
1916	5,732,001	6,333,567	1939	4,702,259	7,420,013
1917	5,800,988	8,248,007	1940	4,867,799	7,616,247
1918	4,515,695	7,132,470	1941	6,516,345	10,272,509
1919	5,496,164	9,264,017	1942	7,397,960	11,515,907
1920	5,605,952	10,980,453	1943	4,464,943	7,024,285
1921	4,375,712	8,034,540	1944	3,061,434	4,881,516
1922	6,239,144	10,457,557	1945	3,681,632	6,134,452
1923	7,143,883	13,237,141	1946	6,887,517	12,142,018
1924	7,711,206	13,515,267	1947	8,030,898	15,288,923
Totals from 1903 through 1947				227,230,267	$327,721,490

[1]Estimated.

Table 5 presents the amount and value of Portland cement produced annually in Missouri.

The Manufacture of Portland Cement. Portland cement, the basic compound of concrete, is made by carefully mixing and grinding the proper amounts of crushed limestone and clay, shale or slag, and burning the mix in rotating horizontal retorts or kilns to form marble-like balls called clinker. The clinker when ground to the requisite fineness, with or without gypsum or other additives, is finished cement ready for the consumers' use.

CLAY AND CLAY PRODUCTS

The production of raw clay and clay products constitutes one of the most important mineral industries in the State. The average annual production of clay and shale during the past four years is approximately 1,569,000 short tons; and the estimated value of clay products manufactured annually is now about $25,000,000.

The larger part of the clay and shale mined is fire clay of the plastic, hard, and soft flint varieties, and diaspore and burley. Most of the clay is used in the manufacture of refractory products by plants situated in the State. A small quantity of the diaspore mined is utilized in making abrasives, and a considerable tonnage of the hard white flint fire clay is used in making non-ceramic products.

Shales and brick clays constitute about 19 per cent of the annual clay production. Of this amount about half is used in making Portland cement, while the rest is utilized mainly in the manufacture of structural clay products such as building bricks, sewer tile, structural tile, and facing tile. Only a small quantity of ball clay has been produced annually in Missouri since 1942. Fire clays constitute 75 per cent of the average State production; cement shales constitute 12 per cent; and brick clay and shale, and diaspore and burley clays constitute 7 per cent and 6 per cent, respectively.

Production curves shown in Figure 2 illustrate the tonnage and value of clay mined in Missouri for the period of 1926 through 1947. The curves reflect general business conditions during the period, except during the latter years of World War II when production decreased, owing largely to the shortage of manpower and curtailed activities in building construction. During the past two years production has increased, owing to the demand for building materials. A few brick and pottery plants that closed during the war are now operating successfully.

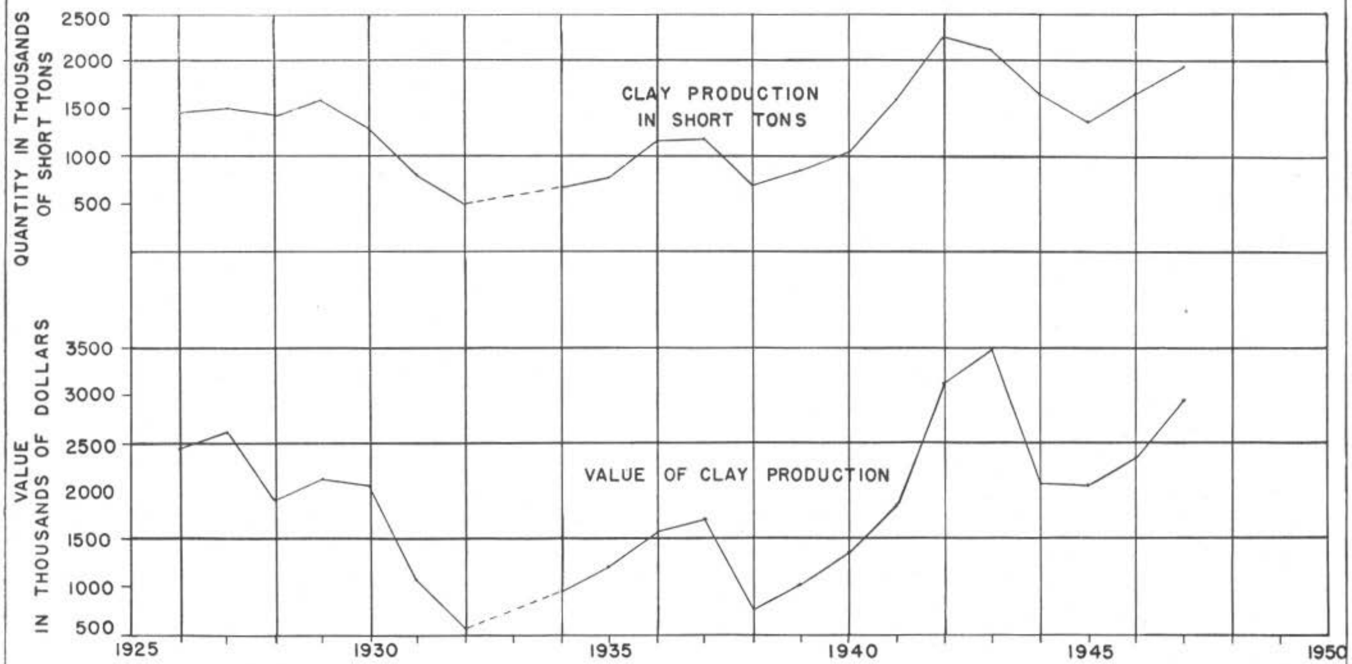

FIGURE 2. —CURVES SHOWING PRODUCTION OF CLAY IN MISSOURI DURING THE PERIOD 1926 THROUGH 1947

(All figures are from the reports of the Missouri State Mine Inspectors)

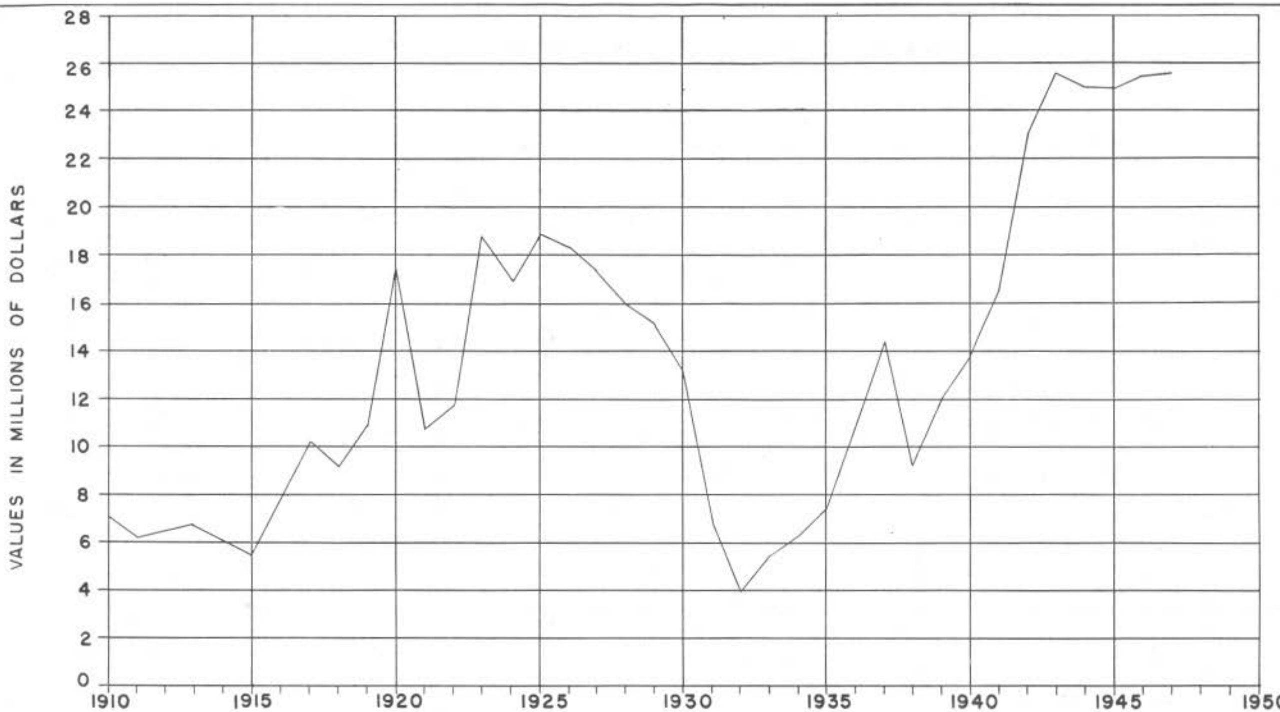

FIGURE 3 – CURVE SHOWING DOLLAR VALUE OF CLAY PRODUCTS IN MISSOURI DURING THE PERIOD 1910 THROUGH 1947

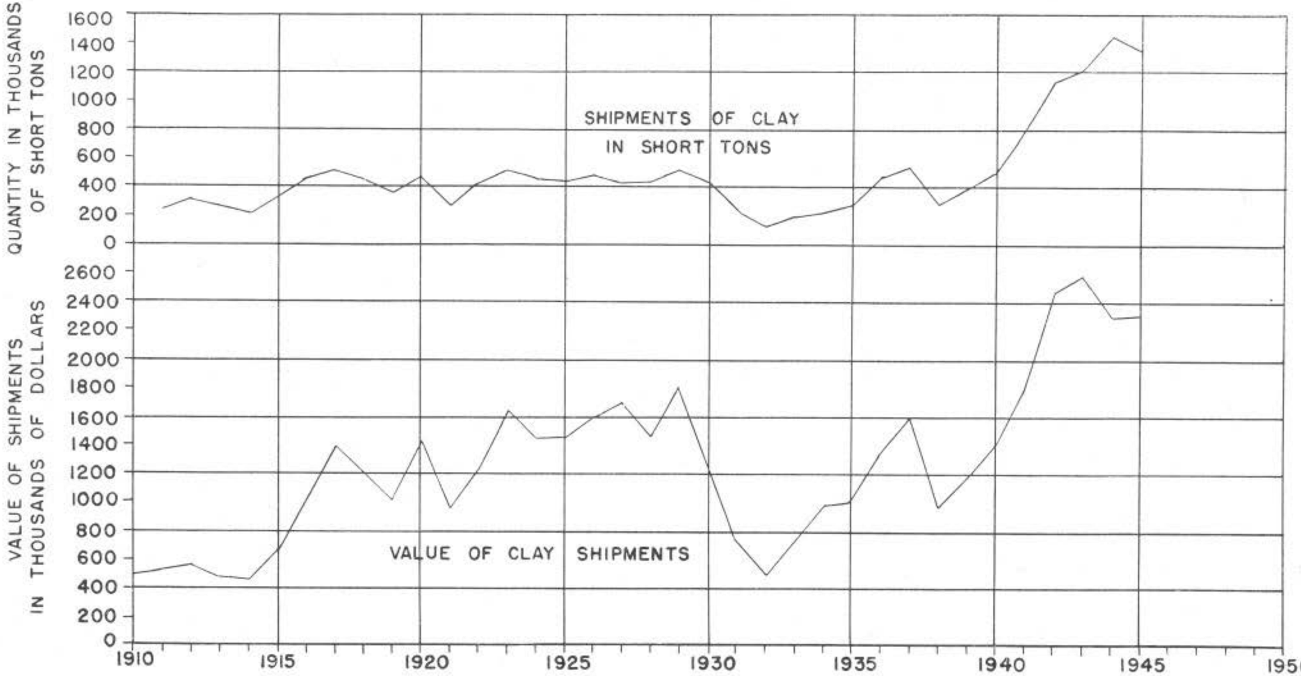

FIGURE 4- CURVES SHOWING SHIPMENTS OF CLAY IN MISSOURI DURING THE PERIOD 1910 THROUGH 1945

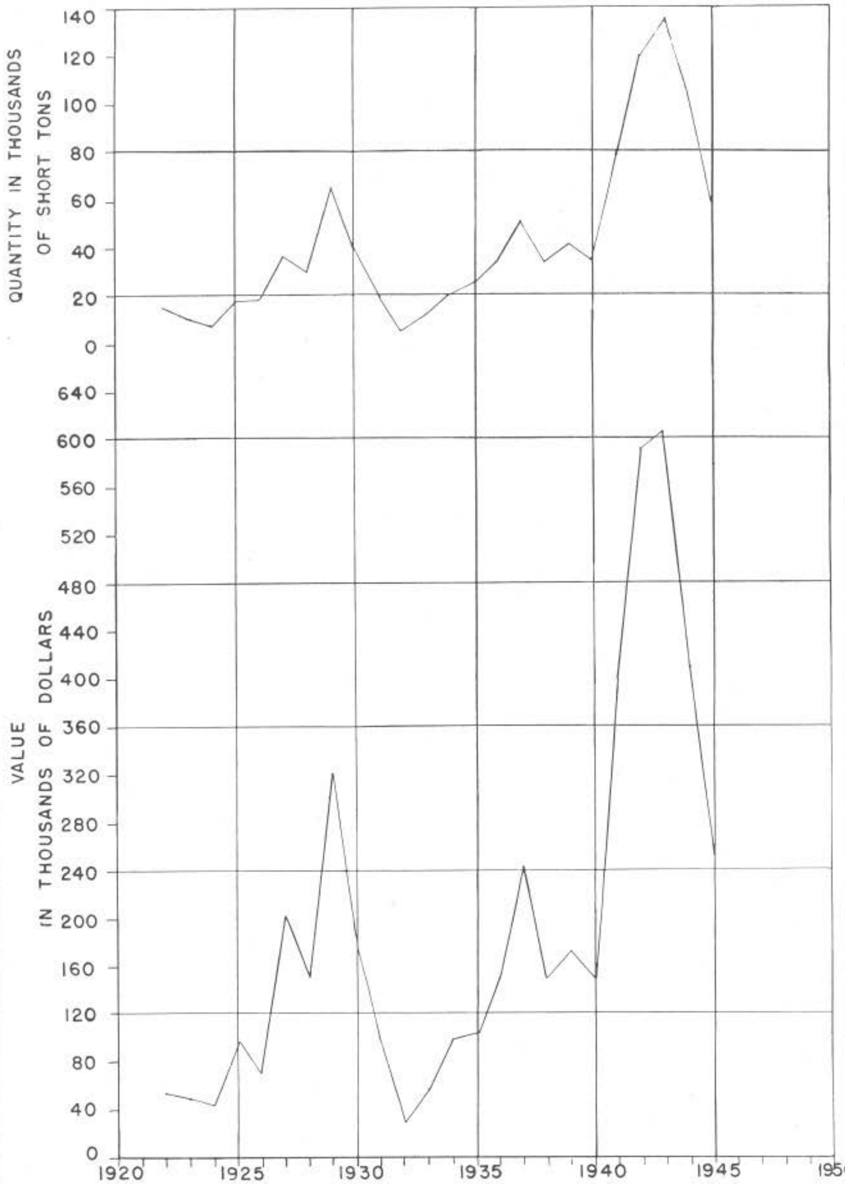

FIGURE 5— CURVES SHOWING PRODUCTION OF DIASPORE AND BURLEY CLAYS DURING THE PERIOD 1922 THROUGH 1945

The value of clay products produced in the State during the period 1910 through 1947 are shown by Figure 3. Statistics covering production of clay products for the past four years are not available, but the values indicated on the curve have been estimated. As the value of production is influenced mainly by the demands for refractories by the steel industry, the curve reflects pertinent business trends. The production of clay products reached a maximum during World War II and has remained at much the same level during the last two years. This may be attributed largely to the reconstruction program and inflationary conditions following the war. It appears that approximately 1,744,411 short tons of clay and shale valued at $4,051,157 were produced in 1947. Table 6 summarizes the annual production and value of clay shipped, and also the value of the clay products produced through 1947.

Shipments of clay made by producers during the period 1910 through 1945 are shown by curves in Figure 4. Fire clay, diaspore, and burley clays constitute the larger part of the shipments. Only a small quantity of kaolin and ball clay has been produced since 1910. Table 7 shows the tonnage distribution and value of clay mined and shipped annually during the period 1939 through 1945. The figures represent production which was sold on the open market or shipped by the producer for his own use. Tonnages listed for 1944 and 1945 include quantities mined from plant pits and burned into clay products by the producer. The curves show that the shipments of clay reached a maximum during the war, but have declined slightly since 1944. Extensive mining and stockpiling of reserve material during the early part of the emergency may account for the increase in shipments. The decline following was due to a shortage in manpower. Clay shipments during 1946 and 1947 have increased owing to the demand created by present construction work.

The shipments of diaspore and burley clays represent quite accurately the production of these raw materials, as they must all be transported to the manufacturing plants. The tonnage and value of these important clays are shown by curves in Figure 5. The production reached a peak in 1943, because of the demands for refractory products during the war emergency. The decrease in production in 1944 and 1945 may be attributed to the lack of manpower and to the rapid depletion of known reserves. The production during the past two years has declined in part because the producers are not finding sufficient new sources of supply. The results of systematic exploration for deposits indicate that the reserve of diaspore may be exhausted in the near future.

Table 6

Annual Production and Value of Clay Shipped[1]; Also Value of Clay Products in Missouri

Year	Amount and Value of Clay Sold						Gross Value of Clay Products
	Refractory Clays		Other Clays		Total Clays		
	Short Tons	Value	Short Tons	Value	Short Tons	Value	
Prior to 1899	....	....	....	....	....	....	$101,227,188
1899	90,599	$347,493	6,726	$27,907	97,325	$375,400	3,666,616
1900	107,143	192,094	17,523	55,190	124,666	247,204	3,736,567
1901	142,577	275,388	11,689	19,945	154,266	295,333	4,474,553
1902	117,187	130,020	4,214	4,842	121,401	134,862	5,166,414
1903	185,328	341,012	5,794	4,525	191,122	345,537	5,661,607
1904	181,209	311,970	4,229	6,528	185,508	318,498	5,481,504
1905	166,539	302,609	6,185	19,816	172,724	322,425	6,203,411
1906	158,845	346,437	6,413	19,356	165,258	365,793	6,696,275
1907	167,043	428,349	4,259	15,204	171,302	443,553	6,898,871
1908	124,970	238,747	31,788	25,777	156,758	264,524	5,631,456
1909	205,792	420,911	8,735	41,757	214,527	462,668	7,440,183
1910	282,834	488,365	4,611	21,068	287,445	509,433	7,087,766
1911	215,468	498,179	12,223	13,909	227,691	512,088	6,274,353
1912	287,925	552,514	7,776	9,792	295,701	562,306	6,412,861
1913	235,606	465,900	2,426	4,3 7	238,032	470,277	6,602,076
1914	203,755	432,786	5,426	30 917	209,181	463,703	6,077,284
1915	303,432	604,777	4,953	36,263	308,385	641,040	5,431,569
1916	435,620	940,309	3,963	48,575	439,583	988,884	7,640,995
1917	491,674	1,306,721	5,593	79,617	497,267	1,386,338	10,291,977
1918	452,792	1,101,652	11,654	91,344	464,446	1,192,996	9,155,088
1919	339,833	982,126	1,552	21,907	341,385	1,004,033	10,997,949
1920	440,728	1,397,080	8,256	16,109	448,984	1,413,189	17,474,542
1921	255,794	929,774	989	8,361	256,783	938,135	10,668,691
1922	409,865	1,226,953	2,263	11,669	412,128	1,238,622	11,746,008
1923	491,211	1,607,927	4,586	16,862	495,797	1,624,789	17,903,774

Table 6

Year	Amount and Value of Clay Sold						Gross Value of Clay Products
	Refractory Clays		Other Clays		Total Clays		
	Short Tons	Value	Short Tons	Value	Short Tons	Value	
1924	453,972	$1,422,942	5,598	$ 18,515	459,570	$1,441,457	$ 16,338,161
1925	447,062	1,442,456	5,944	21,424	453,006	1,463,880	17,521,866
1926	452,449	1,539,271	8,297	31,755	460.746	1,571,026	17,618,931
1927	409,520	1,669,551	6,970	24,241	416,490	1,693,792	16,392,171
1928	420,586	1,425,564	5,440	17,080	426,026	1,442,644	14,891,273
1929	490,069	1,770,896	7,630	26,552	497,699	1,797,448	14,994,548
1930	405,880	1,233,287	6,947	42,500	412,827	1,275,787	12,517,707
1931	212,782	709,645	6,399	28,962	219,181	738,607	6,442,039
1932	127,776	508,590	1,460	9,090	129,236	517,680	3,897,558
1933	176,269	708,291	900	4,836	177,169	713,127	5,572,752
1934	222,403	957,349	619	4,505	223,022	961,854	6,323,896
1935	267,523	999,953	835	6,909	268,358	1,006,862	7,443,931
1936	471,546	1,331,432	700	4,9 0	472,246	1,336,382	10,795,047
1937	519,316	1,525,519	245	3,720	519,561	1,529,239	14,383,035
1938	258,656	904,522	62	244	258,718	904,766	9,369,683
1939	384,567	1,171,643	98	386	384,665	1,172,029	12,023,348
1940	487,650	1,391,045	10,500	9,887	498,150	1,400,932	13,758,734
1941	794,705	1,782,139	11,108	16,203	805,813	1,798,342	16,478,920 [2]
1942	1,110,962	2,450,752	21,880	17,418	1,132,842	2,468,170	23,065,106
1943	1,231,305	2,526,315	10,669	11,983	1,242,174	2,538,298	25,397,652
1944	1,215,173	2,153,551	233,657	126,506	1,448,830	2,280,057	25,000,000 [2]
1945	1,090,084	2,136,855	265,265	174,805	1,355,349	2,311,660	25,000,000 [2]
1946	1,173,332	2,823,205	515,897	334,482	1,689,229	3,257,687	25,500,000 [2]
1947	1,205,971	3,714,812	538,440	336,345	1,744,411	4,051,157	25,600,000 [2]
						Total........	$662,375,936

[1]Tonnage and value of clays for 1945 through 1947 include all clays used by processors. Production data prior to 1945 are those clays sold or shipped and do not include clay converted into clay products or cement in integrated plants at mine or pit.
[2]Estimated.

Table 7

Shipments of Clay Mined in Missouri

Year	Fire Clay		Diaspore and Burley		Miscellaneous Clay and Shale		Total Clay Shipped	
	Short Tons	Value	Short Tons	Value	Short Tons	Value	Short Tons	Value
1939	344,072	$ 997,499	40,495	$ 174,144	98	$ 386	384,665	$1,172,029
1940	453,291	1,234,442	34,276	153,472	10,583	13,018	498,150	1,400,932
1941	714,808	1,376,466	78,897	405,673	11,108	16,203	804,813	1,798,342
1942	991,605	1,859,628	119,357	591,124	21,880	17,418	1,132,842	2,468,170
1943	1,096,149	1,921,454	135,156	604,861	10,869	12,583	1,242,174	2,538,898
1944	1,107,739	1,699,569	107,434	453,982	233,657	126,506	1,448,830	2,280,057
1945	1,031,977	1,883,441	58,107	253,414	265,265	174,805	1,355,349	2,311,660
Totals.........	5,739,641	$10,972,499	573,722	$2,636,670	553,460	$360,919	6,866,823	$13,970,088

History of Clay Mining and Industry. The first clay to be mined and fashioned into ceramic ware in Missouri was that mined by pre-historic Indians long before the coming of white men. It was sometime after the first French communities along the Mississippi River were settled that common brick were made for chimneys and the more pretentious buildings. The early history of the clay industry in Missouri has not been compiled, but it is certain that earthenware and stoneware potteries were among the early manufacturing enterprises. Such potteries supplied the needs of the pioneer for crocks, jars, and kitchenware. It is not known when the first stoneware plant was established, but the Caldwell Pottery at Caldwell, Callaway County, was started in 1827 and the Booneville Pottery at Booneville, Cooper County, was started in 1840.

The first efforts to make firebrick in St. Louis began about 1845 when a small plant was erected on Gravois Road near Meramec Street. The industry began to grow shortly thereafter. In 1855, Richard Howe and a Mr. Hamilton established plants at Cheltenham, west St. Louis. Other plants were soon established and the city of St. Louis became and is yet an important center of quality refractories.

Building brick manufacture had been established prior to the firebrick industry and has continued a large industry to this day. Sewer tile and drain tile are also important business enterprises which use many thousands of tons of clay annually.

Paving brick, which were much in vogue between 1890 and 1915, are now but seldom used.

Uses of Clay. Clay has a multitude of uses. The refractory clays which make up about three-fourths of the clays mined in Missouri are utilized to make firebrick and fire clay cements. High duty, quality-made firebrick are manufactured to exacting specifications at Farber, Fulton, Mexico, St. Louis, Vandalia, and Wellsville. The brick are used as linings in the furnaces of the iron and steel, copper, lead, zinc, lime, cement, and magnesia industries, and in the fireboxes of steam-generating equipment at power plants.

The shales and other clays go into the manufacture of cement, sewer pipe, drain tile, chimney linings, and various types of building brick.

At present the stoneware industry and potteries produce articles made for the tourist trade, as well as flowerpots and other specialties.

Another interesting and important use of certain clays is in the manufacture of Haydite, an artificial light weight aggregate.

Stephen J. Hayde of Kansas City, Missouri, developed Haydite shortly before World War I. His product gained wide recognition in 1917 and 1918 when the United States government adopted it as a light weight aggregate to make concrete ships. At that time it was manufactured at the Atlas Cement plant at Hannibal, Missouri, and at the Los Angeles Pressed Brick Company plant in the State of California. At present the Carter-Waters Corporation of Kansas City, Missouri, produce Haydite which is sold for aggregate in concrete blocks and monolithic concrete. Concrete made with Haydite aggregate is lighter in weight and has better insulation properties than standard concrete. It will also take nails so that interior finishing can be nailed or screwed directly to it.

COAL

Production of Coal in 1946 and 1947. In 1946 the production of bituminous coal from Missouri was 3,732,815 tons, a decrease of 6.3 per cent from the previous year. In 1947, however, production was 4,020,000 tons, an increase of 7.7 per cent above 1946.

Searight[1] estimates the 1947 production was sold at the mines for approximately $13,500,000, whereas the 1946 production was valued at $10,432,591. Of the 1947 production, Searight says, " . . . nearly one-fourth (23.1 per cent) was used in the operation of railroads. Nearly 30 per cent (28.9 per cent) of it was put to industrial uses and approximately 27 per cent (27.4 per cent) went to retail dealers to be used in heating homes and other buildings." Most of the remainder was shipped for use in other states, particularly in Iowa.

Figure 6 is a graph showing the annual coal production from 1840 through 1947 and the annual value of that production from 1890 through 1947. The graph shows that production of Missouri coal increased sharply between 1915 and 1921 to a high of 5,670,549 tons and dropped precipitously to 2,480,880 tons in 1924. At no time since, despite the great business depression of the thirties, has coal production been so little, and at no time since has it reached the high of the World War I period. Table 8 presents the record of coal production beginning with 1840.

Coal Mining in Missouri. When Captain Zebulon Pike traveled up the Osage River of Missouri in 1806, he reported that the river bank near old Fort Carondelet contained a bed of coal[2]. We do not know that this was the first discovery, nor do we

[1]Searight, Walter V., Missouri Geol. Survey Inf. Circ. no. 3, 1949.

[2]Shepard, E. M., Early History and Exploration: Geology of Vernon County, Missouri Bur. of Geology and Mines, vol. XIX 2d ser., p. 18, 1926.

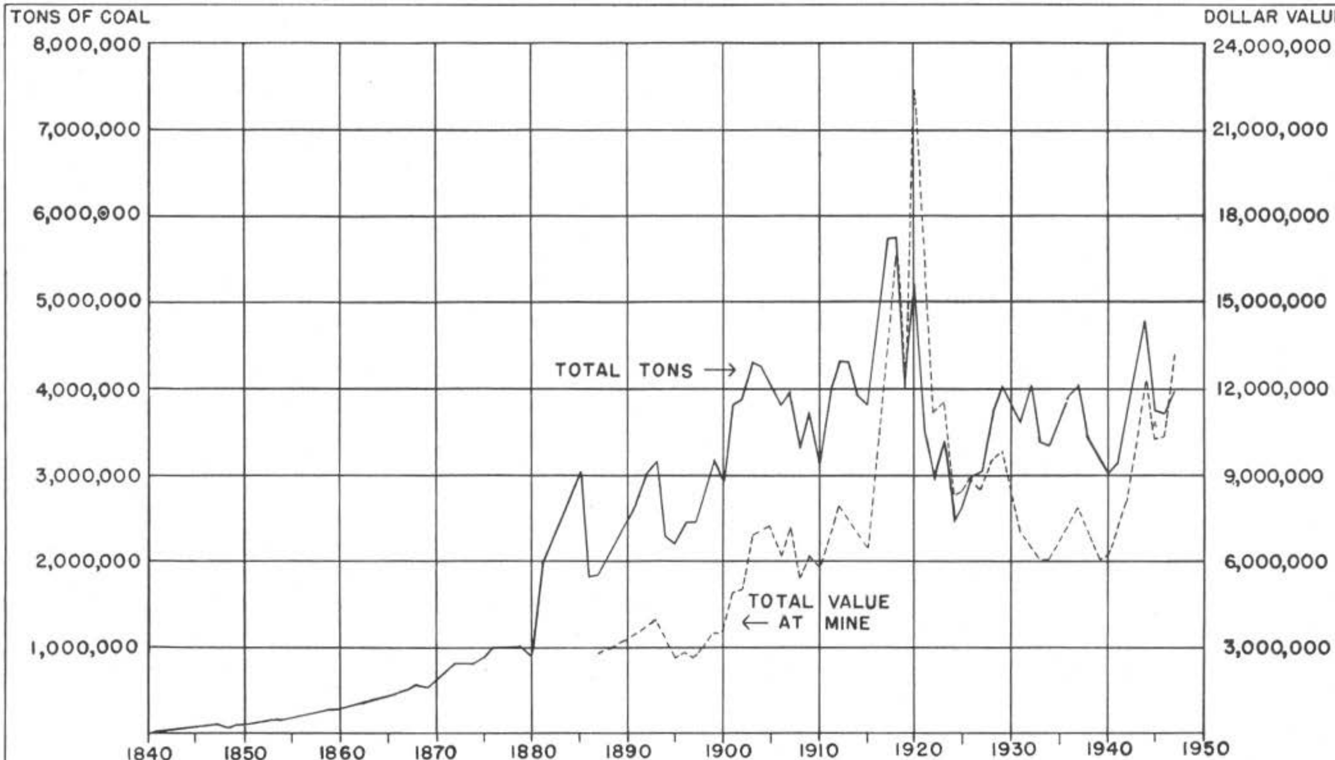

FIGURE 6 — CURVES SHOWING PRODUCTION OF COAL IN MISSOURI DURING THE PERIOD 1840 THROUGH 1947

know when coal was first mined in Missouri; but we do have a record that 249,302 bushels of coal[1] or about 10,000 short tons were mined in 1840. Since then, there has been an annual production which supplies up to a third of the State's need for coal.

Table 8

Annual Production and Value of Coal Mined in Missouri

Year	Short Tons	Value	Year	Short Tons	Value
1840	9,972		1894	2,383,322	$ 3,013,075
1841	12,000		1895	2,228,081	2,675,690
1842	15,000		1896	2,420,147	2,741,711
1843	25,000		1897	2,429,388	2,684,757
1844	35,000		1898	2,838,152	3,148,862
1845	50,000		1899	3,191,811	3,582,110
1846	68,000		1900	2,995,022	3,643,975
1847	80,000		1901	3,802,088	4,716,331
1848	85,000		1902	3,890,154	5,325,832
1849	90,000		1903	4,265,328	6,730,515
1850	100,000		1904	4,241,912	7,003,078
1851	125,000		1905	3,983,378	7,147,665
1852	140,000		1906	3,758,008	6,352,913
1853	160,000		1907	3,997,936	7,306,125
1854	175,000		1908	3,317,315	5,644,330
1855	185,000		1909	3,756,530	6,319,586
1856	200,000		1910	3,188,965	5,814,381
1857	220,000		1911	3,971,768	6,918,578
1858	240,000		1912	4,339,856	7,633,864
1859	260,000		1913	4,318,125	7,468,308
1860	280,000		1914	3,935,980	6,802,325
1861	300,000		1915	3,811,593	6,595,918
1862	320,000		1916	4,742,146	9,044,505
1863	360,000	$92,928,639	1917	5,670,549	13,755,864
1864	375,000		1918	5,667,730	17,126,498
1865	420,000		1919	3,979,798	12,766,366
1866	450,000		1920	5,369,565	22,230,000
1867	500,000		1921	3,551,621	13,915,500
1868	541,000		1922	2,924,750	11,153,000
1869	550,000		1923	3,403,151	11,575,000
1870	621,930		1924	2,480,880	8,154,000
1871	725,000		1925	2,694,215	8,281,000
1872	784,000		1926	3,008,495	8,950,984
1873	784,000		1927	3,064,343	8,698,000
1874	789,680		1928	3,732,421	9,636,923
1875	840,000		1929	4,030,311	10,023,348
1876	1,008,000		1930	3,864,445	9,016,356
1877	1,008,000		1931	3,620,497	7,248,000
1878	1,008,000		1932	4,069,598	6,654,000
1879	1,008,000		1933	3,432,212	6,175,000
1880	844,304		1934	3,352,283	6,278,000
1881	1,960,000		1935	3,645,996	6,924,000
1882	2,240,000		1936	3,984,999	7,559,000
1883	2,520,000		1937	4,091,394	7,978,000
1884	2,800,000		1938	3,436,118	6,814,000
1885	3,080,000		1939	3,273,550	6,138,603
1886	1,800,000		1940	3,096,741	6,320,770
1887	1,832,731	2,749,096	1941	3,145,288	7,013,745
1888	2,028,104	2,900,189	1942	3,519,877	8,372,358
1889	2,223,477	3,030,414	1943	4,309,636	10,755,849
1890	2,437,399	3,234,351	1944	4,778,652	12,315,606
1891	2,650,018	3,480,866	1945	3,982,724	10,322,177
1892	3,017,285	3,825,828	1946	3,732,815	10,432,591
1893	3,190,442	3,999,681	1947	4,020,000	13,226,000
Totals 1840 through 1947				246,313,001	$550,274,036

1840-1886 Mineral Resources U. S., 1910, U. S. Geol. Survey, p. 154, 1911.
1887-1899 13th Annual Report of the State Mine Inspectors of the State of Missouri for year ending June 30, 1899.
1900-1931 Annual Reports of the State Mine Inspectors of the State of Missouri for respective years.
1932-1947 Minerals Yearbooks 1932 through 1946, and Preprint on Coal from Minerals Yearbook for 1947, U. S. Bur. Mines, U. S. Government Printing Office, Washington, D. C.

[1]Taylor, R. C., Statistics of Coal: Philadelphia, p. 171, 1848.

Coal occurs in the lower or Cherokee group of the Pennsylvanian rocks, which cover western, northwestern, and northern Missouri. The Cherokee group outcrops in a belt extending from Barton County in the southwestern part of the State to Clark County in the northeastern part of the State. The coal beds in this belt are easily accessible and, where of economic thickness, they have been or are being mined. The beds dip gently to the northwest, and thus the coals are deeper in that direction. The chief production has been from Bates, Macon, Lafayette, Barton, Henry, Adair, Randolph, Ray, Vernon, and Johnson counties.

Large scale early mining operations were by underground methods, the coal being brought to the surface through inclined and vertical shafts. However, at many places where the soil and rock overburden were thin, the coal was exposed by stripping with horse-drawn scrapers and mined from the surface. As the years progressed, strip-mining costs were reduced, and that method became more common where the nature of the terrain and overburden permitted its use. By 1915, Missouri was second among the states in the amount of coal so mined with 655,670 tons. The all-time high demand for coal during 1917 through 1921 further stimulated the development of both strip and shaft mining, but during the depressions that followed many of the higher-cost underground mines were closed. By 1929, 1,800,000 of the 4,030,000 tons of coal produced were mined from strip pits. This trend continued until in 1944 when 4,050,234 tons or 84.8 per cent of the total tons mined were by strip methods. In 1945, the percentage increased to 85.2 per cent or 3,492,302 tons of the 3,982,724 total tons produced, and in 1946 almost 90 per cent, or 3,340,921 out of 3,732,815 tons were mined as a result of stripping operations. The figures are not yet available for 1947.

In 1944, Missouri strip mines produced 14.51 tons of coal per man-shift, while the corresponding amount for underground mines was but 2.8 tons per man-shift. The latter rate is well below the national average, because Missouri underground mines are not as fully mechanized as are those of the nation as a whole, and the beds are not as thick as they are in many mining districts. In 1944, 83.7 per cent of the coal from Missouri's underground mines was machine-cut, but all was hand-loaded. Throughout the nation as a whole for the same year, 90.5 per cent of the coal mined by underground means was machine-cut and 70.5 per cent of it was mechanically loaded.

Future of Missouri Coal Production. In the marketing area in which Missouri coal is sold, more heat units can be purchased for a dollar spent on coal than for either petroleum or natural gas. In the same area, Missouri coal has the advantage over out-of-state coal with its higher freight cost. As far as can be foreseen, these factors will continue to exist and thus provide Missouri coal with a dependable domestic market in the northern and northwestern part of the State.

It is obvious that many underground mines are marginal producers when the average production is but 2.8 tons of coal per man-shift. Such mines cannot long compete with out-of-state coal or that mined by strip methods within the State. It is probable that the operators mining coal that is thicker than 3 feet will materially increase productivity in underground mines by mechanical loading, or similar devices, while many of those working the thinner coals will suspend operations until the development of new mining techniques or a change in the demand.

Uses of Coal. Coal is a highly complex combination of organic and inorganic compounds from which almost all things are possible. Indeed, man has made tens of thousands of products from coal. It heats his home, powers his factories, reduces his metals, generates his electricity, fertilizes his fields, provides him with medicines, and forms the basic ingredient of his nylon, plastics, dyes, and perfumes.

During the years 1944 through 1947 the nation's coal was distributed to consumers as follows: (All figures are in thousands of short tons.)

	1944	1945	1946	1947
Collieries	2,712	2,442	2,250	2,489
Foreign ships	1,559	1,785	1,381	1,689
Power utilities	78,887	71,603	68,739	86,017
Railroads	132,049	125,120	110,166	112,500
Coking plants	105,296	95,349	82,999	104,664
Steel mills	10,734	10,084	8,603	10,048
Cement plants	3,789	4,215	6,969	7,852
Other industrials	131,898	127,164	118,659	122,038
Retail dealers	124,906	121,805	100,586	99,163
Exports in excess of imports	25,398	27,480	40,764	68,600
	617,228	587,047	541,116	615,060

This tabulation shows that power plants, railways, and various industrial plants, together with household buying for domestic needs, account for most of the demand. Of the industrial users, the iron and steel industry are the heaviest consumers, for not only does that industry directly consume coal for power and heat, but it also requires that 80 to 120 million tons of coal be coked annually to provide metallurgical coke for reducing the iron ores to pig iron. Approximately 80 per cent of all coal coked is for the iron-steel industry.

A ton of coal coked in a by-product oven yields approximately 1,420 pounds of coke, 10,260 cubic feet of gas, 55 pounds of coal tar, 20 pounds of ammonium sulphate, and 19 pounds of light oils. Much of the by-product gas and tar is used in steel plants to heat boilers and metal. The remainder is sold to other industrial and domestic users in either crude or refined form. Pyridine bases, ammonia, and ammonium thiocyanate are recovered from the gases. The coal tar is distilled and scrubbed to recover phenol, cresols, cresylic acid, crude anthracene, pitch coke, and road tar; the light oils are refined to produce benzol, toluol, naptha, and xlyol. It is this group of compounds that form the chemical raw materials from which aspirin, sulfa drugs, disinfectants, food colors, perfumes, dyes, plastics, explosives, solvents, and a host of other chemical marvels are made.

COBALT

The demand for cobalt was substantially less during 1946 and 1947 than during World War II. As a result, the St. Louis Smelting and Refining Division of the National Lead Company suspended production of cobalt-nickel concentrates at its Fredericktown plant. Some calcines (roasted concentrate) were shipped to the Pyrites Company of Wilmington, Delaware, for reduction in 1946, and a somewhat smaller amount was marketed in 1947. The Missouri Geological Survey is not at liberty to publish the figures on this production.

In the past few years the uses of cobalt have increased greatly and because of its importance, it is on the list of metals critical to the welfare of the nation. The largest use of cobalt is in the manufacture of stellite-type alloys which contain 45 to 55 per cent cobalt, 30 to 35 per cent chromium, and 12 to 17 per cent tungsten. Stellite is used to make heavy-duty, high-temperature, high-speed cutting tools and dies for manufacturing purposes. Among other important and critical uses for special cobalt alloys is the manufacture of parts for gas turbines, jet aircraft engines, and turbo-superchargers. These alloys must be capable of maintaining their strength, corrosion and wear resistance at temperatures of 1200 to 1600 degrees Fahrenheit.

Another very important use of cobalt is the manufacture of the permanent magnet alloys, Alnico and Vicalloy, as well as other magnet alloys. Many improvements in the efficiency of electrical apparatus and sound transmitting equipment are due to the development of this series of alloys. Important amounts of cobalt are used in the manufacture of valve steels, special welding rods, and in electroplating. It is also used in making porcelain enamels and for giving glass blue coloration.

Another very important use is that of cobalt oxide as a catalyst to aid in the manufacture of ammonia and in the synthesis of gasoline from coal. This last use will probably increase in importance as our oil resources become depleted and we turn to the liquefaction of coal.

History of Cobalt Mining in Missouri. Cobalt was mined in Missouri as early as 1844 or 1845 when a small furnace was built in Madison County to process the complex copper-nickel-cobalt ores from the Copper Mine northwest of Fredericktown. A total of 225 tons of matte containing copper, cobalt, and nickel was shipped to England in the period 1845 to 1848. There is no basis for estimating the amount of cobalt that may have been recovered, but it seems probable it was at least 12,500 pounds. The mine was in almost continuous operation from 1857 to 1864, as the nickel associated with the cobalt was in demand for nickel

Table 9

Annual Production and Value of Cobalt in Missouri

Year	Pounds[1]	Value[1]	Year	Pounds	Value
1844-1846	12,500	$15,000	1899	8,060	$15,100
1847-1856	9,000	13,500	1900	5,310	10,540
1857-1863	24,000	36,000	1901	10,520	24,048
1864-1868	12,000	18,000	1902	2,940	6,714
1869-1881	30,000	45,000	1903	94,450	228,000
1882	2,600	6,780	1904	17,320	42,600
1883-1884	18,000	27,000	1905	None	......
1885	6,620	14,680	1906	None	......
1886	6,800	13,140	1907	2,150	4,215
1887	14,420	25,860	1908	[2]	[2]
1888	6,680	14,290	1909	65,700	76,500
1889	10,970	27,850	1910-1917	......	......
1890	5,340	12,870	1918	[2]	[2]
1891	5,670	13,140	1919	56,000	122,452
1892	6,120	14,540	1920	102,000	262,801
1893	6,630	12,450	1921-1943	......	......
1894	5,330	8,420	1944	[2]	[2]
1895	11,380	15,950	1945	[2]	[2]
1896	8,420	14,300	1946	[2]	[2]
1897	15,350	26,100	1947	[2]	[2]
1898	4,920	8,360			
Totals from 1844 through 1947[3]......................				587,200	$1,176,200

[1]Estimated.
[2]The Missouri Geol. Survey is not at liberty to publish these production figures.
[3]The total excludes the very important production years 1944-1947, and also those of 1908 and 1918.

coinage. It is estimated that 60,000 of the 246,000 pounds of nickel coined during 1857 through 1864 were from the Mine La Motte property and that the cobalt recovered in refining the nickel may have been 35,000 pounds. An unknown part of this production was probably from the Buckeye tract near Fredericktown.

In 1870 the La Motte Lead Company rehabilitated the Copper Mine plant and made many small shipments of a complex matte containing cobalt, but there is no record of the production until 1882 when it is known that the value of combined cobalt and nickel was $12,500. An almost continuous small production was made each year thereafter until 1904, when the furnace was shut down.

In 1907 the North American Lead Company erected a smelter to treat the ores from the Buckeye Mine. It operated until 1910 producing nickel, cobalt, and copper. In 1916 the Missouri Cobalt Company acquired the property, remodeled the reduction plant, and in 1918 resumed production of cobalt, nickel, and copper. In October 1920 the plant was shut down, and no cobalt was produced again until July 1944, when the St. Louis Smelting and Refining Division of the National Lead Company began production from the upper Schulte and O'Brien tracts southeast of Fredericktown. This company produced concentrate containing many hundred thousand pounds of cobalt from then until September 1946, when the cobalt-nickel-copper unit of the concentrating plant was put out of production by the lessened demand.

COPPER

During 1946 and 1947, the production of copper declined from the all-time high established in 1945, but remained well above the production rate which existed prior to World War II.

Statistics on copper production compiled jointly by the Missouri Geological Survey and the U. S. Bureau of Mines are presented in Table 10. The data show that 3,520,000 pounds of the metal were produced in 1947, as compared with 3,714,000 pounds in 1946 and 6,798,000 pounds in 1945. The known recorded production since 1880 has totalled 46,174,162 pounds valued at $6,842,145.

Brief History of Copper Mining in Missouri. The first copper discovery in Missouri is believed to be that made in Shannon County by hunters in the early 1800's. When news of the discovery reached the Mississippi River settlements, a group of Ste. Genevieve residents dispatched Joseph Slater to the discovery area to investigate. Slater arrived in the Current River country in 1837 or 1838. After checking the discovery, he purchased

Table 10

Annual Production and Value of Copper in Missouri

Year	Pounds	Value	Year	Pounds	Value
1838-1840	600,000[1]	$120,000[1]	1923	202,556	$27,776
1841-1843	......	......	1924	182,811	23,948
1844-1846	60,000[1]	12,000[1]	1925	12,100	1,718
1847-1856	......	......	1926	1,077,000	150,780
1857-1863	60,000[1]	15,600[1]	1927	451,000	59,081
1864-1869	......	......	1928	65,000	9,360
1870	48,000[1]	10,080[1]	1929	2,240	394
1871-1881	......	......	1930	176,600	22,958
1882	294,695	55,992	1931	......	......
1883	260,306	39,046	1932	......	......
1884	230,000	32,200	1933	......	......
1885-1905	630,000[1]	81,900[1]	1934	46,276	3,702
1906	54,347	10,489	1935	67,660	5,616
1907-1910	3,150,000[1]	400,700[1]	1936	382,000	35,144
1911	640,411	80,051	1937	538,000	65,098
1912	440,725	72,719	1938	......	......
1913	576,204	89,312	1939	......	......
1914	44,463	5,914	1940	1,370,000	154,810
1915	402,160	70,378	1941	2,800,000	330,400
1916	386,200	95,005	1942	2,600,000	314,600
1917	365,013	99,649	1943	2,680,000	348,400
1918	577,665	142,683	1944	6,604,000	891,540
1919	1,617,200	300,799	1945	6,798,000	917,730
1920	1,512,539	278,307	1946	3,714,000	601,668
1921	137,591	17,749	1947	3,520,000	739,200
1922	797,400	107,649			
Totals from 1838 through 1947				46,174,162	$6,842,145

[1]Estimated.

mining rights from the hunters. In the next two or three years it is reported[1] that 1,500 tons of smelting ore were produced from the Slater and Jerktail mines. Part of this tonnage was smelted in Shannon County and the remainder was shipped to Swansea, Wales, to be smelted. It seems probable that the hand-picked ore contained at least 20 per cent recoverable copper or about 600,000 pounds of copper worth approximately $120,000. Slater lost title to the mines in 1841. Successive owners worked the property with but small success, and production since the initial operation has been unimportant. The Sutton mine, a few miles from the Slater mine, was developed in 1924. During 1925 and 1926, two cars of ore containing 16,905 pounds of copper were shipped.

About the time Slater arrived in Shannon County, H. N. Tong discovered the Copper Mine in Madison County on the Mine La Motte domain. He worked it for its copper content, but the ores

[1]Williams, C. P., Industrial Reports: Geological Survey of Missouri, 1877, p. 164.

were in a refractory combination with nickel and cobalt, and this made reduction difficult. In 1844 or 1845, a small smelting furnace was built to process the ores, and the complex copper-nickel-cobalt matte produced was shipped to England for further reduction. In all, about 225 tons, containing perhaps 60,000 pounds of copper, were shipped between 1845 and 1848. In 1870, the La Motte Lead Company reopened the Copper Mine and constructed a furnace for the partial reduction of copper, nickel, and cobalt ore. A small production was reported almost every year from then until 1904, when the furnace was shut down.

Copper minerals in combination with nickel and cobalt minerals were also found at several other mines in the vicinity of Fredericktown, Madison County. Usually such minerals were mixed with the more common lead ores, but certain ore bodies on the Buckeye tract of the Missouri Cobalt Company and, more recently, on the upper Schulte and O'Brien tracts of the St. Louis Smelting and Refining Division of the National Lead Company, have been mined chiefly for the contained copper, nickel, and cobalt.

The ore at the Buckeye Mine was discovered in 1843 by John Craddock, who sold out to the organizers of the Buckeye Copper Mining Company. A small but unknown production was made between 1844 and 1849 and again in 1860 to 1863. In 1901, the Buckeye tract was purchased by the North American Lead Company, who erected a smelter in 1907 to treat the ores. The plant operated until 1910. In 1916, the property was taken over by the Missouri Cobalt Company, who remodeled the reduction plant and operated the mine from 1918 until October 1920. During the series of operations from 1903 through 1920, approximately 6,000,000 pounds of copper were produced.

In July 1944, the St. Louis Smelting and Refining Division began production of copper, nickel, and cobalt concentrates, as well as of lead, from their properties southeast of Fredericktown. In September 1946, the company stopped mining the higher grade nickel-cobalt ores with which much copper is associated, but copper concentrate is still recovered in the mill from lead-copper ores.

In addition to the copper mineralization enumerated above, there has been a continuous but small production of copper from the lead mines of the St. Joseph Lead Company and other lead mines in southeast Missouri. Chalcopyrite ($CuFeS_2$) is commonly associated with the lead ores and is concentrated with the lead sulfide (PbS), from which it is recovered, in the lead refineries of the St. Joseph Lead Company at Herculaneum and of the

Federal plant, American Smelting and Refining Company at Alton, Illinois.

Minor amounts of copper have been mined from the Cornwall and Swansea-Herzog mines in Ste. Genevieve County.

Uses of Copper. Copper is one of the most useful of the metals and probably the first one used by man.

In times of peace more than half of all the copper used annually in the United States goes into the manufacture of electrical apparatus, such as electrical generators and motors, power and light lines, telephone, telegraph, radio equipment, and accessories for them. The remainder is largely used in the manufacture of brass, bronze, and other copper alloys which enter into building construction, ship building, the automotive and aircraft industries, and in the manufacture of cartridge cases.

In times of war, the uses remain much the same, but a larger percentage of the total is channeled to the military. More copper is required for the manufacture of cartridge brass. Larger amounts are used in accelerated naval and other ship construction, and more goes to meet the additional requirements for military vehicles, such as aircraft, tanks, and artillery.

The chemical industry also uses considerable copper to produce blue vitrol or hydrous copper sulfate, copper acetate, copper carbonate, and the oxides of copper. Blue vitriol, the most common of these chemicals, is produced commercially by the action of sulfuric acid on copper or copper oxide. It is used in coppering steels for layout work, in copper-plating baths, certain dyestuffs, and fungicides. Copper acetate is an ingredient of some paints, lacquers, and inks; and copper carbonate is employed in special paint pigments. Cuprous oxide, a reddish powder formed by the oxidation of copper at high temperatures, is used to give a red coloration to glass and ceramics. It is also used to make an ingenious alternating current rectifier. This device functions because electric current will flow readily from cuprous oxide to metallic copper, but will resist flow in the opposite direction, thus rectifying alternating current to form pulsating direct current. Cupric oxide, a dark black-brown powder, is used to produce green or blue color in ceramics and glass.

The great usefulness of copper is due to its high electrical and thermal conductivity, combined with the ease with which it is worked. It also has a high degree of corrosion resistance. Much copper is reclaimed each year, as very little of the metal is lost through wear or corrosion. Scrap copper from worn-out, obsolete or broken equipment is remelted, refined, and fabricated into new equipment. In 1946, such reclaimed scrap was equal to 66 per cent of that year's new production.

GALLIUM

In 1946 the Eagle-Picher Lead Company of Joplin, Missouri, was the only producer of gallium in the entire United States. The gallium was obtained in the smelting of zinc sulfide ores from Oklahoma, Kansas, and Missouri.

Gallium is a remarkable metal in that it remains liquid over a greater temperature range than any other element. It melts at 86 degrees Fahrenheit but does not boil short of 3092 degrees Fahrenheit. Allan F. Matthews[1] reports that gallium was used "by the Manhattan project as a volatile carrier to sweep out impurities during uranium analyses."

The amount of gallium produced has not been published, but it is known to be but a few pounds. During World War II the price averaged about $3.00 a gram, or $1,360 a pound.

Federal law has prohibited the export of gallium since October 17, 1946, except by special permission.

GERMANIUM

The only commercial production of germanium in 1946 was the several hundred pounds produced by the Eagle-Picher Lead Company of Joplin as a by-product of the zinc ores from the Tri-State District of Oklahoma, Kansas, and Missouri. No data are yet available on production in 1947. About one pound of germanium is recovered during the smelting of 1500 tons of zinc ore.

Germanium has high electrical resistance, expands when frozen, and has anti-corrosive properties. The chief use is in electronic equipment, particularly in radar rectifiers.

It has been employed as a catalyst in the hydrogenation of coal and is being alloyed experimentally with several of the metals. The metal was sold at $180 a pound in 1946.

INDIUM

Another and relatively rare metal which was produced durinf World War II by the Eagle-Picher Lead Company was indium. It, like cadmium, gallium, and germanium, is recovered in the smelting of zinc concentrates from the Tri-State district. The demand for indium decreased in 1945 and none was pro-

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[1]Matthews, Allan F., author of chapter Minor Metals, U. S. Bur. Mines Minerals Yearbook, p. 1275, 1946.

duced in 1946. Indium, which sells for $2.25 a troy ounce, was chiefly used as a thin plating on lead for special bearing surfaces. The indium improved corrosion resistance, allowed better retention of oil film, and increased the strength of the bearing. Certain low-melting alloys and other special plating alloys may also contain indium.

IRON ORE AND PIG IRON

Iron Ore in 1946 and 1947. In 1946 Missouri produced 156,350 long tons of iron ore, an increase of 39 per cent over that in 1945. In 1947, production increased an additional 9.6 per cent to 171,356 gross tons. The value of the production is not reported by the Federal Bureau of Mines, as less than three producers contributed to the total. The State Mine Inspector[1], however, reports the value of the iron ore produced in 1946 to be $754,188 and that for 1947, $901,922. The ore was derived solely from the Iron Mountain Mine operated by the M. A. Hanna Company. It was shipped to furnaces at Granite City, Illinois, as well as to other furnaces.

Brief History of Iron Mining and Smelting in Missouri[2] [3]. Iron ore was first mined and smelted in Missouri about 1815 when Ashebran's furnace was built and placed in operation two miles east of Ironton. This furnace, the first operated west of Ohio, used hematite ore mined from nearby Shepherd Mountain.

In 1819 and 1820, the Harrison-Reeves furnace was built three miles southeast of Bourbon, Crawford County, on Thicketty Creek, a tributary of the Meramec River. The next furnace to be built was that of Eversol, Perry, and Ruggles between the towns of Potosi and Caledonia. In January 1829, the Meramec Springs furnace was completed near St. James, Phelps County. The furnace was operated intermittently for thirty years and after being rebuilt was operated again towards the end of the century. The stack of the old blast furnace is still standing.

Other charcoal furnaces put into blast were the Iron Mountain furnaces built in 1846 and 1848 (Iron County), the Pilot Knob furnaces erected in 1848 and 1853 (Iron County), the Scotia built in 1849 (Crawford County), the Franklin or Moselle furnace in 1857 (Franklin County), the Irondale furnace in 1859 (Washington County), the Osage furnace in 1873 (Camden County), the Knotwell or Ozark furnace in 1874 (Phelps County),

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[1]Keith, Charles C., 59th and 60th Annual Reports of Division of Mine Inspection in Missouri, dated, respectively, 1946 and 1947.
[2]Nason, Frank L., A Report on the Iron Ores of Missouri: Missouri Geol. Survey, pp. 303-332, 1892.
[3]Cozzens, Arthur B., The Iron Industry of Missouri: vol. XXXVI, The Missouri Historical Review, pp. 48-60, October 1941.

the Midland furnace in 1875 (Crawford County), the Sligo furnace in 1880 (Dent County), and the Nova Scotia furnace in 1881 (Dent County).

Under the stimulus of World War I, two hot blast charcoal furnaces were built in southern Missouri. The first of these was erected about 1916 by the Mid-continent Iron Company at Midco, near Fremont in Carter County. The company operated a complete by-product charcoal plant and produced tar and wood alcohol as well as iron. It operated about eighteen months before being closed. The second furnace was that of the Missouri Iron and Steel Company at Brandsville, Howell County. It was abandoned before completion when the war terminated.

During the nineteenth century, when all but the last two charcoal furnaces were built, great industrial changes were taking place in the iron and steel industry of the nation. Charcoal which had been the dominant fuel for centuries was replaced by coal and coke. In the country as a whole, the use of anthracite exceeded that of charcoal by 1855. By 1869 coke was in greater demand for iron smelting than was charcoal and by 1875 the use of coke predominated in pig iron manufacture. No longer was it necessary for iron furnaces to be in or near forests; no longer was furnace capacity restricted by the difficulties attendant to cutting and coaling the timber from 100 to 150 acres of land for each 1000 tons of pig iron.

The change in fuels resulted in the development of larger furnaces. Several coal- and coke-burning blast furnaces were built in St. Louis. The first was the Pioneer furnace erected in 1863. It operated through 1873, but was torn down and removed in 1874. In 1869 the Vulcan Iron Works built a furnace in south St. Louis at the junction of Davis Street with the Mississippi River. The same firm erected a second furnace in 1872. Four more furnaces were constructed between 1870 and 1872 by the Missouri Furnace Company near 6400 South Broadway. This firm was later known as the St. Louis Blast Furnace Company and one or more of its furnaces operated until 1910. One stack was put in blast again in 1915 and served until 1923. Still another coke-fired blast furnace was that of the Jupiter Iron Works erected in 1873 and remodeled in 1887. These furnaces ranged from 56 to 75 feet in height and were 15 to 20 feet in diameter. Ores were obtained chiefly from the Iron Mountain and Pilot Knob mines. The coking coal was chiefly Connellsville from Pennsylvania.

In 1872, the blast furnaces of Missouri produced 101,158 tons of pig iron. By 1887, pig iron production was 123,780 long tons and the tonnage of iron ore produced was 427,785 long tons.

In addition to supplying the Missouri furnaces, the mines shipped iron ores to furnaces in Ohio and Pennsylvania. This area with the advantages of nearby markets, excellent river, lake and rail transportation was also the area nearest to the excellent coking coals of Pennsylvania, West Virginia, and eastern Kentucky. Large-scale, highly-efficient, low-cost pig iron and steel manufacture resulted. The price of a ton of pig iron on the Pennsylvania markets in 1810 was $55.30. As the industry developed the costs declined. In 1873 the price was $42.75, but by 1875 the price was only $25.50. By 1887, the year of maximum production in Missouri, pig iron sales averaged $19.02 a long ton.

Competition to produce cheaper iron resulted in a demand for cheaper ore. That demand was met by the newly discovered iron ores of the Lake Superior region which could not only be mined cheaply but could be transported by boat at very low cost to Lake Erie ports and thence the 60 to 120 miles to the furnaces of Youngstown and Pittsburgh. Shipments of iron ore from Lake Superior ports increased from 2,466,201 long tons in 1885 to 4,764,107 in 1887 to 7,292,643 tons in 1889 to 9,003,725 tons in 1890. In 1900 Lake Superior ore shipments were 19,080,379 tons and by 1907 they were 42,266,668 tons. Such competition rapidly drove the amount offered for Missouri ores from $3.40 a ton in 1883 to an average of $2.20 in 1890, $2.07 in 1893, $1.36 in 1895 and $1.08 in 1897. It was not until 1916 that iron ore prices were again as much as $3.00 per ton at the mine.

In the years from 1887 to 1894, the price of pig iron continued to decline until in the latter year it averaged $9.85 a long ton, and Bessemer steel rails could be purchased at $18.75 a ton. Furnace after furnace was unable to meet the competition and was shut down. From then until the entry of the United States into World War I, Missouri maintained a small intermittent production from one or two furnaces. In 1918, a third furnace was put in operation in St. Louis, and 83,432 tons of pig iron were produced, having an average value of $36.97 at the furnaces. From then on production of pig iron varied considerably until 1925, when the last furnace was shut down.

Table 11 shows the annual production and value of pig iron and iron ore in Missouri from the earliest operations through 1947. It is interesting to note that despite the competition of the Lake Superior mines, Missouri has continued to produce and ship iron ores every year except 1933.

The Iron Ores in Missouri. The iron ores of Missouri are the red or hematite ores (Fe_2O_3), the brown or limonite ores ($HFeO_2$), and magnetite (Fe_3O_4).

Table 11

Annual Production and Value of Iron Ore and Pig Iron in Missouri 1815-1947

Year	Iron Ore			Pig Iron		
	Long Tons	Value Per Ton	Total Value	Long Tons	Value Per Ton	Total Value
1815-1849	100,000	$3.00	$300,000	35,714	$50.00	$1,785,700
1850-1860	310,000	3.00	930,000	98,214	50.00	4,910,700
1861-1869	625,000	3.00	1,875,000	187,500	50.00	9,375,000
1870	316,000	....	....	64,735	33.25	2,152,439
1871	240,000	....	....	65,916	35.125	2,315,300
1872				90,320	48.875	4,414,390
1873				76,367	42.75	3,264,689
1874				67,693	30.25	2,047,713
1875				53,318	25.50	1,359,609
1876	2,582,694	5.00	15,693,470	60,913	22.25	1,355,314
1877				65,683	18.875	1,239,767
1878				42,409	17.625	747,459
1879				75,600	21.50	1,625,400
1880	386,197	4.33	1,672,233	94,239	28.50	2,685,812
1881	604,007	4.50	2,718,031	98,028	25.125	2,462,954
1882				101,461	25.75	2,612,621
1883	295,430	3.40	1,004,462	92,222	22.375	2,063,467
1884	233,235	3.40	792,999	53,606	19.875	1,065,419
1885	234,160	2.70	632,232	45,897	18.00	826,146
1886	379,776	2.60	987,418	66,534	18.75	1,247,512
1887	427,785	2.80	1,197,798	123,780	21.00	2,599,380
1888	217,931	2.60	566,620	81,943	18.875	1,546,674
1889	265,718	2.20	584,580	76,950	17.75	1,365,862
1890	232,835	2.20	512,237	89,771	18.40	1,651,786
1891	138,356	2.50	345,890	29,229	17.52	512,092
1892	126,000	2.50	315,000	57,020	15.75	898,065
1893	86,983	2.07	180,055	32,360	14.52	469,867
1894	73,688	1.28	94,321	30,000	9.76	292,800
1895	40,202	1.36	54,675	20,000	11.14	222,800
1896	41,826	1.36	56,883	20,000	10.47	209,400
1897	56,256	1.08	60,756	23,883	12.10	288,984
1898	81,799	1.14	93,251	35,000	9.90	346,500
1899	84,306	1.42	119,715	35,000	18.00	630,000
1900	88,791	1.52	134,962	40,000	18.85	754,000
1901	72,202	1.60	115,523	40,000	15.25	610,000
1902	73,609	1.60	117,774	40,000	20.92	836,800
1903	54,350	1.74	94,569	40,000	19.12	764,800
1904	49,045	1.88	92,205	25,000	14.13	353,250
1905	116,666	1.43	166,832	60,000	16.63	997,800
1906	103,992	1.95	202,784	60,000	19.98	1,198,800
1907	109,273	2.02	220,731	60,000	20.56	1,233,600
1908	95,721	2.21	211,543	60,000	15.96	957,600
1909	112,100	2.34	262,314	60,000	16.25	975,000
1910	78,691	2.15	169,186	55,536	18.26	1,014,213
1911	72,788	2.11	153,716	66,665	16.63	1,108,940
1912	42,120	2.21	92,996	20,000	13.93	278,600
1913	37,134	2.52	93,628	19,000	15.08	271,440
1914	37,554	2.02	75,696	30,000	13.42	402,600
1915	40,190	2.48	99,853	30,000	13.21	396,300
1916	34,914	3.34	116,484	39,018	16.96	661,745
1917	38,771	3.48	134,906	83,266	27.29	2,272,329
1918	71,968	3.76	270,337	83,432	36.96	3,084,136
1919	53,626	4.16	223,144	49,383	33.40	1,649,271
1920	50,825	4.54	230,827	81,682	45.04	3,678,623
1921	36,431	4.65	169,516	17,028	28.19	479,957
1922	58,320	4.20	244,928	10,000	21.98	219,800
1923	54,348	4.56	247,975	4,513	24.68	111,381
1924	79,847	5.07	405,622	21,371	21.41	457,553
1925	40,043	3.83	153,420	3,758	20.08	75,461
1926	124,371	4.28	532,536	....	....	....
1927	78,605	4.02	315,670	....	....	....
1928	94,899	3.98	377,847	....	....	....
1929	171,456	3.86	661,055	....	....	....
1930	132,749	3.83	508,354	....	....	....
1931	112,055	3.01	337,144	....	....	....
1932	25,418	2.84	72,144	....	....	....
1933	No Production			....	....	....
1934	4,154	3.49	14,490	....	....	....
1935	2,069	4.24	8,764	....	....	....
1936	3,770	4.78	18,031	....	....	....
1937	21,397	2.86	61,187	....	....	....
1938	27,171	1.67	45,279	....	....	....
1939	38,755	1.53	59,185	....	....	....
1940	57,283	2.52	144,069	....	....	....

Table 11

Annual Production and Value of Iron Ore and Pig Iron in Missouri 1815-1947

Year	Iron Ore			Pig Iron		
	Long Tons	Value Per Ton	Total Value	Long Tons	Value Per Ton	Total Value
1941	18,473	3.20	59,192	....	....	....
1942	66,104	3.08	203,463	....	....	....
1943	52,893	2.91	153,997	....	....	....
1944	19,293	5.17	99,560	....	....	....
1945	112,668	4.39	494,147	....	....	....
1946	156,350	4.82	754,188	....	....	....
1947	171,356	5.26	901,922	....	....	....
Averages..	....	$3.61	....	....	$25.95	....
Totals.....	11,374,792	....	$41,111,321	3,292,074	....	$85,435,620

Hematite ores. Hematite ores produced through 1947 have totalled 10,528,926 tons or more than 92 per cent of the State's iron ore production. Commercial mining of hematite has been limited to the hard specular hematites directly associated with the rhyolite porphyry in Iron and St. Francois counties and to the hematite in filled sink structures of the Central Ozark counties. Minor bedded deposits of hematite in the Silurian and Pennsylvanian sediments are described by Crane[1], but they have never been commercially mined.

The filled sink deposits are found in a roughly circular area covering Crawford, Phelps, Dent, Franklin, Iron, Reynolds, Texas, Shannon, Pulaski, Maries, Washington, and Miller counties. The ore deposits occur as filling in circular or elliptical sink structures in the Roubidoux and Gasconade rock formations. The deposits mined have ranged in size from those yielding but a few hundred tons to one producing about one million tons.

The ores are usually soft red hematite with minor amounts of specular hematite and limonite. They may be in the form of compact masses or as boulders of ore mixed with residual clay and chert and perhaps some sandstone from the walls of the sink. These deposits have yielded 3,801,768 tons or about 33.4 per cent of the State's total iron ore production.

The specular hematite ores mined from the rhyolite porphyry at Iron Mountain, Pilot Knob, Shepherd, Russell, Buford, and Cedar Mountains have totaled 6,727,158 tons or 59 per cent of the iron ore credited to Missouri. Of this amount the Iron Mountain Mine has produced about 4,980,000 tons and Pilot Knob Mine about 1,640,000 tons. The ore is chiefly a dense, hard, crystalline hematite, which occurs as primary veins in the porphyry and as replacement masses. At Iron Mountain and Pilot

[1]Crane, C. W., The Iron Ores of Missouri: vol. X, 2d ser., Missouri Geol. Survey, pp. 146-149, 1912.

Knob there were also boulder and "conglomerate" ores, which were formed through the accumulation of weathered vein ore. The veins differ greatly in size. The main vein at Big Mountain (Iron Mountain Mine) was said to be a mass 60 feet wide. The enclosing porphyry is traversed by numerous interconnecting veins which, locally, are so numerous as to constitute low grade ore, which is now being concentrated to blast furnace grade in a jig mill on the property. In 1946, this mill beneficiated 380,536 tons of low grade material to produce 155,152 tons of concentrate. It is interesting to note that in 1891 the surface and conglomerate ores at Iron Mountain were also being beneficiated in jigs.

Brown ores. The brown ores have a wide areal distribution throughout the Ozark region. They are found to some degree in almost every Ozark county. The principal ore-bearing areas, however, are on the south, southeast, and west flanks of the Ozark plateau. Brown ores have been mined commercially in Washington, Madison, Iron, Bollinger, Stoddard, Wayne, Butler, Ripley, Carter, Oregon, Reynolds, Shannon, Howell, Ozark, Douglas, Christian, Greene, Dade, Benton, and Camden counties.

The brown or limonite ores are found as large and small masses scattered through the residual clays or concentrated into larger ledge-like masses. Some of the ores are massive and hard, others are stalactitic or pipe ores, and still others are earthy-ocherous ores. Same of the massive brown ore bodies are the oxidized, near-surface portion of the red ores of the filled sinks, or of pyrite deposits[1] in filled sinks.

The chief impurities of the brown ores are silica in the form of chert or sand grains and unaltered iron sulfides. Frequently the chert is cemented together with limonite to form a breccia-like mass of low grade ore. Clay is another objectionable impurity which, if not removed, may make the ore unacceptable at the furnace.

The clay can be removed by washing the ore in a log washer, but pyrites and silica must be kept out of the shipping ore by selective mining and careful sorting, which may make the cost prohibitive.

The brown ore deposits are numerous and small. They are so extremely variable in both horizontal and vertical extent that surface indications are difficult or impossible to interpret in terms of tonnage.

Reference to Table 12 shows that 845,866 tons of ore classified as brown ore have been shipped to consumers. This amount is about 7.5 per cent of the total iron ore production.

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[1]Grawe, O. R., Pyrites Deposits of Missouri: vol. XXX, 2d series, Missouri Geol. Survey & Water Resources, 1945.

Table 12

Annual Production of Iron Ores in Missouri in Long Tons

Year	Specular Ore in Porphyry	Red and Blue Ores (Filled Sinks)	Brown Ores Primary and Secondary	Total
Prior to 1893	5,097,124	2,449,453	26,015	7,572,592
1893	65,518	19,665	1,800	86,983
1894	45,727	26,741	1,220	73,688
1895	23,551	16,651	......	40,202
1896	14,724	27,042	60	41,826
1897	18,736	37,520	......	56,256
1898	65,553	16,246	......	81,799
1899	51,873	32,100	333	84,306
1900	38,797	39,540	10,454	88,791
1901	59,181	12,729	292	72,202
1902	47,751	17,338	8,520	73,609
1903	26,259	16,517	11,574	54,350
1904	9,841	21,562	17,642	49,045
1905	21,194	56,835	38,637	116,666
1906	12,476	53,165	38,351	103,992
1907	......	63,906	45,367	109,273
1908	8,300	53,789	33,632	95,721
1909	14,194	62,689	35,217	112,100
1910	7,000	49,149	22,542	78,691
1911	17,660	42,819	12,309	72,788
1912	6,557	32,164	3,399	42,120
1913	3,000	30,009	4,125	37,134
1914	1,100	30,954	5,500	37,554
1915	1,400	33,645	5,145	40,190
1916	5,000	22,568	7,346	34,914
1917	6,008	21,370	11,393	38,771
1918	23,597	32,358	16,013	71,968
1919	12,367	32,500	8,759	53,626
1920	11,154	30,000	9,671	50,825
1921	14,681	21,750	......	36,431
1922	36,950	20,088	1,282	58,320
1923	26,382	15,000	12,966	54,348
1924	49,425	23,000	7,422	79,847
1925	4,043	36,000	......	40,043
1926	75,000	45,000	4,371	124,371
1927	47,605	31,000	......	78,605
1928	69,899	25,000	......	94,899
1929	134,181	30,120	4,155	171,456
1930	97,012	35,422	315	132,749
1931	1,588	52,234	58,233	112,055
1932	1,816	6,805	15,797	25,418
1933		No Pro	duction	
1934	350	200	3,704	4,154
1935	649	1,294	126	2,069
1936	1,948	1,822	......	3,770
1937	1,592	1,514	18,291	21,397
1938	91	18,749	8,331	27,171
1939	......	9,340	29,415	38,755
1940	......	13,760	43,523	57,283
1941	......	9,735	8,738	18,473
1942	1,696	15,360	49,048	66,104
1943	96	5,082	47,715	52,893
1944	7,774	2,469	9,050	19,293
1945	108,668	......	4,000	112,668
1946	155,814	......	536	156,350
1947	171,356	......	......	171,356
Totals.........	6,727,158	3,801,768	845,866	11,374,792

Magnetite ore. The small amount of magnetite, which is found with the hematite from Iron Mountain and Shepherd Mountain, is the only magnetite that has been marketed from Missouri. Magnetic surveys made by the Missouri Geological Survey in 1931 and 1932 disclosed an important magnetic anomaly about one mile south of Bourbon, Crawford County[1].

[1]Grohskopf, J. G., and Reinoehl, C. O., Magnetic Surveys: Missouri Bur. Geology and Mines, 57th Biennial Report, Appendix IV, 1933.

In 1942 the Survey called this to the attention of the United States Bureau of Mines. After joint magnetic and electrical resistivity measurements were made by both organizations, the Bureau of Mines drilled four holes to determine if magnetite ore were the cause of the anomaly. Hole 1, which was completed in rhyolite at a depth of 1824 feet, cut through many veins of magnetite a few inches thick. Hole 2, drilled approximately 1500 feet to the north of Hole 1, penetrated four zones of magnetite mineralization, which totaled 125.7 feet in thickness and analyzed 43.5 per cent iron. Deflection Hole 2A checked Hole 2 closely. Hole 3, drilled 500 feet to the north of Hole 2, cut through 58 feet of mineralized rhyolite that contained 43.4 per cent iron in the form of magnetite. Although it is against the policy of the Federal Bureau of Mines to publish estimates of tonnage, it is easy to see, on the basis of the data presented in "Report of Investigations 3961", that the drilling done suggests indicated ore that would amount to several millions of tons. Ore dressing tests by the Bureau of Mines indicate that the ore could be beneficiated by either flotation or magnetic separation to produce a concentrate containing 65 per cent iron and 7.5 per cent silica[1].

Magnetic surveying shows still another magnetic anomaly about 10 miles northeast of Bourbon and four miles northwest of Sullivan, Missouri, but it is yet untested.

The Future of Iron Mining. The future of iron mining in Missouri as elsewhere depends upon the ability of the miner to deliver competitive ore to the furnace or other consuming points.

At present, Missouri miners are handicapped by the lack of large high-grade deposits which can produce in competition with the great mines of the Lake Superior region. The Lake ores have the further advantage of favorable water or water-rail freight rates to the Chicago, Detroit, Cleveland, and Youngstown-Pittsburgh blast furnaces.

As the high grade and more accessible ores of the Michigan and Minnesota ranges are depleted, the users of iron ore will be forced to meet their needs by mining and beneficiating lower grade ores and by imports. Already these trends are established. Whereas only 13 per cent of United States' ores were beneficiated in 1925-1929, 22.4 per cent were so treated in 1946.

Ore users are at present developing and mining foreign ores for use along our seaboards. These production trends are accompanied by increasing costs which will eventually make more of Missouri's iron ores economic. Under such conditions the silicious hematite ore bodies at Pilot Knob and the Bourbon

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[1]McMillan, W. D., Exploration of the Bourbon Magnetic Anomaly, Crawford County, Missouri: U. S. Bur. Mines Rept. Inv. 3961, October 1946.

magnetite deposit may be expected to be brought into production. Such a demand will further stimulate exploration and this will, in turn, lead to new discoveries.

If for national defense or other reasons new iron and steel furnaces should be built nearer the geographic center of the United States, the iron mining industry of Missouri will be further stimulated.

Uses of Iron Ore. By far the most important use of iron ore is in the manufacture of iron and steel. Of the total production in the United States for 1946, 84 per cent was consumed in iron blast furnaces, 4.3 per cent in steel furnaces, and 11.1 per cent was sintered with mill scale, flue dust, and pyrite cinder for consumption in blast and steel furnaces. Of the remaining 0.6 per cent, ferro-alloy furnaces used slightly more than half.

Other uses, which together total almost 0.3 per cent, were in cement, paint, mineral wool, and miscellaneous as ship ballast, and as flux in smelting silicious nonferrous ores.

Iron oxide paints are used in substantial quantity in the manufacture of red, yellow, and brown paints for houses and barns. During the war, the natural earth pigments were in great demand for camouflage painting of military and industrial establishments and equipment. Yellow iron oxide compounded with chromic oxide formed the well-known olive drab shade used so extensively on trucks, "jeeps", aircraft, artillery, and tanks.

LEAD

Lead in 1946 and 1947. 1947 marked the fortieth consecutive year in which Missouri has been the chief lead-producing state. In 1946 it produced 41.4 per cent of the nation's domestic lead. Reference to Table 13 shows that 139,112 tons of lead were recovered in 1946 as compared to 132,246 tons in 1947. The tabulation shows that the Southeastern Missouri district, principally situated in St. Francois and Madison counties, accounts for most of the metal; lesser amounts are recovered from the Southwestern Missouri and Central Missouri districts.

Brief History of Lead Mining in Missouri[1]. Lead deposits were first noted in 1700 in what is now Missouri by Penicant of Le Sueur's party. Commercial mining followed in 1720 or 1721 when Renault discovered, and with 200 French workmen and some 500 slaves from St. Domingo worked, the Mine La Motte in Madison County. By 1726 mining had extended northward into Washington County. All operations ceased in 1731 when the French crown

[1]Winslow, Arthur, Lead and Zinc Deposits: vol. VI, Missouri Geol. Survey, pp. 267-302, 1894.

Table 13

Lead Production in Missouri

Year	Southeast Missouri		Central Missouri		Southwest Missouri		Total	
	Short Tons	Value	Short Tons	Value	Short Tons	Value	Short Tons	Value
Prior to 1937	5,883,597	$647,635,067	16,846	$1,831,046	837,528	$82,476,781	6,737,971	$731,942,894
1937	153,205	18,078,190	(inactive)		4,426	522,268	157,631	18,600,458
1938	118,870	10,936,040	(inactive)		3,157	290,444	122,027	11,226,484
1939	153,520	14,431,068	(inactive)		2,759	259,346	156,279	14,690,414
1940	169,893	16,989,300	15	1,500	2,144	214,400	172,052	17,205,200
1941	164,342	18,734,982	46	5,250	1,521	173,394	165,909	18,913,626
1942	197,291	26,436,998	141	18,890	2,116	283,544	199,548	26,739,432
1943	179,012	26,851,800	122	18,300	5,776	866,400	184,910	27,736,500
1944	169,622	27,139,520	340	54,400	4,721	755,360	174,683	27,949,280
1945	173,005	29,756,860	48	8,256	3,522	605,784	176,575	30,370,900
1946	135,796	29,603,528	95	20,710	3,221	702,178	139,112	30,326,416
1947	129,516	37,300,608	65	18,720	2,665	767,520	132,246	38,086,848
Totals........	7,627,669	$903,893,961	17,718	$1,977,072	873,556	$87,917,419	8,518,943	$993,788,452

Table 14

Annual Production and Value of Lead in Missouri[1]

Year	Short Tons	Value	Year	Short Tons	Value
Prior to 1800	18,000	$1,800,000	1917	233,564	$40,173,008
1800-1819	25,330	2,279,700	1918	193,919	27,536,498
1820-1829	19,078	1,907,800	1919	163,167	17,295,702
1830-1849	73,385	6,604,110	1920	165,037	26,405,920
1850-1859	51,245	5,525,820	1921	180,085	16,207,650
1860-1869	31,591	5,369,570	1922	178,412	19,625,320
1870-1879	160,683	18,960,594	1923	169,743	23,764,020
1880-1893	371,123	31,432,061	1924	189,929	30,388,640
1894	39,966	2,625,045	1925	211,584	36,815,616
1895	38,733	2,512,252	1926	207,046	33,127,360
1896	41,530	2,468,918	1927	198,760	25,043,760
1897	47,678	3,442,352	1928	195,393	22,665,588
1898	50,638	3,800,621	1929	198,469	25,007,094
1899	48,729	4,355,414	1930	199,632	19,963,200
1900	58,582	5,187,102	1931	160,121	11,848,954
1901	77,716	6,862,710	1932	117,159	7,029,540
1902	86,207	7,027,870	1933	84,980	6,288,520
1903	88,484	7,471,881	1934	90,493	6,696,482
1904	91,576	8,003,768	1935	97,493	7,799,440
1905	96,031	9,142,199	1936	110,428	10,159,376
1906	110,267	12,651,751	1937	157,631	18,600,458
1907	138,093	14,637,858	1938	122,027	11,226,484
1908	143,900	12,087,600	1939	156,279	14,690,414
1909	158,812	13,657,832	1940	172,052	17,205,200
1910	160,426	14,117,488	1941	165,909	18,913,626
1911	178,246	16,042,140	1942	199,548	26,739,432
1912	176,466	15,881,940	1943	184,910	27,736,500
1913	175,545	15,447,960	1944	174,683	27,949,280
1914	192,129	14,986,062	1945	176,575	30,370,900
1915	209,909	19,731,446	1946	139,112	30,326,416
1916	232,459	32,079,342	1947	132,246	38,086,848
Totals from earliest records through 1947				8,518,943	$993,788,452

[1]Production and value of lead through 1893 was obtained from Arthur Winslow's "Lead and Zinc Deposits of Missouri," vol. VII, sec. 2, Missouri Geol. Survey, pp. 500-540, 1893; production records from 1894 through 1931 were obtained from Mineral Resources U. S. compiled by the U. S. Geol. Survey and the U. S. Bur. Mines. Similar data for 1932 through 1947 were obtained from the U. S. Bur. Mines Minerals Yearbooks.

cancelled the charter of the bankrupt Mississippi Company under whom Renault was working. Subsequently, mining was resumed, but it was done in a desultory manner until about 1799 when Moses Austin, a skilled mine operator from Virginia, erected a shot tower and works for the manufacture of sheet lead. By 1802 Austin had increased the recovery of lead from the ores by building and operating a reverberatory furnace. These improvements, together with improved demand, stimulated mining to the extent that production in the period 1800-1819 was 25,330 tons as compared to 18,000 tons for the 80-year period prior to 1800.

From 1820 to the beginning of the Civil War lead production increased still further. Mining was extended into other parts of the State when lead was discovered outside of the Southeast Missouri district. Choteau erected a lead furnace in Cole County in 1827 to treat ores discovered there earlier. By 1848 lead had been discovered in Moniteau, Benton, Camden, Morgan, and Cole counties in the Central district, and in that same year William Tingle began mining lead two miles east of Joplin in that now famous zinc-lead district.

The Civil War decreased lead production. The Union forces destroyed the Mine La Motte furnaces in 1861, but later the same year they were rebuilt and operated for the remainder of the war.

In the years 1865 to 1880 there was an unprecedented growth in lead mining. Industrial expansion created a lead shortage, which, in turn, forced the price up and stimulated exploration and mining. In 1869 the St. Joseph Lead Company introduced the diamond drill which greatly aided in making new discoveries, particularly of disseminated lead ores in the Southeastern district. The Central district reached the peak of its production prior to 1880 at about the time that new discoveries of rich lead-zinc ores were being made at Joplin, Webb City, and other places in the Southwest Missouri district.

Following 1880 there was an almost continuous increase in lead production effected by the development of large scale operations. Peak production was attained in 1917 when 233,564 tons of lead were recovered from Missouri ores. Since that time production has varied from 211,566 tons in 1925 to 84,980 tons in the depression year of 1933. Maximum production during World War II was in 1942, when 199,548 tons of lead metal were produced.

The decrease in metal production in 1942 compared with 1917 was due to a number of factors, among which was the movement of mine equipment from the Joplin district about 1917 to the newly discovered and more profitable ores of northeast Oklahoma and southeast Kansas. Still another factor was the decreasing grade of the ores mined. In 1942 the mines of the Southeastern Missouri "lead belt" recovered but 55 pounds of lead from each ton of ore, whereas in 1917 each ton yielded 69 pounds. Another important factor was the difference in metal prices. In 1917, under competitive marketing, lead sold for an average of $172 a ton, but under government controls in 1942 the average price per ton was $38 less. The annual production and value of lead in Missouri through 1947 is presented in Table 14.

Present Prices and Supply. The production of lead in Missouri declined each year of the war, increased slightly in 1945, but decreased again in 1946 and 1947. The decreases during the war can largely be explained by man power shortages and the increasingly narrow margin of profit as costs increased. The same factors caused decreasing production throughout the United States. Necessary military and civilian needs were met, however, without great difficulty, because of imports and the increased amount of secondary or used lead that was re-smelted.

After victory in Europe and the reduction in military needs, War Production Board Order M-38 was amended to allow greater civilian uses of lead in 1944, 1945, and 1946. The last control was removed December 27, 1946. Throughout 1945 the base price of lead was 6.50 cents in New York. However, premium payments to certain producers brought the average price up to 8.64 cents. On June 3, 1946, the Office of Price Administration established the base price level at 8.25 cents, New York. This base, plus premium payments, prevailed except for a short time until November 9, when lead controls were removed as part of a presidential order. Under free market conditions lead prices advanced to 12.55 cents at New York on December 16, 1946. The pressure of consumer demand continued to force the price upward until on March 3, 1947, it was at 15.00 cents a pound, where it remained throughout the year. The average price in 1946 was 10.90 cents per pound as compared to 14.40 cents in 1947.

During 1948 there were a series of price increases in lead. By November 1, 1948, the metal sold at an all-time high of 21.5 cents a pound in New York. This price level continued until March 1949 when foreign offerings and buyer resistance caused the price to drop to 17 cents. By May 10, 1949, lead sold for 14 cents a pound in New York, 13.8 cents a pound in St. Louis, and 80 per cent concentrate at Joplin sold for $176.71 a ton.

The competition among buyers did not react to increase production immediately when controls were removed for the reasons that ore reserves were short because of reduced development programs during the war and because the fall in the price of zinc had resulted in the closing of certain zinc-lead operations in the Tri-State area of which southwest Missouri is a part.

The increased price has permitted lead mine operators to mine low grade ore bodies and will without doubt greatly increase the tonnage figures of rock that can be profitably mined, if the ratio of selling price and mining costs continue favorable. It must always be borne in mind that as high quality ores are depleted throughout our mining districts, scarcities will normally develop which will stimulate buyers to bid higher prices and producers to develop improved technologies. As a result, the productive life of the mines is extended.

Uses of Lead. Lead was known to the Ancients, being mentioned in the Old Testament and by Pliny and other Roman writers. The Romans used it for water pipes and learned to make low melting point solders by alloying lead with tin.

Lead alloys with practically all other metals and in alloys it finds some of its most important uses. Lead alloyed with antimony, in varying amounts with or without tin or bismuth, makes type-metal which melts at a moderate temperature and which, when cast in type molds, makes fully-formed type because it expands when solidified.

Lead alloyed with tin is solder, and with tin and usually zinc, antimony, or copper it forms pewter; these and other alloys form babbitt or bearing metal.

Other uses of lead metal are in cable coverings and pipe, sheeting to protect operators from radioactivity and X-rays, lead foils, calking, collapsible tubes, ammunition, and others.

The oxides of lead have a very wide use in chemical manufacture, in the preparation of paints and varnishes, in the manufacture of storage batteries, flint glass, and ceramic glazes.

Red lead (Pb_3O_4) is used as a pigment. In proper oil it forms the standard protective or priming coat for iron and steel structures. White lead, the basic lead carbonate, has been and is one of the chief paint pigments, but its use is declining somewhat owing to competition from the more chemically inert titanium pigments.

Storage batteries in the electrical systems of automobiles use much lead, as the battery plates are gridworks of antimonial lead filled with a paste made by moistening litharge (lead-monoxide) and red lead with sulfuric acid.

Lead is also used in compounding rubber, in refining petroleum, and in the manufacture of lead tetraethyl, the antiknock component of ethyl gasoline.

Lead, one of the first metals known to man, has aided greatly in the development of this and preceding civilizations. If it should disappear, our way of living, with its automobiles, high speed engines, telephones, newsprint, and ethyl gasoline would immediately require great adjustments and adaptations.

Uses as tabulated by the U. S. Bureau of Mines follow:

Consumption of Refined Lead in the United States 1942-46, by uses, in short tons

	1942	1943	1944	1945	1946
Ammunition	48,025	64,023	31,479	29,315	16,857
Bearing metals	8,466	10,189	15,941	14,104	11,012
Brass and bronze	5,294	5,748	7,845	7,069	5,328
Cable covering	128,535	117,802	110,417	86,158	69,004
Calking lead	9,047	8,618	9,411	13,374	8,314
Casting metals	3,106	3,072	4,425	5,322	3,566
Collapsible tubes	9,966	11,425	12,482	7,428	7,189
Foil	9,359	5,816	11,190	2,185	2,143
Pipe, traps and bends	21,411	18,724	24,387	24,061	27,372
Sheet lead	31,700	27,738	31,546	30,624	26,430
Solder	13,371	15,472	22,390	27,475	32,279
Storage batteries	62,604	68,239	68,769	60,179	56,726
Terneplate	2,336	815	2,190	2,178	1,526
Type metals	943	812	1,269	1,401	1,487
White lead	56,476	36,809	54,333	35,611	43,294
Red lead and litharge	100,563	124,715	157,080	157,171	128,513
Tetraethyl lead	50,152	65,320	83,067	75,890	47,965
Chemicals and insecticides	6,298	8,172	10,703	8,567	8,169
Annealing	5,229	5,987	5,719	5,525	5,514
Galvanizing	484	819	1,073	988	1,132
Lead plating	[1]	941	494	1,130	1,182
Weights and ballast	[1]	9,269	22,964	9,539	3,089
Other	33,746	64,940	33,646	32,205	22,497
Total	607,111	675,465	722,820	637,499	530,588

[1]Included under "Other."

LIME

During 1946 and 1947 sales of lime by producers in Missouri were 799,742 and 889,090 tons, respectively. In those years, as in 1945, the State was third among the states, being exceeded only by Pennsylvania and Ohio.

Few states have limestones better suited to the manufacture of quality lime than Missouri. The oolitic Spergen limestone near Ste. Genevieve is the raw material for the important lime burning industry there. Lime produced from the Spergen of the Ste. Genevieve area is unusually pure and hence is in demand by the chemical industry. Other Mississippian limestones are burned to lime at or near Hannibal, Seneca, Pierce City, Galloway, and Springfield. At Glen Park, Jefferson County, the Ordovician Kimmswick limestone is mined to supply local lime kilns.

In lime, as in cement, Missouri produces an excess beyond the needs within the State, the domestic consumption being only one-third of the production. The excess production is shipped chiefly to Illinois, Iowa, Kansas, and some to other states.

Uses of Lime. Lime has a diversity of uses which are classified as chemical-industrial, building, and agricultural. But little

Table 15

The Tonnage and Value of Lime Produced in Missouri
1944-1947

Use	1944		1945		1946		1947	
	Short Tons	Value	Short Tons	Value	Short Tons	Value	Short Tons	Value
Building	29,398	$212,333	24,285	$189,239	42.280	$399,461	[2]	[2]
Metallurgical	223,801	1,264,845	120,391	744,469	104,641	710,287	[2]	[2]
Paper mills	[1]	[1]	[1]	[1]	[1]	[1]	[2]	[2]
Tanneries	[1]	[1]	[1]	[1]	[1]	[1]	[2]	[2]
Water purification	70,823	475,468	97,990	659,621	112,588	877.970	[2]	[2]
Refractory	[1]	[1]	[1]	[1]	[1]	[1]	[2]	[2]
Other	459,552	2,858,561	395,030	2,542,403	432,943	3,069,987	[2]	[2]
Totals	908,340	$5,820,028	753,932	$5,031,222	799,742	$5,931,485	889,090	$7,006,426

[1]Figures that may not be given are grouped in the totals.
[2]Breakdown is not yet available.

lime is used in Missouri under the agricultural classification, as agstone is a cheaper means of supplying the same plant food elements and soil-conditioning effect.

As quicklime deteriorates under normal storage conditions, the manufacturer also sells hydrated lime which is stable and which, because of careful control in the hydration process, is superior for building plasters to that hydrated on the construction job by less skilled workmen. Most chemical-industrial demand, and all refractory demand, however, is for a non-hydrated product.

About 95 per cent of Missouri's total lime production is used in chemical and industrial uses. The remainder goes to the building industry for limes and mortars. Among the chemical-industrial uses are dead-burned dolomite for basic open hearth linings in the steel industry, lime for water purification, lime to treat sewage and industrial wastes, lime for glass manufacture, lime for bleaches, and for silica-lime brick. Lime is also used in

Table 16

Annual Production and Value of Lime in Missouri

Year	Short Tons	Value	Year	Short Tons	Value
Prior to 1897	[1]	[1]	1922	203,984	$1,953,524
1897		$404,885	1923	246,326	2,505,785
1898	187,000[2]	297,401	1924	243,465	2,354,175
1899	105,000[2]	383,543	1925	273,348	2,610,954
1900	110,000[2]	398,010	1926	263,467	2,218,943
1901	150,000[2]	546,549	1927	267,776	2,189,420
1902	140,000[2]	515,780	1928	303,014	2,252,420
1903	170,000[2]	641,948	1929	316,579	2,319,886
1904	160,288	597,258	1930	265,771	1,861,105
1905	186,173	787,069	1931	224,416	1,481,240
1906	207,334	916,693	1932	174,427	1,034,850
1907	190,300	877,970	1933	230,051	1,121,295
1908	167,060	701,321	1934	272,236	1,538,900
1909	182,460	815,367	1935	312,462	1,759,918
1910	179,550	846,123	1936	379,354	2,047,189
1911	158,368	722,563	1937	426,514	2,326,928
1912	148,885	721,896	1938	298,151	1,724,140
1913	161,770	734,009	1939	516,988	2,800,379
1914	155,680	686,051	1940	607,062	3,184,293
1915	155,501	691,042	1941	736,200	4,106,468
1916	199,260	956,300	1942	853,020	4,915,784
1917	234,936	1,435,914	1943	963,301	6,046,453
1918	201,737	1,721,800	1944	908,340	5,820,028
1919	180,749	1,735,705	1945	753,932	5,031,222
1920	209,113	2,319,285	1946	799,742	5,931,485
1921	159,194	1,656,560	1947	889,090	7,006,426
Totals 1897 through 1947				15,829,374	$100,254,252

[1]Data are insufficient for estimates.
[2]Estimated.

asphaltic paving, baking powders, the manufacture of lubricating greases, soaps, certain paints, insecticides, medicines, and paper, as well as rubber. It is used in sugar refining, petroleum refining, and in the tanning industry. Table 15 gives the tonnage and value of lime produced in Missouri by uses. Table 16 presents the annual production and value of lime from 1897 through 1947.

MANGANESE

The demand for manganese was greatly stimulated by World War II, and interest was renewed in the potentialities of Missouri manganese deposits. As a result of this demand, 431 tons of manganese ore were produced during 1941, 1942, and 1943. Since 1943 none has been marketed, and interest in the manganese prospects of the State has diminished.

Although consumption declined somewhat after the war, manganese is yet in great demand and the government is attempting to acquire a stockpile of this essential and critical material. At present, domestic manganese ores supply less than 8 per cent of the nation's needs, the remainder being imported from India, the Gold Coast, Russia, the Union of South Africa, Cuba, Chile, and Brazil.

Uses of Manganese. The need for manganese ores is critical because modern steel making depends on manganese. Each ton of steel made in the United States during 1946 required an average of 12.7 pounds of manganese. The manganese used in steel manufacture accounts for 95 per cent of the total consumption, the remainder being used in manufacturing dry batteries and chemicals.

About 85 per cent, or 964,000 short tons, of the manganese ores consumed in 1946 were converted into ferromanganese which is used for deoxidizing steels and for alloying with steel and bronze. When chipped ferromanganese is added to molten steel in the open hearth furnaces, the manganese purifies or deoxidizes the steel by uniting with the oxygen and sulfur. The manganese so used up is drawn off with the slags, but any remaining unites with the steel as an alloy. Ferromanganese or manganese metal is also used to alloy steels. Manganese iron alloys form hard, wear-resisting steels and iron castings, which are much favored when abrasion is a factor in the wearing life of an article. All commercial steels contain manganese, but the term "manganese steel" is normally applied only to those steels containing 10 to 15 per cent of the metal. Cold-working tends to harden high manganese steels, and it is interesting to know that heat-treated shovel teeth or tractor shoes which have a Brinnell hardness of 185 to 200 when new, may attain a Brinnell of 550 upon being used for some time.

Manganese bronze is a brass containing iron and manganese. It casts quite readily to produce a hard, high strength alloy useful in making marine propeller blades, valve stems, aircraft engines, and various machinery parts that need high strength combined with resistance to marine corrosion.

During 1946 manufacturers of dry cells in the United States used 47,600 tons of manganese ore in making flashlight, telephone, and other dry batteries. Chemical plants used 16,180 tons of manganese ore in making manganese sulfate for fertilizer, barium manganate for green paint pigment, and hydroquinone for medical and photographic use. Minor amounts of ore are used to make various other chemical substances.

Manganese Ores in Missouri. In 1818 Henry Schoolcraft[1] noted the presence of manganese ores in southeastern Missouri. Subsequently, manganese occurrences were described by the scientists, Litton, Swallow, Broadhead, Pumpelly, Nason, Keyes, Buehler, and Grawe in their various reports on the geological features of Missouri.

The manganese ores of the State occur as manganiferous veins in porphyry, as manganiferous replacements in tuffs, as manganese ore nodules in residuum, and as manganiferous chert breccias. The ores are found in Iron, Madison, Reynolds, and Shannon counties.

A study of the veins in the porphyry shows that the ore mineral braunite has replaced the porphyry. Although the known veins are narrow and hence uneconomic at present prices, it is quite possible that wider and more profitable veins may be discovered.

The known manganiferous tuff deposits are quite small and of negligible importance. The manganiferous chert breccias, however, contain considerable manganese, which may be commercially important, when a workable process can be developed for extracting the metal. The chert breccia ores average about 17 per cent manganese, almost 52 per cent insoluble, and 0.74 per cent cobalt. If sufficient tonnage can be proven, the value of the cobalt will perhaps offset the low manganese values. The Missouri Geological Survey has an excellent report by O. R. Grawe on "Manganese Deposits of Missouri"[2].

The first production of manganese ores appears to have

[1]Schoolcraft, H. R., A view of the lead mines of Missouri, including some observations on the mineralogy, geology, geography, antiquities, soil, climate, population and production of Missouri and Arkansas, and other sections of the Western Country, 1819.

[2]Grawe, O. R., Manganese deposits of Missouri, Appendix VI, Biennial Report of the State Geologist, 1943.

Table 17

Production and Value of Manganese in Missouri

Year	Short Tons	Value
1872	100[1]	$ 500
1881	2,000[1]	25,000
1890	35[1]	1,000
1899	16	160
1916	45[1]	1,200[2]
1917	45[1]	1,500[2]
1918	45[1]	1,800[2]
1936 } 1937 }	50	750
1941	12	500
1942	239	10,600
1943	180	8,000
1944	....	....
1945	....	....
1946	....	....
1947	....	....
Totals..........	2,750	$51,010

[1]Approximations.
[2]Estimated.

come from the Cuthbertson Mine, 3½ miles southwest of Arcadia in Iron County sometime prior to 1872. In 1881 this mine produced about 2000 tons of ore which was shipped to the Missouri Iron Furnaces in St. Louis. The mine was worked for a short time during World War I and again briefly in 1939 and 1941.

About 1890 a shaft was sunk on the Turley property in Shannon County, and one car of 32 per cent ore was shipped. About the same time a manganiferous iron ore was mined near Cornwall in Madison County and was used as a smelter flux at Mine La Motte.

The next activity was brought about under the stimulus of World War I and resulted in the production of a total of perhaps three carloads of ore from Madison, Reynolds, and Shannon counties. As is noted in the introductory paragraph, production during and just before World War II totalled 431 tons. Table 17 tabulates, as far as is known, the tonnage and value of Missouri manganese ores.

MINERAL WOOL

Mineral wool is a wool-like heat and sound insulating material made from suitable rock, furnace slag, or other mineral ingredients. It was first obtained as a product of nature from the volcanic craters of Hawaii. This natural mineral wool is known as Pele's hair.

Table 18

Production of Mineral Wool in the United States, 1943 through 1944, by Products

Product	Home Insulation		Industrial Insulation		Total	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
1943						
Loose wool (sold as such)	62,978	$1,720,375	6,600	$ 191,584	69,578	$ 1,911,959
Granulated wool (sold as such)	277,833	10,257,797	6,704	219,975	284,537	10,477,772
Bats	56,737	4,386,006	3,416	659,799	60,153	5,045,805
Rolls	10,117	541,256	65	2,819	10,182	544,075
Felt	6,781	791,781	37,764	5,236,679	41,545	6,028,460
Blocks	453	40,960	11,068	1,900,450	11,521	1,941,410
Boards	....	....	26,003	12,495,640	26,003	12,495,640
Mineral-wool insulating cement	3,432	283,006	18,839	1,230,681	22,271	1,468,687
Blankets	402	68,862	9,111	1,246,908	9,513	1,315,770
Pipe covering	11	1,522	6,875	1,443,969	6,886	1,445,491
Other	4,029	91,024	5,306	904,617	9,335	995,641
Totals	422,773	$18,137,589	128,751	$25,533,121	551,524	$43,670,710
1944						
Loose wool (sold as such)	59,787	$ 1,609,235	5,410	$ 188,876	65,197	$ 1,798,111
Granulated wool (sold as such)	308,441	11,344,433	5,178	160,509	313,619	11,504,942
Bats	52,007	3,633,878	7,446	1,203,245	59,453	4,837,123
Rolls	6,394	372,938	565	30,955	6,959	403,893
Felt	4,683	427,393	38,998	5,154,208	43,681	5,581,601
Blocks	....	....	14,633	1,927,618	14,633	1,927,618
Boards	....	....	36,728	24,635,485	36,728	24,635,485
Mineral-wool insulating cement	1,823	135,861	10,695	825,906	12,518	961,767
Blankets	1	148	7,353	1,021,819	7,354	1,021,967
Pipe covering	....	....	5,240	958,692	5,240	958,692
Other	1,344	54,921	1,570	796,676	2,914	851,597
Totals	434,480	$17,578,807	133,816	$36,903,989	568,296	$54,482,796

Mineral wool is a term which includes rock wool, slag wool, and is sometimes used to include certain fibers made of glass melts. It consists of a mass of fine, somewhat flexible glass fibers matted together to form an excellent non-combustible insulating material that is used widely in home and industrial insulation.

The manufacturing process consists of proportioning the mineral ingredients and melting them in an electric, gas or coke-fired cupola furnace to form a molten silicate glass or slag. The molten slag is poured or drawn from the furnace as a uniform stream into a nozzle-directed blast of air or steam which breaks the slag into a mass of minute felted fibers that quickly chill in the collecting chamber.

Mineral wool is marketed as loose wool, as granulated pellets, in bats or matted pads, and as blankets stitched between layers of treated kraft paper. Various manufacturers also produce mineral wool blocks, sheets and boards which are used as heat transfer barriers at temperatures ranging from minus 30° Fahrenheit to oven and furnace temperatures up to 1600° Fahrenheit.

Table 18, which follows, shows the production of mineral wool in the United States during 1943 and 1944. Since then there has been no compilation of data. The Bureau of Mines estimates, however, that 1945 production was approximately 720,000 short tons valued at $70,000,000 and that the 1946 total is perhaps 20 per cent above the 1945 estimate.

Mineral Wool in Missouri. Mineral wool is manufactured at Joplin in Jasper County and at Easely in Boone County. The plant at Joplin utilizes lead smelter slags and mill chats as the raw material, and the Easely plant uses the dolomitic Sedalia limestone, which is a natural wool rock.

Insulation has become an important and essential element in home construction. Not only does it save fuel costs, but it promotes health and comfort and gives an added measure of fire protection by introducing non-combustible insulating barriers in ceilings, roofs, and walls.

NICKEL

The end of World War II and the resumption of peacetime pursuits resulted in a decrease in the consumption of nickel. The lessened demand for nickel and cobalt caused the St. Louis Smelting and Refining Division of the National Lead Company to suspend operation of the nickel-cobalt section of its concentrator in September 1946. Exploration to increase reserves, and research to improve the reduction of the ores has been continued by the company, but no commercial production was reported in either 1946 or 1947.

Uses of Nickel. Nickel is chiefly used in alloys, particularly with iron and copper. Nickel steels, nickel-chromium steel, nickel cast iron, nickel-chromium-molybdenum steels and iron form the important ferro-alloys that are sold as stainless steels, high strength cast irons, resistance wires, and grids. Nickel in amounts from 0.5 to 10 per cent progressively hardens cast iron. With chromium it is most widely used to make stainless steel alloys that combine heat and corrosion resistance with an ability to resist shock and fatigue.

Such steels are used widely in industrial plants. High nickel-chromium iron and steel are used for pumps and compressors handling corrosive liquids or gases in oil refining and food processing. There are many hundred such alloys which find specialized uses in industry as cams, gears, dies, shafting, and rolls.

Nickel is also widely used as an alloy with copper. It is soluble in all proportions with copper, and as the nickel is

Table 19

Annual Production and Value of Nickel in Missouri

Year	Pounds	Value	Year	Pounds	Value
1844-1846	25,000[1]	$31,300[1]	1899	22,541[1]	$ 8,566[1]
1847-1856	18,000[1]	22,500[1]	1900	9,715	3,886
1857-1863	60,000[1]	75,000[1]	1901	6,700	3,551
1864-1868	....	....	1902	5,748	2,720
1869-1881	40,000[1]	75,600[1]	1903	114,000	45,900
1882	5,200[1]	5,720[1]	1904	24,000	11,400
1883-1884	No Pro	duction	1905	No Pro	duction
1885			1906	No Pro	duction
1886			1907	Production	Not Reported
1887			1908	[2]	[2]
1888			1909	328,403	122,600
1889 (1885-1893)	143,000[1]	85,750[1]	1910-1917	No Pro	duction
1890			1918	[2]	[2]
1891			1919	260,000	85,118
1892			1920	276,000	103,361
1893			1921-1943	....	....
1894	9,616[1]	3,269[1]	1944	[2]	[2]
1895	10,302[1]	3,091[1]	1945	[2]	[2]
1896	17,170[1]	4,464[1]	1946	[2]	[2]
1897	23,707[1]	7,823[1]	1947	No Pro	duction
1898	11,145[1]	3,956[1]			
Totals from 1844 through 1947[3]				1,410,647	$705,575

[1]Estimated.
[2]The Missouri Geol. Survey is not at liberty to publish these production figures.
[3]The total excludes the very important production years 1944-1946 as well as that of 1908 and 1918.

increased the alloy melting point is increased. Added to brasses or bronzes, nickel will toughen and strengthen the resulting alloys. One such nickel-brass alloy known as nickel silver or German silver is an alloy of copper, zinc, and nickel widely used both by the machine industries and in the silverware trade. The most common nickel silver is 18 per cent nickel, 55 to 65 per cent copper, and the remainder zinc.

Monel metal is another nickel alloy. It averages 67 per cent nickel, 28 per cent copper, and 5 per cent combined iron, manganese, silicon and other elements. It is used for chemical apparatus, marine fittings, kitchen and restaurant equipment, and valves.

Another alloy of nickel, the one with which we are perhaps the most familiar, is coinage nickel which at present contains 25 per cent nickel.

History of Nickel Mining in Missouri. Nickel was first produced in Missouri in 1844 when a small furnace was erected to produce copper-nickel-cobalt matte from the ores of the Copper Mine on the Mine La Motte property two and a half miles northwest of Fredericktown. In the three-year period, 1844 through 1846, about 225 tons of matte were produced and shipped to England for refining. The next record of production was in 1857. In that year the records show that the nickel purchased by the United States Mint for the first nickel coinage was obtained from Mine La Motte. Mine La Motte continued to be the chief source of domestic nickel for several years, but eventually it was superseded by the Gap Mine at Lancaster, Pennsylvania, which produced a less refractory ore. Subsequently, in 1883 and again in 1891, the Gap Mine was shut down and the area near Fredericktown was again the chief source of nickel ores.

The Buckeye tract, now belonging to the Missouri Cobalt Company, was still another early producer of nickel and cobalt. It produced a small but unknown amount of nickel between 1844 and 1849 and again in 1860 to 1863.

From 1870 into the year 1904, the Mine La Motte Lead Company produced nickel, cobalt, and copper as by-products of its lead mining activities. In 1904 the smelting unit of that company was shut down.

In the meantime, interest had again been focused on the Buckeye tract where good lead ore was revealed by diamond drilling during the early 90's. In 1901 the North American Lead Company purchased the Buckeye and other tracts, erected a 250-ton concentrator, and while mining the lead ore body, developed a complex lead-copper-nickel-cobalt ore associated with iron pyrite. In 1907 the North American Lead Company built a smelter and further reduced the newly developed ores. This smelter was shut down in 1910 after a production in excess of 86,000 pounds of cobalt oxide and 328,000 pounds of nickel. In July 1916 the Missouri Cobalt Company acquired the property and reconstructed the plant. Production was begun in the summer of 1918 and continued through 1920. During that time approximately 536,000 pounds of nickel were produced.

In 1927 the St. Louis Smelting and Refining Company, now a Division of the National Lead Company, acquired a tract of land south of the Missouri Cobalt Company property and began exploratory drilling. They also leased the main tract and the Rhodes tract, together with plant facilities, from the Missouri Cobalt Company. Their exploration led to the development both of lead and of copper-nickel-cobalt ore bodies.

At the outbreak of World War II, the company took immediate steps to mine and concentrate the ores for smelting. Production of lead, copper, and nickel-cobalt-iron concentrates was begun July 1944. The company continues to produce lead and some copper, but the production of nickel and cobalt was suspended in September 1946.

PETROLEUM AND NATURAL GAS

Production in 1946 and 1947. During 1946 the commercial wells of Missouri produced 42,728 barrels of crude oil and 37,863,000 cubic feet of natural gas. The production of crude oil in 1947 was 31,462 barrels and that of gas was 30,035,000 cubic feet. In addition, gas of unknown amount was produced and used by owners of private wells during the two years.

The production of crude oil in 1947 was from 76 wells in Jackson, Platte, Atchison, and Cass counties, whereas the gas was from 11 wells in the same counties. The Polo gas field in Caldwell County remained capped except for minor use near the wells.

The activity in drilling for oil and gas from 1945 through 1947 is summarized in Table 20. Table 21 lists all recorded oil and gas production in Missouri through 1947. Estimates for years in which production was unrecorded are also included.

Brief History of the Oil and Gas Industry in Missouri. The first wells for oil and gas were drilled in Kansas City soon after the Civil War. One well drilled near the old Union Depot about 1872 is reported to have yielded a small quantity of oil. Other wells yielded small flows of gas.

Table 20

Wells Drilled for Oil and Gas in Missouri during the period 1945-1947

County	1945			1946			1947		
	Oil Wells	Gas Wells	Dry Holes	Oil Wells	Gas Wells	Dry Holes	Oil Wells	Gas Wells	Dry Holes
Atchison			4			2			
Bates		7	4						
Caldwell						5			
Cass		3	5			2		5	3
Clay			1						2
Clinton									1
Gentry						1			1
Holt									1
Jackson	3	4	9	7	4	3	6	4	9
Johnson						1			
Lincoln						1			
Morgan						1			
New Madrid			1						
Nodaway			2			1			
Platte		3	3						5
Putnam			1						
Ray						1			1
Stoddard			1			1			
Vernon			1			4			3
Totals	3	17	32	7	4	23	6	9	26
Total feet drilled	36,186			27,567			19,028		

Wells were drilled in Barton, Bates, Jackson, Ray, and Lafayette counties between 1870 and 1880, and possibly some test wells were drilled in Cass, Clay, and Carroll counties during the period. In most instances outcrops of asphaltic sandstone and "tar springs" spurred exploration, but the wells drilled were of little economic importance and the records were not made public.

The interest in oil and gas exploration was maintained from 1880 to 1900. Additional holes were drilled in the counties previously drilled and others were drilled in Vernon, Clinton, Holt, Pettis, and McDonald counties in western Missouri and in Chariton, Macon, Marion, Randolph, and St. Charles counties in the central and eastern part of the State. A number of gas wells were brought into production on the western border of the State, and small quantities of oil were produced at Adrian and Rich Hill in Bates County and at Richmond in Ray County. The gas was used for illumination and heat in homes near the fields and in Kansas City. The gas wells of the Belton field in northwestern Cass County and the Martin Ranch oil wells in southwest Jackson County were drilled during the period 1902 through 1906. The development of gas near Martin City, Jackson County, in 1908 supplied the town with natural gas for several years.

Table 21

Annual Production and Value of Oil and Gas in Missouri

Year	OIL		GAS	
	Oil in Bbls.	Value of Oil	Gas in Thousands of Cubic Feet	Value of Gas at Wells
1865-1887	100 [3]	$200 [3]		
1888	12 [4]	24 [4]	200,000 [3]	$30,000 [3]
1889	20 [4]	40 [4]	238,000 [4]	35,867 [4]
1890	278 [4]	556 [4]	70,000 [4]	10,500 [4]
1891	25 [4]		10,000 [4]	1,500 [4]
1892	10 [4]		25,100 [4]	3,775 [4]
1893	50 [4]		14,000 [4]	2,100 [4]
1894	8 [4]		30,000 [4]	4,500 [4]
1895	10 [4]		23,300 [4]	3,500 [4]
1896	43 [4]		10,000 [4]	1,500 [4]
1897	19 [4]		3,300 [4]	500 [4]
1898	10 [4]		970 [4]	145 [4]
1899	132 [4]		1,900 [4]	290 [4]
1900			3,650 [4]	547 [4]
1901			8,800 [4]	1,328 [4]
1902			14,300 [4]	2,154 [4]
1903			47,100 [4]	7,070 [4]
1904			39,200 [4]	6,285 [4]
1905			46,180 [4]	7,390 [4]
1906			33,560 [4]	7,210 [4]
1907			108,090 [4]	17,010 [4]
1908			152,280 [4]	22,592 [4]
1909			49,117 [4]	10,025 [4]
1910			47,144 [4]	12,611 [4]
1911			50,315 [4]	10,496 [4]
1912			53,013 [4]	11,576 [4]
1913			20,865 [4]	6,795 [4]
1914			18,085 [4]	5,319 [4]
1915			27,645 [4]	7,731 [4]
1916	11,000	17,100	69,236 [4]	17,594 [4]
1917			31,425 [4]	8,230 [4]
1918			22,120 [4]	5,548 [4]
1919			4,800 [4]	3,000 [4]
1920			3,800 [4]	2,600 [1]
1921			4,000 [4]	2,130 [1]
1922			2,600 [4]	780 [1]
1923			17,000 [1]	1,300 [3]
1924			71,000 [2]	6,525 [2]
1925			34,000 [2]	3,100 [2]
1926			1,000 [1]	150 [1]
1927			300 [2]	45 [1]
1928			360,000 [2]	45,000 [1]
1929			324,000 [2]	32,000 [2]
1930			1,064,000 [2]	72,000 [2]
1931			1,534,000 [2]	122,720 [1]
1932			932,000 [2]	82,016 [1]
1933	10,000 [2]	6,000 [2]	673,000 [2]	59,224 [1]
1934	35,000 [2]	29,000 [2]	549,000 [2]	78,500 [1]
1935	45,000 [2]	40,000 [2]	609,000 [2]	87,000 [1]
1936	40,000 [2]	35,000 [2]	399,000 [2]	57,000 [1]
1937	40,000 [2]	42,000 [3]	444,000 [2]	38,000 [1]
1938	40,000 [3]	42,000 [3]	1,369,000 [1]	109,520 [1]
1939	40,000 [1]	40,000 [3]	538,000 [1]	48,420 [1]
1940	44,000 [1]	40,000 [3]	310,000 [1]	29,846 [1]
1941	47,000 [2]	41,000 [1]	196,000 [1]	27,440 [1]
1942	36,000 [2]	41,000 [1]	100,000 [1]	14,000 [1]
1943	36,000 [1]	41,000 [1]	124,000 [1]	17,360 [1]
1944	45,000 [1]	52,650 [1]	152,447 [1]	22,429 [1]
1945	37,714 [1]	40,731 [1]	77,575 [1]	8,913 [1]
1946	42,728 [1]	44,375 [1]	37,863 [1]	4,467 [1]
1947	31,462 [1]	54,326 [1]	30,035 [1]	3,907 [1]
Totals........	581,621	$607,002	11,430,115	$1,241,080

[1]F. C. Greene, Missouri Geol. Survey & Water Resources.
[2]U. S. Bur. Mines Yearbooks.
[3]Estimated.
[4]U. S. Geol. Survey, Mineral Resources U. S.

Additional minor discoveries of gas were made between 1900 and 1920, including that in 1903 in St. Louis and later at Noel and Anderson in McDonald County.

According to Frank C. Greene[1], 2495 wells were completed in Missouri to the end of 1932. Of these 320 produced oil, 1139 produced gas, and 1036 were dry holes. He states that many dry holes were probably unreported.

The wells, individually, were small producers. The average oil well yielded one to ten barrels of oil per day and the gas wells flowed at an average production rate of but little more than 10,000 cubic feet.

The production of oil has increased since 1932 to an average of about 40,000 barrels per annum, but the production of gas has declined from a high of 1,534,000,000 cubic feet in 1931 to 30,035,000 cubic feet in 1947.

Until 1942 the commercial oil and gas production of Missouri was confined to Vernon, Bates, Cass, Jackson, Platte, Clay, and Clinton counties. Production was from sands in the Cherokee group of rocks in the Pennsylvanian system at depths of 400 to 700 feet. The Cities Service Company discovered and produced oil from the "Bartlesville sand" of the Cherokee group at Tarkio, Atchison County, in December 1942. The productive sand lies at a depth of 1500 feet, the maximum, so far, from which oil has been produced in the State.

A new gas field[2] was discovered by the Skelly Oil Company in 1940 about two miles southwest of Polo, Caldwell County. By 1943, 20 wells had been drilled with an initial open flow capacity of 33,000,000 cubic feet. The only gas used from the field to date has been that by farm owners.

The gas is piped to points of consumption. From Vernon County on the south to Clinton County on the north, many homes are served with natural gas from private wells. Production from wells of several small distribution systems is probably not included in the estimates of the Federal Geological Survey and the Bureau of Mines presented in Table 21. Among such systems was that of Charles C. Nigro, which supplied part of south Kansas City from five or six gas wells near 71st and Oak Streets. Another system was that on the W. S. Dickey estate, now a part of the University of Kansas City. The towns of Holt in Clay County, Martin City in Jackson County, and Belton in Cass County were also supplied for several years with natural gas from wells in

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[1]Greene, Frank C., Oil and Gas Developments in Missouri in 1933-34, Appendix III, 58th Biennial Report, Missouri Geol. Survey & Water Resources, 1935.

[2]Greene, Frank C., and McQueen, Henry S., The Polo Gas Field, Appendix 1, 62nd Biennial Report, Missouri Geol. Survey & Water Resources, 1943.

their respective vicinities. Two towns, Avondale in Clay County and Lees Summit in Jackson County, have also received much of their gas supply in the past from private wells. The United Brick and Tile Company also owned private wells near their plants at Harrisonville, Cass County, and Knobtown, Jackson County. The gas was used in firing kilns.

Future of Missouri Oil and Gas Industry. The factors generally considered requisite to a potentially productive area are: (a) source beds which must be carbonaceous marine shales or limestones; (b) porous rocks which can act as a reservoir for storage; (c) impervious cap rock which prevents escape of any oil or gas from the reservoir rock; and (d) structure which favors the local accumulation of oil and gas. Those factors prevail in a potential area of production. Geologists and production men have noted that almost invariably where oil is present the reservoir and other rocks below the level of surface waters contain salt water rather than fresh water.

If one or more of these essential geological conditions are absent, the area is considered unfavorable. If all are present, the area is potentially productive but exploration may prove it to be barren of oil or gas.

The Ozark region is unpromising because it lacks extensive source beds and because the existing reservoir rocks are everywhere saturated with fresh water. Furthermore, the rock formations which commonly contain oil and gas elsewhere in Missouri and the adjoining states have long since been removed by erosion.

Certain western counties in the State have for years been producing small flows of gas and oil from shallow Pennsylvanian "sands." There the requisite source beds, reservoir rocks, cap rocks, and structures, in combination with mineralized waters, exist. Efforts to date to develop new production from the formations underlying the Pennsylvanian beds have been unsuccessful in Missouri. The Mississippian production in the McLouth field in Leavenworth and Jefferson counties, Kansas, as well as the deeper Devonian production in nearby southeast Nebraska, lead to the belief that deeper production may yet result in western Missouri.

Asphaltic residues in the Mississippian formations of southwest Missouri and the occasional presence of small gas pockets suggest the possibility of Mississippian production. This possibility is rather remote, however, as the reservoir rocks contain fresh water and numerous wells in the area have never revealed economic amounts of either oil or gas.

The Lincoln fold and much of northern Missouri are areas with some possibilities. Favorable structures in the Pennsylvanian sediments are, however, difficult to find under the glacial drift cover. Possibly pre-Pennsylvanian structures may have merit as potentially productive areas, if they can be found.

The coastal plain in extreme southeast Missouri is another area that may contain oil and gas. Physiographically, the region is part of the Gulf Costal Province which has been productive in Louisiana, Texas, and Arkansas. Subsurface geologic structures which may contain oil and gas cannot be determined by surface observations, however, and drilling done to date has not been successful in discovering producing horizons. Further geophysical prospecting may aid in discovering whether subsurface conditions are favorable.

PYRITES

The iron sulfides, pyrite and marcasite, are grouped under the name pyrites. Pyrites are mined primarily as a source of sulfur in the manufacture of sulfuric acid. The iron oxide residue remaining after roasting may be used as an iron ore and sometimes is in demand as an ingredient of cement calcines.

The percentage of total sulfuric acid made from pyrites has declined in the past twenty years owing to the increasing use of elemental sulfur to replace pyrites in commercial acid manufacture. A unit of elemental sulfur makes about twice as much acid as a unit of mine-run pyrites. The use of sulfur has the further advantages that burning equipment is simpler, that the resulting gases have fewer impurities, and that there is no problem of disposing of the sintered residue. However, in the eastern states pyrites are used in large volume to make acid, the operation being made profitable by the cheapness of pyrites and by the utilization of the iron oxide residues. In 1946 pyrites sold for an average of $3.85 a long ton, but the same amount of sulfur sold for $16.00 f.o.b. Texas mines.

Pyrites Mining in Missouri. The last mining of pyrites in Missouri was in 1940 when 29,325 long tons valued at $74,088 were marketed. That year marked the end of a period of production which began in 1932. During that time production ranged from 3,958 to 32,496 long tons annually and a total of 199,567 tons valued at $530,465 were produced.

Apparently, the first production of pyrites was in 1904 or 1905, when a few carloads of "sulfur ore" were shipped from Crawford, Phelps, and Jefferson counties. In 1906 it is reported that 4,500 tons of pyrites were mined from the Flat Rock mine three miles south of St. James, Phelps County. This latter production was shipped to Tennessee to make sulfuric acid for use in the manufacture of phosphate fertilizer.

From 1907 through 1909 there was no production of pyrites, but in 1909 the Commercial Acid Company of East St. Louis, Illinois, erected a plant designed to burn pyrites and did extensive prospecting of pyrites deposits in Missouri. In 1910 mining was begun at the Leslie Mine in Franklin County. From then through 1920 there was an annual production which ranged from about 1000 tons to 7,459 tons.

From 1921 through 1931 there was no production. The depression which began in 1929 became acute in 1932, and acid manufacturers again returned to the use of pyrites as a cheaper source of sulfur. The period 1932 through 1940 was the peak productive period of the pyrites mines. Table 22 shows the annual production and value for each year since the beginning of the industry.

Pyrites have been produced in three general areas. The most important has been an area 30 miles wide by 80 miles long ex-

Table 22

Annual Production and Value of Pyrites in Missouri

Year	Long Tons	Value
1905	120	$ 360
1906	4,500	13,500
1907-1909	....	....
1910	1,000[1]	3,170[1]
1911	1,200	3,800
1912	2,118	5,825
1913	5,878	19,779
1914	5,189	15,568
1915	6,307	28,256
1916	8,494	27,729
1917	7,459	22,376
1918	7,674	69,202
1919	5,715	41,148
1920	1,524	11,910
1921-1931	....	....
1932	3,958	9,258
1933	18,355	50,161
1934	14,557	51,640
1935	24,883	77,263
1936	27,293	77,660
1937	19,872	50,070
1938	28,828	71,956
1939	32,496	68,369
1940	29,325	74,088
1941-1947	....	....
Totals.........	256,745	$793,088

[1]Estimated.

tending in a northeasterly direction across Franklin, Crawford and Phelps counties. The marcasite and pyrite are found in sink structures, usually beneath zones of oxidation which may have been mined in the past as a source of iron ore. A second area is that in Madison County between Fredericktown and Marquand. In this area pyrites occur locally as replacement deposits in the lower Bonneterre dolomite. The third area is coincident with the coal areas of the State. The first production from this source was made in 1913 when the Standard Coal and Mining Company shipped a trial lot of coal brasses (pyrites) which had been hand-picked from the coal refuse. In 1918 when submarine warfare restricted imports of Spanish pyrites, the pyrites accompanying coal were again considered as a source and one carload was produced and shipped by the Marceline Coal and Mining Company in Linn County.

It seems entirely possible that in the future pyrites may be recovered from the coal washery refuse of the State. The total sulfur content of most Missouri coals averages about 3.4 per cent of the run-of-mine coal. This sulfur occurs in the form of pyrite (or marcasite), gypsum, and organic sulfur. The sulfur in the form of pyrites occurs chiefly as lenses or bands paralleling the bedding of the coal, although some is found as filling in vertical cracks and as concretions of varying sizes. The pyrites are the only sulfur-bearing constituent that could be feasibly recovered. It could be recovered by heavy-media separation, by jigging, or by flotation of the refuse from coal washing. In general, it may be said that about 25,000 tons of pyrites could be recovered annually as a by-product of our 4,000,000-ton coal production, and at the same time a considerable amount of coal combined with the refuse might be recovered.

SAND AND GRAVEL

During 1946 and 1947 the sand and gravel industry had busy years owing to expanded construction programs and the continuation of industrial demands for glass and molding sands.

In 1946 combined sand and gravel production was 5,136,904 tons with a value at the washing-screening plants of $4,070,773. In 1947 the production increased to 8,136,657 tons with a value of $5,486,811.

Silica Sand. The amount of silica sand reported to the Missouri Geological Survey as sold or used by Missouri producers in 1946 was 586,277 tons valued at $1,061,687. The production data for 1947, as published by the U. S. Bureau of Mines, on silica sand is not yet available, but the State Mine Inspector reports 863,830 tons at a somewhat higher unit value.

Silica sand differs from other sand treated here in that it is composed almost entirely of pure grains of silica. It is quarried or mined from the St. Peter sandstone formation, which crops out as an irregular belt up to 10 miles wide. The outcrop can be traced from southern Cape Girardeau County northwesterly through Perry, Ste. Genevieve, Jefferson, Franklin, St. Louis, St. Charles, Warren, and Montgomery counties. The length of the outcrop zone is about 150 miles. Along the north bank of the Missouri River in Montgomery and Warren counties, the outcrop width is very narrow because of the steep slopes, but in Perry and Cape Girardeau counties the outcrop is wide because of the more gentle slopes.

Silica sand is now being produced in Jefferson, St. Charles, and St. Louis counties. The producers in 1946 were:

Tavern Rock Sand Co., St. Charles County
W. W. Goran, St. Louis County
Pioneer Silica Products Co., St. Louis County
Aubuchon Silica Mining Co., Jefferson County
Pittsburgh Plate Glass Co., Jefferson County
Silica White Sand Co., Jefferson County
Lucas Silica & Real Estate Co., Jefferson County

Uses of Silica Sand. The glass industry is the chief consumer of silica sand. In 1946 it used 408,510 tons valued at $731,945 as "melting sand," and an additional large amount for grinding and polishing plate glass. Silica sand forms 52 to 65 per cent of the raw mix used to manufacture glass. After melting has driven off the volatile materials of the glass mix such as carbon dioxide, silica forms 60 to 75 per cent of the finished glass. As very minor amounts of impurities affect the transparency, color, brightness and hardness of glass, the specifications of the glass maker rigidly limit iron, magnesia, alumina, and organic matter in the ingredients.

The St. Peter sandstone of Missouri is a friable, high-purity silica sandstone that readily meets glass sand specifications after it is washed. The washing removes most of the small amount of clay and practically all of the iron. An average of numerous analyses of unwashed sand from the mine of the Pittsburgh Plate Glass Company showed the sand to contain 99.405 per cent silica, 0.210 per cent alumina, 0.075 per cent ferric oxide, 0.072 per cent calcium oxide, and 0.068 per cent magnesium oxide. The washed dry sand usually contains less than 0.05 per cent each of iron and alumina and often contains more than 99.97 per cent silica.

Silica sand is also used as a grinding and polishing medium, and much of it is so used in grinding plate glass at the plant of the Pittsburgh Plate Glass Company, Crystal City. A considerable amount is also used in the finishing of dimension stone. This process requires a rough, hard sand, without oversize particles which might gouge grooves in the stone or glass being ground.

The second largest use for silica sand is as molding sands in iron, steel, and brass foundries. Formerly, all molding sands were natural sands which contained natural bonding materials such as clay. Now, however, fully two-thirds of the molding sand produced in Missouri is silica sand to which bentonite or some other bonding agent has been added. Sands so prepared often give better results because of their uniformity, their high refractory qualities, and their greater permeability.

Silica sand has numerous other uses. In Missouri it is used to make sand-lime bricks and silica flour. The latter, which is finely ground silica, is used in cleansing and polishing compounds, in foundry facings, and in various ceramic uses such as the making of glazes and zinc retorts. Other uses of silica sand, to which little or none of the Missouri product is put, are burnishing sands, sand for the manufacture of carborundum and ferrosilicon, and sand for sand blasts, filter beds, and railroad engines.

Other Sand and Gravel. Silica sand accounts for but about ten per cent of the total material listed under sand and gravel. The remainder is made up of creek and river sands and gravels, or of sand and gravel obtained from glacial deposits.

In the Ozark area, chert fragments and sand derived from the weathering of cherty dolomites and sandstones amply supply the region's needs. Elsewhere, necessary supplies are obtained by dredging the larger rivers or by drag-line washer installations on gravel and sand bars.

Table 23 shows the total reported silica sand sold or used by Missouri producers in 1944 through 1947. Table 24 shows total sand and gravel production as taken from the annual volumes of the U. S. Bureau of Mines' *Minerals Yearbooks* and the U. S. Geological Survey's *Mineral Resources of the United States*. Silica sand could not be segregated, but glass sand is reported for the years published.

The uses of sand and gravel are chiefly in concrete construction, paving, road surfacing, and as railroad ballast and fill.

In recent years, there has been a trend away from natural sand and gravel in some types of construction. The Missouri Highway Department uses crushed limestone in concrete pave-

Table 23

Silica Sand, Sold or Used by Producers in Missouri
1944-1947

Uses	1944		1945		1946		1947	
	Short Tons	Value at Plant	Short Tons	Value at Plant	Short Tons	Value at Plant	Short Tons	Value at Plant
Glass sand	[1]	[1]	[1]	[1]	408,510	$731,945	499,465	$894,958
Molding sand	161,543	$207,317	[1]	[1]	[1]	[1]	83,993	89,917
Polishing sand	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Other sand [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Totals	590,839	$992,614	603,682	$1,013,999	586,277	$1,061,687	[1]	[1]

[1]Figures were given by producer with understanding they would be held in confidence. The totals where given include confidential production.

[2]Includes ground silica, filter sand, and miscellaneous.

Table 24

Total and Annual Production of Sand and Gravel in Missouri

Year	Sand						Gravel		Total Sand and Gravel	
	Glass Sand		Other Sand		Total Sand		Short Tons	Value	Short Tons	Value
	Short Tons	Value	Short Tons	Value	Short Tons	Value				
1902	134,587	$82,552	...	...	...	...	...	...	...	...
1903	82,232	46,914	146,451	$79,122	228,683	$126,036	...	...	...	...
1904	121,629	68,503	1,811,459	583,106	1,933,088	651,609	...	...	...	...
1905	123,467	66,401	1,619,281	565,850	1,742,748	632,251	342,592	$102,303	2,085,340	$734,554
1906	101,862	65,393	2,487,939	823,289	2,589,801	888,682	474,857	147,696	3,064,658	1,036,378
1907	138,483	92,898	2,062,134	518,442	2,200,617	611,340	874,663	179,634	3,075,280	790,974
1908	111,517	83,106	1,890,497	496,489	2,002,014	579,595	586,144	147,389	2,588,158	726,984
1909	98,480	73,082	2,296,741	574,773	2,395,221	647,855	1,933,031	353,476	4,328,252	1,001,331
1910	186,342	130,686	2,852,106	722,880	3,038,448	853,566	3,070,012	485,953	6,108,460	1,339,519
1911	117,756	82,705	2,342,456	700,706	2,460,212	783,411	1,145,701	259,263	3,605,913	1,042,674
1912	129,030	81,817	2,364,683	752,551	2,493,713	834,368	1,193,667	253,911	3,687,380	1,088,279
1913	130,676	91,284	2,632,248	785,118	2,762,924	876,402	1,363,202	232,831	4,126,126	1,109,233
1914	160,190	112,484	2,046,649	650,592	2,206,839	763,076	1,321,839	257,827	3,528,678	1,020,903
1915	145,920	91,380	1,086,546	357,388	1,232,466	448,768	1,656,745	226,716	2,889,211	675,484
1916	163,706	121,692	2,114,592	505,214	2,278,298	626,906	1,364,907	250,728	3,643,205	877,634
1917	153,970	162,838	1,555,063	755,047	1,709,033	917,885	565,039	183,860	2,274,072	1,101,745
1918	141,062	202,763	1,163,273	431,428	1,304,335	634,191	439,281	138,562	1,743,616	772,753
1919	135,683	209,938	1,109,938	487,192	1,245,621	697,130	419,674	176,203	1,665,295	873,333
1920	153,421	269,205	1,060,175	707,223	1,213,596	976,428	695,718	379,924	1,909,314	1,356,352
1921	300,000 [1]	450,000 [1]	1,843,139 [1]	1,019,081 [1]	975,570	712,627	563,503	305,698	1,539,073	1,018,325
1922	...	...	...	...	1,167,569	756,454	802,776	306,916	1,970,345	1,063,370
1923	145,769	203,931	1,808,616	993,570	1,954,385	1,197,501	1,764,858	810,028	3,719,243	2,007,529
1924	161,604	225,963	1,652,009	906,137	1,813,613	1,132,100	2,267,587	921,336	4,081,200	2,053,436
1925	165,200	252,271	2,551,716	1,762,976	2,716,916	2,015,247	2,806,689	1,579,940	5,523,605	3,595,187
1926	145,383	204,067	2,491,498	1,522,942	2,636,881	1,727,009	1,975,071	1,253,233	4,611,952	2,980,242
1927	99,026	144,259	1,861,203	1,218,501	1,960,229	1,362,760	2,869,244	1,512,770	4,829,473	2,875,530
1928	145,554	188,960	2,278,377	1,429,958	2,423,931	1,618,918	2,827,295	1,629,895	5,251,226	3,248,813
1929	123,141	178,531	2,823,262	1,991,156	2,946,403	2,169,687	2,829,326	2,121,477	5,775,729	4,291,164

Table 24

Year	Sand						Gravel		Total Sand and Gravel	
	Glass Sand		Other Sand		Total Sand					
	Short Tons	Value	Short Tons	Value	Short Tons	Value	Short Tons	Value	Short Tons	Value
1930	131,233	207,748	2,818,385	2,003,010	2,949,618	2,210,758	3,007,148	2,565,320	5,956,766	4,776,078
1931	129,146	192,401	1,980,863	980,432	2,110,009	1,172,833	2,697,617	1,473,923	4,807,626	2,646,756
1932	107,301	160,292	1,202,240	594,916	1,309,541	755,208	2,216,832	1,359,232	3,526,373	2,114,440
1933	161,126	228,287	1,024,796	480,347	1,185,922	708,634	2,248,618	959,414	3,434,540	1,668,048
1934	145,104	193,265	821,399	496,668	966,503	689,933	1,414,950	772,807	2,381,453	1,462,740
1935	175,587	251,779	995,077	621,118	1,170,664	872,897	1,938,440	1,016,890	3,109,104	1,889,787
1936	175,425	265,502	1,080,002	570,284	1,255,427	835,786	2,819,138	1,566,518	4,074,565	2,402,304
1937	200,475	294,371	1,565,007	807,528	1,765,482	1,101,899	2,644,226	1,379,565	4,409,708	2,481,464
1938	....	....	....	....	1,198,896	882,961	2,070,960	1,036,185	3,269,856	1,919,146
1939	....	....	....	....	1,893,340	1,318,134	1,964,066	992,861	3,857,406	2,310,995
1940	....	....	....	....	1,921,661	1,283,681	2,135,910	1,027,540	4,057,571	2,311,221
1941	....	....	....	....	2,494,719	1,661,402	2,907,184	1,558,684	5,401,903	3,220,086
1942	2,240,000[1]	3,360,000[1]	12,159,365[1]	7,839,774[1]	2,097,772	1,538,263	2,392,878	1,393,661	4,490,650	2,931,924
1943	....	....	....	....	1,621,291	1,427,813	1,629,242	870,743	3,250,533	2,298,556
1944	....	....	....	....	1,517,399	1,442,125	1,665,777	928,136	3,183,176	2,370,261
1945	....	....	....	....	1,654,287	1,645,395	1,835,488	1,135,072	3,489,775	2,780,467
1946	408,510	731,945	2,228,735	1,660,652	2,637,245	2,392,597	2,499,659	1,677,851	5,136,904	4,070,448
1947	499,465	894,958	2,153,587	1,772,350	2,653,052	2,667,308	5,483,605	2,819,503	8,136,657	5,486,811
Totals...	7,889,062	$10,764,171	77,981,507	$39,167,810	86,035,982	$49,849,429	79,725,159	$38,751,474	165,761,141	$88,600,903

[1]Estimated.

ment and bridges rather than gravel, and in certain jobs such as the Bull Shoals dam in northwest Arkansas, the government specifications require the sand fraction of the concrete to be limestone screened to the optimum size.

SILVER AND GOLD

Missouri annually produces several thousand troy ounces of silver as a by-product of the lead mining industry of Southeast Missouri. There has never been any authentic gold production in Missouri.

Nearly all of the silver, like much of the copper, has been recovered in the process of purifying the lead at the smelters. An average of about 0.5 troy ounce of silver is recovered from each ton of pig lead refined. Some silver has also been recovered from the smelting and refining of copper concentrate from the Fredericktown area.

Total silver recovered from Missouri ores from 1904 through 1947 weighed 4,582,368 troy ounces, or 157.4 tons, worth $3,234,976. Table 25 gives the production by years.

Small amounts of gold are known to exist at places in the glacial drift that overlies most of the State north of the Missouri River. The gold there, like the containing glacial debris, was carried into the State by the ice sheets of Pleistocene time. At no place is there evidence to suggest that gold values may have been concentrated to form a commercial deposit.

Uses of Silver. Silver has long been used for coinage and monetary stocks, as well as for jewelry. The manufacture of photographic film, particularly of motion picture film, and new uses in bearing metals and electrical contacts have greatly increased the percentage of the metal for industrial use in recent years.

Other common uses are in silverware, dental and medical supplies, silver solders, headlight and searchlight reflectors. During the recent war, silver was used to replace copper busbars in a New York aluminum reduction plant.

STONE

In both 1946 and 1947 the value and amount of stone exceeded that of 1945. As postwar construction demand continued, the production of stone, exclusive of sandstone, increased from 5,314,160 tons in 1945 to 7,258,990 tons in 1946 and to 8,438,325 tons in 1947.

Table 25

Annual Production and Value of Silver in Missouri

Year	Troy Ounces	Value	Year	Troy Ounces	Value
1905	12,900	$ 7,869	1927	233,931	$132,638
1906	31,268	20,950	1928	176,840	103,451
1907	25,300	16,700	1929	181,638	96,813
1908	49,400	26,400	1930	170,210	65,531
1909	15,200	7,900	1931	40,000	11,600
1910	32,200	17,400	1932	1,128	318
1911	49,867	26,429	1933	....	....
1912	35,438	21,794	1934	63,066	40,770
1913	35,620	21,514	1935	110,551	79,459
1914	61,168	33,826	1936	163,720	126,801
1915	57,756	29,282	1937	179,700	138,999
1916	129,450	85,178	1938	292,000	188,768
1917	61,586	50,747	1939	213,400	144,853
1918	46,939	46,939	1940	260,314	185,112
1919	90,401	101,249	1941	367,688	261,467
1920	111,128	121,130	1942	69,106	49,142
1921	69,902	69,902	1943	111,285	79,136
1922	212,656	212,656	1944	92,243	65,595
1923	177,270	145,361	1945	94,822	67,429
1924	103,694	69,475	1946	69,401	56,076
1925	83,340	57,838	1947	93,600	84,708
1926	105,242	65,671			
Totals 1905 through 1947........................				4,582,368	$3,234,976

Limestone, Dolomite, and Marble. Producers' reports for 1946 show that 5,332,240 tons of crushed or broken limestone and dolomite were sold or used by them in 1946 compared to 3,943,-040 tons in 1945. In addition to the crushed limestone, 23,130 tons of dimension limestone and 5,530 tons of marble were marketed by producers. In 1947 the production of crushed limestone was increased to 6,262,750 short tons and that of dimension limestone was increased to 77,730 short tons.

Table 26 shows the tonnage and value by uses for 1944 through 1947, and Table 27 summarizes total limestone production through 1947. The largest single use in any of the three years, according to Bureau of Mines figures, was in concrete and road paving. This use alone was more than doubled between 1944 and 1947.

Agricultural limestone in 1946 and 1947. The second largest use of limestone was in agriculture as agstone. In 1947 more agstone (ground limestone or dolomite applied to the soil) was used by the farmers of Missouri than in any previous year. Preliminary figures obtained from the U. S. Department of Agriculture indicate that in 1947 the total limestone and dolomite applied as a soil supplement and alkalizer was approximately

Table 26

Limestone, Dolomite, and Marble Sold or Used by Missouri Producers Exclusive of Use in Cement and Lime

Use	1944		1945		1946		1947	
	Short Tons	Value at Plant	Short Tons	Value at Plant	Short Tons	Value at Plant	Short Tons	Value at Plant
Industrial								
Agricultural limestone	1,113,140	$1,537,284	985,060	$1,453,607	1,445,460 [2]	$2,223,431	2,071,890 [3]	$3,397,264
Fluxing stone	13,370	18,541	14,360	18,176	15,180	20,037	18,730	26,587
Miscellaneous industrial	281,200	729,523	269,970	715,281	511,450	1,013,240	371,470	860,975
Total industrial	1,407,710	$2,285,348	1,269,390	$2,187,064	1,972,090	$3,256,708	2,462,090	$4,284,826
Construction								
Concrete and road material	1,537,610	$1,846,009	2,040,210	$2,455,980	3,022,450	$3,960,953	3,242,690	$4,478,649
Railroad ballast	336,260	266,686	109,540	115,736	125,600	136,071	102,080	119,553
Riprap	240,880	374,475	523,900	637,538	212,100	319,219	458,260	739,776
Building construction—								
Marble	812	79,189	2,670	217,716	4,630	309,967	3,474	366,049
Limestone	496 [1]	18,749	[1]	[1]	1,120	1,980	[1]	[1]
Rubble	3,300	7,374	11,590	27,357	21,480	76,830	74,700	128,240
Flagging	[1]	[1]	[1]	[1]	530	4,388	710	5,901
[4]Total construction	2,119,932	$2,595,972	2,688,840	$3,460,157	3,387,910	$4,809,408	3,884,384	$5,995,756
Monuments (marble)	1,248	$58,632	1,170	$64,900	900	$41,718	248	$24,357
Total industrial, construction and monument use	3,528,890	$4,939,772	6,959,400	$5,712,121	5,360,900	$8,107,834	6,346,722	$10,304,939

[1]Data incomplete or unavailable for publication.

[2]The Department of Agriculture shows 1,857,789 tons distributed under the Federal Farm Program alone and estimates the total to have been 2,300,000 tons. Figure presented in the Table is from records of U. S. Bur. Mines.

[3]Figures presented are obtained from the U. S. Bur. Mines. Preliminary figures obtained from the U. S. Department of Agriculture show 3,300,688 tons for 1947.

[4]Totals are incomplete so as to conceal confidential data.

Table 27

Annual Production and Value of Limestone Quarried in Missouri, Exclusive of That Used in Lime and Cement Manufacture

Year	Dimensional Limestone		Crushed Limestone		Total Limestone	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
1860-1900	6,205,000[2]	$12,086,960[2]	[1]	[1]	[1]	[1]
1901		450,343	[1]	$365,380	[1]	$1,362,272[3]
1902		619,246	[1]	572,113	[1]	1,697,139[3]
1903		1,475,032	[1]	1,041,656	[1]	2,516,688[3]
1904		1,505,872	[1]	1,369,355	[1]	2,875,227[3]
1905		811,263	[1]	1,426,901	[1]	2,238,164[3]
1906		861,403	[1]	1,126,931	[1]	1,988,334[3]
1907		785,962	[1]	1,367,955	[1]	2,153,917[3]
1908		757,604	[1]	1,372,532	[1]	2,130,136[3]
1909	4,880,000[2]	957,264	[1]	1,154,019	[1]	2,111,283[3]
1910		869,777	[1]	1,490,827	[1]	2,360,604[3]
1911		837,577	[1]	1,342,190	[1]	2,179,767[3]
1912		689,063	[1]	1,684,662	[1]	2,373,725[3]
1913		533,953	[1]	1,953,067	[1]	2,486,020[3]
1914		455,010	[1]	1,705,948	[1]	2,160,958[3]
1915		533,204	[1]	1,394,330	[1]	1,927,534[3]
1916		607,740	[1]	1,382,679	[1]	1,990,419[3]
1917		327,026	1,312,862	1,351,838	[1]	1,679,677[3]
1918	34,628	168,005	672,806	772,936	[1]	1,359,755[3]
1919	100,870	328,350	1,014,620	1,430,679	1,115,490	1,759,029
1920	140,880	550,942	1,272,340	2,225,994	1,413,220	2,776,936
1921	153,080	425,717	1,196,460	1,843,740	1,349,540	2,269,457
1922	200,000[2]	400,000[2]	1,359,880[2]	2,009,202[2]	1,559,880	2,409,202
1923	200,000[2]	400,000[2]	1,911,130	2,889,386	2,068,230	3,173,622
1924	205,690	399,020	2,034,510	3,217,080	2,240,200	3,616,100
1925	288,140	425,868	2,431,940	3,657,052	2,720,080	4,082,920
1926	189,800	330,545	2,808,140	4,079,635	2,997,940	4,410,180
1927	151,780	281,841	2,419,570	3,149,771	2,975,710	3,972,567
1928	279,037	531,537	2,998,763	3,944,598	3,277,800	4,476,135
1929	217,800	420,063	3,875,630	5,284,178	4,093,430	5,704,241
1930	160,600	250,923	3,494,320	4,568,552	3,654,920	4,819,475
1931	100,471	189,329	3,250,189	3,773,140	3,350,660	3,962,469
1932	30,904	55,712	3,106,996	3,167,795	3,137,900	3,223,507
1933	29,420	50,471	2,775,400	3,144,321	2,794,820	3,194,792
1934	2,910	3,039	2,391,800	2,657,389	2,394,710	2,660,428
1935	76,160	130,033	2,145,790	2,322,003	2,221,950	2,452,036
1936	51,680	90,299	3,374,850	3,642,454	3,426,530	3,732,753
1937	46,900	74,895	3,511,480	4,134,184	3,558,380	4,209,079
1938	38,700	76,606	3,252,850	3,941,705	3,291,550	4,018,311
1939	49,090	80,247	3,819,930	3,893,687	3,869,020	3,973,934
1940	65,260	99,448	5,713,380	5,568,043	5,778,640	5,667,491
1941	46,530	73,580	6,129,200	6,570,989	6,175,730	6,644,569
1942	78,660	146,923	6,665,760	7,523,705	6,744,420	7,670,628
1943	14,210	44,700	4,279,750	5,381,233	4,293,960	5,425,933
1944	4,370	29,433	3,522,460	4,772,518	3,526,830	4,801,951
1945	12,520	33,787	3,943,040	5,396,318	3,955,560	5,430,105
1946	23,130	83,198	5,332,240	7,672,951	5,355,370	7,756,149
1947	77,730	289,531	6,262,750	9,608,614	6,340,480	9,898,145

[1]Data are insufficient for estimate.

[2]Estimated.

[3]In the period 1901 through 1918 the total value of limestone in each year exceeds the sum of the values for crushed and dimension limestone. The statistical record is not clear as to the reason, but it may be that limestone used by lime burners or cement plants was in part included in the total value for each of those years, or that the component figures were not complete.

3,300,688 tons, of which 2,263,106 tons were distributed under the Federal Farm program.

Although agricultural limestone is being applied in record amounts, it appears that about 5,300,000[1] tons of limestone must be applied to Missouri farm soils in order to offset the annual loss due to leaching, erosion, and cropping. It is estimated that present total soil deficiencies in limestone and dolomite amount

[1]Data developed by Department of Soils, College of Agriculture, University of Missouri, and published June 1, 1947, by Missouri Limestone Producers Association.

Table 28

Agstone Used in Missouri from 1923 through 1947

Year	Short Tons	Value	Average Price Per Ton
1923	30,800	$ 42,285	$1.37
1924	14,610	19,690	1.35
1925	40,090	54,668	1.36
1926	57,000	71,523	1.25
1927	61,750	77,875	1.26
1928	87,780	102,028	1.62
1929	131,860	161,838	1.23
1930	101,900	112,532	1.10
1931	60,370	50,113	0.83
1932	31,700	24,486	0.77
1933	35,490	25,907	0.73
1934	53,880	50,231	0.93
1935	47,190	45,638	0.97
1936	215,070	237,837	1.10
1937	207,810	230,303	1.11
1938	150,920	162,430	1.08
1939	252,840	246,231	0.97
1940	599,130	577,922	0.96
1941	649,010	619,132	0.95
1942	1,004,370	1,112,758	1.11
1943	895,970	1,131,848	1.26
1944	1,113,140	1,537,284	1.38
1945	985,060	1,453,607	1.47
1946	1,445,460	2,223,431	1.54
1947	2,071,890	[1]	[1]

[1]Not yet available.

to approximately 45,000,000 tons. The worth of agstone is so well established that we may expect the use to continue to grow until it stabilizes at the depletion rate of about 5 to 5½ million tons annually. A comparison of the amounts used beginning with 1923 and ending with 1947 is given in Table 28. During that time the use of agstone has increased sixty-nine fold.

Missouri is particularly well favored with limestone quarry sites. In 1946 limestone was produced in 54 of the State's 114 counties.

Dimension limestone and marble. In 1947 dimension limestone sales in Missouri were 77,730 tons as compared to 23,130 tons in 1946, and 12,520 tons in 1945. The value of such stone increased from $83,198 in 1946 to $289,531 in 1947. The sales of dimension marble in Missouri increased from 3,840 tons valued at $282,616 in 1945 to 5,530 tons valued at $351,685 in 1946. In 1947 the tonnage of dimension marble decreased to 3,720 tons, but because of higher unit value the gross worth increased to $390,406.

Table 29

Limestone and Marble Sold by Producers in the Carthage District, Jasper County, Missouri, 1942-1947, by Classes

Year	Dimension Stone (rough and dressed)							Other Uses[1]		Total	
	Building		Monumental		Total						
	Cubic Feet	Value	Cubic Feet	Value	Cubic Feet	Short Tons (approximate)	Value	Short Tons	Value	Short Tons (approximate)	Value
1942	22,580	$100,581	9,590	$23,271	32,170	2,650	$123,852	436,600	$538,697	439,250	$662,549
1943	11,950	66,326	10,910	33,532	22,860	1,910	99,858	299,730	487,519	301,640	587,377
1944	14,180	94,338	14,680	58,632	28,860	2,420	152,970	218,190	476,750	220,610	629,720
1945	30,230	211,299	14,150	64,900	44,380	3,660	276,199	223,160	444,518	226,820	720,717
1946	49,190	289,866	10,610	41,718	59,800	5,080	331,584	265,260	550,998	270,340	882,582
1947	40,810	366,049	2,980	24,357	43,790	3,720	390,406	[2]	[2]	[2]	[2]

[1]Other uses include stock feed, poultry grit, glass limestone, filter beds, and limestone for calcium carbide manufacture.

[2]Not available.

The State is an important producer of dimension limestone and marble for buildings. In 1946, the Federal Bureau of Mines listed Missouri first among the states in the production of marble for buildings. Both Georgia and Tennessee exceeded Missouri in total marble, however, because of their production of monument marble.

The quarries of Bedford, Indiana, produce about 80 per cent of the architectural and finished limestone sold in the United States, but the producers of the Carthage, Missouri, district, because of greater non-construction uses, sell almost as great a tonnage of stone.

Marble and dimension limestones are also quarried at Phenix, Greene County, and at two quarries in Ste. Genevieve County. Each area, like that at Carthage, produces excellent stone which is widely used. Limestone and marble sold by producers in the Carthage district from 1942 through 1947 is given in Table 29.

Missouri stone is found in the finest types of public and private construction from New England and Georgia on the east to California, Oregon, and Hawaii on the west.

The Missouri Geological Survey and Water Resources in 1946 published a Report of Investigations, "Missouri Marble", by Norman S. Hinchey. It describes the stones quarried for building purposes and gives partial lists of users.

Other limestone or dolomite. Missouri limestones also have important uses as fluxing stone, railroad ballast, riprap, and miscellaneous other uses such as rock wool melts and whiting manufacture.

Fluxing stone from Missouri is used primarily to flux iron ores at the blast furnace and lead ores at the lead smelters. The coarsely broken stone used as riprap is placed on the natural and artificial banks of streams to control erosion. Such work is usually done on a large scale. In 1946, 212,100 tons of riprap were used, or less than half of the 523,900 tons used in 1945. In 1947 the tonnage so used increased to 458,260 tons.

Railroad ballast is used to provide a well-drained, resilient support for railroad ties. In recent years, as the weight and average speed of trains has been increased, more attention has been given to adequate ballast material, and railway companies go to much expense to secure sound, properly sized ballast stone. Limestone or dolomite used for ballast in 1947 amounted to 102,080 tons.

Granite. The Missouri red granite quarried in the Graniteville area of Iron County has been noted many years for its fine qualities as a rough construction and monument stone. Production of granite in Missouri, both in terms of amount and value, increased in 1946 and 1947 but, since the production data were given in confidence, they cannot be revealed.

One of the most interesting features of the Missouri granite industry is that about 90 per cent of the rough monument stone quarried is shipped to New England, where it is in demand as a contrasting stone with the gray granites of Vermont and other New England states.

Granite and rhyolite porphyry are found in Madison, Iron, St. Francois, Ste. Genevieve, Wayne, Carter, Shannon, Reynolds, and Washington counties. These stones and a diabase that occurs in Madison County were quarried quite extensively in the last quarter of the 19th century and the early part of the present one. At that time many city streets and sidewalks were paved with granite blocks or slabs.

At present the red granite in the vicinity of Graniteville is quarried by the A. J. Sheahan Granite Company and the Coggins Granite and Marble Industries. Missouri pink granite is quarried in St. Francois County by the Missouri Granite Corporation.

Missouri red granite is widely known for its richness and warmth of color. The spacing of joints is such that large blocks of stone like the 42-foot shaft of the Thomas Allen Monument at Pittsfield, Massachusetts, can be quarried.

During 1948 the Sheahan Granite Company began building a plant to produce semi-finished stone. In the same year the Coggins firm of Georgia began working its new quarry near Graniteville.

Sandstone. Sandstone is produced in numerous Missouri localities to supply local demand for foundation stone, walls, and stone veneer. Such quarries work intermittently and the production is not recorded. At present the Roubidoux sandstone is widely used in the Ozark region in facing residential and small business buildings.

In the period 1880 to about 1900, the Warrensburg sandstone was quarried extensively at Warrensburg and Miami to supply dimension sandstone for the building trades in St. Louis and Kansas City.

The sandstone west of Miami in Carroll County has been quarried intermittently since then for use as riprap, and some sandstone has been quarried for railway ballast. On the basis of U. S. Bureau of Mines reports, it appears that the maximum production was attained in 1929 and 1930, when 393,570 tons of sandstone valued at $610,628 were quarried for riprap and railway ballast. The last production figures to be made public were for 1934, when 31,890 tons of stone valued at $48,663 were produced.

Asphaltic Sandstone. Asphaltic sandstone is found in certain sandstones of the Cherokee group of Pennsylvanian rocks in several counties in west and southwest Missouri. It has been mined in Barton and Vernon counties to produce a paving material that is used on streets in many cities of Missouri, Kansas, Iowa, and some other states.

At present, the Barton County Rock Asphalt Company is quarrying asphaltic sandstone near Iantha, Missouri. The quarried material is crushed and mixed with additional asphalt to produce a paving material which is marketed under the name of Bar-Co-Roc.

As there are less than three producers of asphaltic rock in Missouri, the production figures for the past several years cannot be given without revealing confidential data. It can be said, however, that as a result of increased activity in highway contruction and maintenance, sales for 1946 exceeded those of 1945. The production declined considerably, however, in 1947.

The bituminous or asphaltic sandstone is brown to black on fresh surfaces. It is composed of quartz sand grains and a small amount of mica cemented with interstitial bitumen. The variable distribution and the composition of the bitumen suggest that it is a residue derived by evaporation of crude petroleum. The freshly quarried rock at Iantha is said to carry from 4 to 7 per cent native bitumen. The Barton County Rock Asphalt Company, in preparing Bar-Co-Roc, blend in an additional 4 per cent of penetration asphalt which improves the product.

Chats. When iron, lead, and zinc ores are crushed and the metallic minerals separated from the rock constituents, there remain the crushed rock known in Missouri as chats. In the Lead Belt of Southeast Missouri the chats are chiefly limestone and dolomite which are further ground and used as agstone.

In southwest Missouri, the chats are mostly flint and chert and are sold for railway ballast, road metal, concrete aggregate, and roofing granules.

In the period 1915 through 1947 approximately 52,610,000 tons of chats were sold for $12,011,000. In 1946 the tonnage sold was 1,889,030 tons for which $762,148 were paid. Railway ballast accounted for 961,030 tons, or 50.8 per cent of the 1946 gross. Requirements for concrete and road metal in the same year were 450,210 tons. The remaining 477,790 tons were used as agstone and for unspecified purposes.

Table 30

Chats[1] Produced in Missouri 1915 through 1947

Year	Short Tons	Value	Year	Short Tons	Value
1915	2,309,191	$346,379	1932	1,300,000	$260,000
1916	2,890,970	433,646	1933	1,934,349	493,597
1917	1,426,716	285,343	1934	1,937,000	484,350
1918	902,129	270,000	1935	1,496,700	243,250
1919	1,375,757	550,300	1936	2,784,800	485,000
1920	1,113,522	501,000	1937	39,810	33,263
1921	1,730,473	260,000	1938	13,430	19,349
1922	1,141,159	175,000	1939	146,240	60,118
1923	1,218,180	185,000	1940	1,470,849	238,266
1924	2,081,075	312,200	1941	2,182,372	458,696
1925	1,596,409	399,102	1942	2,485,210	487,605
1926	1,679,800	419,940	1943	1,331,520	285,999
1927	2,107,620	526,933	1944	1,322,950	319,435
1928	1,904,000	476,000	1945	1,351,970	307,892
1929	2,585,200	494,800	1946	1,889,030	762,148
1930	1,433,284	355,821	1947	2,084,480	744,681
1931	1,343,463	335,865			
Totals from 1915 through 1947				52,609,658	$12,010,978

[1]Includes some other miscellaneous stone.

In 1947 the tonnage of chats sold increased to 2,084,480, valued at $744,681. Railway ballast accounted for 984,300 tons, concrete and road metal for 613,750 tons. The remaining 486,430 tons were used for the most part as agricultural limestone. Relatively small amounts were used as roofing granules.

TUNGSTEN

Tungsten is one of the critical and strategic minerals important both in peace and war. The metal is used chiefly in the manufacture of high-speed cutting tools, with lesser amounts being used in armor-piercing projectiles, gun linings, valve steels, and magnet steels. It is used as the pure metal to make incandescent lamp and radio-tube filaments, X-ray targets, and electrical contact points. As tungsten carbide it has great usefulness, for it is so hard that it will cut sapphire. It will cut machine turnings at three to ten times the speed of high-speed cutting steels. Tungsten carbide has a melting point of 5400 degrees Fahrenheit and ranges in hardness from 9.8 to 9.9 on Moh's scale. Of late years tungsten carbide has been used to replace industrial diamonds in rotary drill bits and in wire-drawing dies. Added to steels, tungsten increases the hardness of the metal, particularly at red heats, through its ability to stabilize the hard iron carbides. Much of the quality of the ancient Damascus sword steels is due to the tungsten content.

Chemical salts of tungsten are used as mordants in the pigment and dye industries.

Tungsten in Missouri. Tungsten has been known to exist as a constituent of the hydrothermal quartz veins of Madison County since before 1893.

The first effort to mine tungsten was made in February 1916 when the Madison Mining Corporation of New York built a small mill at the old Einstein Mine near Silver Mines, Madison County, and began re-working the old mine dumps. Information on the production resulting from this company's three-year operation is incomplete. The Bureau of Mines reports production from Missouri in 1916 but makes no mention of production in 1917 or 1918. Fink[1], however, credits 50 tons of concentrate to Missouri in 1917. Other sources suggest that total production of tungsten for the year 1916 through 1918 reached a total of $250,000. It is believed that an estimate of 100 tons of 60 per cent tungsten concentrate valued at $131,000 approximates the true production during World War I.

The next tungsten production was made in 1927, when the Ozark Tungsten Company of Fredericktown, Missouri, secured control of all the mines in the area and began mining at the Apex Mine. Five tons of concentrate valued at about $3,100 were produced in 1928[2].

Between 1937 and 1945 there were a series of leasing operations which resulted in the production of about 20 tons of tungsten concentrate valued at roughly $28,000. During 1946 and continuing into 1947, the And-Mor Company erected a new mill at

Table 31

Production and Value of Tungsten in Missouri

Year	Short Tons	Value
1916, 1917, 1918	100	$131,000
1928	5	3,110
1937	½	500
1938	1	1,160
1940	13	17,480
1941	3	3,839
1943	1	1,128
1944	1	1,860
Totals.........	124½	$160,077

[1]Fink, Colin G., The Mineral Industry during 1917. McGraw-Hill Book Co., p. 704, 1919.

[2]Fink, Colin G., Mineral Industry during 1928. McGraw-Hill Book Co., p. 611, 1929.

the site of the Apex Mine and undertook rehabilitation of the mine. The property was in production in 1948, but the amount of tungsten concentrate sold has not been reported. Table 31 presents the production data through 1944.

TRIPOLI

Tripoli is a light, minutely porous silicious rock mined in the vicinity of Seneca and Racine, southwest Missouri. It finds wide usage in this country and abroad because of physical characteristics which make it an ideal abrasive in polishing and buffing compounds, such as are used in finishing automobile lacquers and paints. Certain grades of tripoli are also used as fillers and as foundry partings.

The tripoli is found in lenticular deposits in the Boone formation which is in the lower part of the Mississippian System of rocks. The deposits range in area from a few hundred square feet to three acres, and are from a few feet to 12 feet in thickness.

At present, the American Tripoli Company is the only processor of tripoli in the Seneca area. It mines crude tripoli in both Newton County, Missouri, and adjacent Ottawa County, Oklahoma. Mining begins with the removal of the overburden of earth, clay, and chert by power shovels. The surface of the tripoli is cleaned by hand, after which it is drilled and blasted. The broken tripoli is hauled to drying sheds where it dries naturally three to six months before being taken to the modern grinding mill at Seneca for crushing, drying, grinding, sizing, and bagging.

Although Missouri is the chief producer of tripoli, the total amount and value of the product can only be estimated from the statistical record kept by the United States Bureau of Mines, as the tripoli production of Missouri is grouped with that from Oklahoma, as well as with amorphous silica from Illinois and the rottenstone from Pennsylvania. It is estimated that Missouri production of this abrasive through 1947 approximates 308,000 tons valued at $4,105,000.

History of Tripoli Industry in Missouri. Tripoli was discovered in southwest Missouri in 1869. By 1871 a small mill had been built and the Monarch Tripoli Company was selling tripoli scouring bricks. The American Tripoli Company was organized and built a grinding mill in 1887 and soon afterwards installed machinery for the manufacture of filter stones. At that time filter stones were used widely for filtering suspended matter from

Table 32

Tripoli Sold by Missouri Producers

Year	Short Tons	Value at Plant	
		Total	Average
1942	4,961[1]	$69,038[1]	$14.00
1943	4,709[2]	75,607[2]	16.05
1944	6,394[1]	96,131[1]	15.05
1945	6,542	114,188	17.45
1946	12,180	211,244	17.35
1947	19,375	469,927	24.25

[1]Tonnage and value include Arkansas tripoli and Pennsylvania rottenstone.
[2]Tonnage and value include Arkansas and Oklahoma tripoli as well as Pennsylvania rottenstone.

Table 33

Uses of Tripoli in the United States[1]
1944 through 1946

Uses	1944		1945		1946	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
Abrasives	13,218	$210,592	11,113	$188,262	21,206	$406,620
Concrete admixture	316	4,552	1	18	....	....
Filler	3,423	66,147	3,969	65,569	4,450	89,721
Oil well drilling, foundry facing, and unspecified	1,468	20,572	3,164	52,980	3,299	52,758
Totals	18,425	$301,863	18,247	$306,829	28,955	$549,099

[1]Includes Pennsylvania rottenstone and Illinois amorphous silica.

domestic water supplies. After 1919 this use declined and by 1924 the manufacture of filter stones had ceased except for special orders. In the meantime, substantial foreign and domestic outlets had been established for the powdered tripoli which was marketed in several grades. Table 32 shows the amount and value of the tripoli sold by Missouri producers from 1942 through 1947 and Table 33 shows the uses of tripoli in the United States. In 1946 Missouri produced 12,180 tons of tripoli, while the total of tripoli, rottenstone, and amorphous silica used in the country was 28,955 tons.

ZINC

Zinc in 1946 and 1947. In 1946 the mines of Missouri yielded 43,000 tons of zinc concentrate, which contained 22,234 tons of recoverable zinc valued at $5,425,096. In 1947 the production was

17,074 tons of zinc valued at $4,131,908. Table 34 presents the zinc production of Missouri by districts for each of the past eleven years as well as collectively for the period prior to 1937. Table 35 gives the total production and value of the zinc produced in Missouri by years.

Brief History of Zinc Mining in Missouri.[1] The first zinc ore mined in Missouri was probably a mixed lead-zinc ore which was mined for the lead content only. Such ores in Missouri were first discovered in Washington, Jefferson, Franklin, and Madison counties. At the time of the early discoveries, however, zinc metallurgy in the United States had not developed to the extent that metal could be made cheaply or efficiently from such ores.

In 1860 the Matthiessen and Hegeler Zinc Company erected an efficient horizontal retort zinc smelter at La Salle, Illinois, to treat the zinc ores of the upper Mississippi basin near Galena, Illinois. Following that company's lead, a small zinc smelter was built at Potosi, Missouri, in 1867, and two years later the Martindale zinc plant was established at Carondelet. Subsequently, the Missouri Zinc Company built a smelter at Carondelet, and the Washington furnace and that of Page and Krause were erected in St. Louis. These furnaces provided a ready market for the ores of Southeast Missouri and stimulated utilization of the zinc ores which had previously been unmined or left in mine dumps.

The zinc ores of the now famous Joplin district were known at that time, but without rail transportation they could not be readily marketed. In 1870 the St. Louis and San Francisco Railway was completed westward to Pierce City, Missouri, and the following year it was extended into Kansas. Ready transportation now permitted exploitation of the rich zinc ores of Southwest Missouri, and it is reported that the first shipment of concentrate from Joplin was made to La Salle, Illinois, in 1872. Mining activity rapidly increased in the Joplin, Oronogo, Webb City, and Granby areas, and in 1873 a zinc smelter was built at Weir City, Kansas. This smelter was followed by others at Pittsburg, Kansas, and in Joplin.

The total zinc production of Missouri prior to 1870 was 67 tons with a value of $8000. In the decade 1870 through 1879 Missouri became the nation's chief source of zinc, producing 56,019 tons of the metal worth $6,545,580.

1880 to World War II. In the 43 years preceding 1918, Missouri held first place among the states as a producer of zinc ores

[1]Winslow, Arthur, Lead and Zinc Deposits, vol. VII, sec. 2, Missouri Geol. Survey, pp. 274-302, 1894.

Table 34

Zinc Production in Missouri, by Districts

Year	Southeast Missouri		Central Missouri		Southwest Missouri		Total	
	Short Tons	Value	Short Tons	Value	Short Tons	Value	Short Tons	Value
Prior to 1937	53,269	$5,973,842	6,352	$586,471	3,329,337	$418,814,856	3,388,958	$425,375,169
1937	11	1,430	....	....	20,589	2,676,570	20,600	2,678,000
1938	....	....	....	....	10,226	981,696	10,226	981,696
1939	....	....	....	....	15,096	1,569,984	15,096	1,569,984
1940	106	13,356	127	16,002	12,470	1,571,220	12,703	1,600,578
1941	893	133,950	207	31,050	20,832	3,124,800	21,932	3,289,800
1942	663	123,318	179	33,294	35,552	6,612,672	36,394	6,769,284
1943	820	177,120	103	22,248	29,490	6,369,840	30,413	6,569,208
1944	1,429	325,812	79	18,012	35,118	8,006,904	36,626	8,350,728
1945	560	128,800	35	8,050	21,580	4,963,400	22,175	5,100,250
1946	451	110,044	....	....	21,783	5,315,052	22,234	5,425,096
1947	295	71,390	....	....	16,779	4,060,518	17,074	4,131,908
Totals........	58,497	$7,059,062	7,082	$715,127	3,568,852	$464,067,512	3,634,431	$471,841,701

Table 35

Annual Production and Value of Zinc in Missouri[1]

Year	Short Tons	Value	Year	Short Tons	Value
Prior to 1870	67	$ 8,000			
1870-1879	56,019	6,545,580	1920	24,509	$3,970,458
1880-1893	433,033	43,303,333	1921	10,845	1,084,500
1894	59,187	4,166,628	1922	16,171	1,843,494
1895	48,563	3,496,536	1923	18,265	2,484,040
1896	46,551	3,714,098	1924	12,920	1,679,600
1897	59,378	4,916,024	1925	14,794	2,248,688
1898	81,408	7,409,060	1926	26,018	3,902,700
1899	93,025	10,805,453	1927	18,737	2,398,336
1900	101,392	8,822,503	1928	12,974	1,582,828
1901	113,440	9,234,287	1929	11,017	1,454,244
1902	114,460	11,055,824	1930	10,811	1,037,856
1903	103,595	11,596,827	1931	3,210	243,580
1904	121,527	13,585,664	1932	986	59,160
1905	112,758	12,301,124	1933	5,042	423,528
1906	116,351	14,404,254	1934	7,059	607,074
1907	116,752	13,776,736	1935	7,263	639,144
1908	107,404	10,095,976	1936	18,709	1,870,900
1909	130,162	14,057,496	1937	20,600	2,678,000
1910	129,589	13,995,612	1938	10,226	981,696
1911	122,515	13,966,710	1939	15,096	1,569,984
1912	136,551	18,844,038	1940	12,703	1,600,578
1913	124,963	13,995,856	1941	21,932	3,289,800
1914	105,994	10,811,388	1942	36,394	6,769,284
1915	136,300	33,802,400	1943	30,413	6,569,208
1916	155,960	41,797,280	1944	36,626	8,350,728
1917	132,918	27,115,272	1945	22,175	5,100,250
1918	55,992	10,190,544	1946	22,234	5,425,096
1919	31,540	4,604,840	1947	17,074	4,131,908
Totals from earliest records through 1947...........				3,634,431	$471,841,701

[1]Early production data through 1893 were obtained from the compilation in Arthur Winslow's "Lead and Zinc Deposits of Missouri", vol. VII, sec. 2, Missouri Geol. Survey, pp. 500-540, 1894. Figures for tonnage and value of zinc from 1894 through 1905 were compiled from statistics presented in the Annual Reports of the State Mine Inspector of Missouri, U. S. Bur. Mines Inf. Circ. 7383, and the U. S. Geol. Survey Mineral Resources U. S. Figures for tonnage and value of zinc from 1906 through 1931 were obtained from Mineral Resources U. S. compiled by the U. S. Geol. Survey and the U. S. Bur. Mines. Similar data for 1932 through 1947 were obtained from the U. S. Bur. Mines Minerals Yearbooks.

for all but two years. New mines were discovered at a rapid rate in the Southwest district during the period 1880 to 1900, and mining was vigorously prosecuted. The year of maximum production in Missouri was 1916, when 304,070 tons of concentrate containing 155,960 tons of recoverable zinc were produced.

In 1911 and 1912 drilling extended the Commerce, Oklahoma, field northwest and northeast into the very large, rich ore bodies in the vicinity of Picher, Oklahoma. There followed a huge mining boom. Exploration equipment was diverted from the Missouri portion of the mining district to the Picher area; new equipment was purchased; and all efforts were made at once to develop and begin mining the rich new ore bodies. Mining and milling equipment were removed from many of the Missouri mines.

Production in the Southwest Missouri field dropped from 155,527 tons of recoverable zinc in 1916 to 55,918 tons in 1918, and to 10,845 tons in 1921. Since 1921 the annual production of zinc in Missouri has averaged about 15,500 tons per year, with production slightly exceeding 36,000 tons of the metal in 1942 and 1944.

World War II to the present time. Until the beginning of World War II the United States produced adequate amounts of zinc to meet its needs. The metal was mostly recovered from large reserves of low-grade ores which were profitably mined under a tariff-supported domestic price. The heavy war demands for zinc beginning in 1939 could not, however, be met economically by domestic production, and imports of foreign zinc were necessary to augment the home supply.

As demand increased, the imports of metal, ore, and concentrate increased to the extent that imports supplied 3 per cent of our zinc in 1939, 13 per cent in 1940, and 21, 29, 39, 34, 39, 37, and 36 per cents, respectively, in 1941, 1942, 1943, 1944, 1945, 1946, and 1947. Imports filled practically all of the increased needs, but it was necessary to pay premiums to many zinc producers in order to maintain domestic production, for costs had increased under wartime conditions. Depending upon the grade of ore and the cost of mining and milling, the mine operators of Missouri received payments ranging from the base price of $55.28 up to $144.38 per ton of 60 per cent zinc concentrate. During the years 1941 through 1945 the average total payments received for a ton of zinc concentrate were $50.08 in 1941, $69.63 in 1942, $100.52 in 1943, $104.51 in 1944, and $109.60 in 1945. Subsidy payments under the premium price plan ceased with its expiration June 30, 1946. The payments were resumed and made retroactively effective when the Office of Price Administration (OPA) was subsequently re-established by Congressional action. On October 14, 1946, the OPA revised the base price of zinc from 8.25 cents to 9.25 cents a pound, but on November 9 the same year the ceiling price was removed from all metals by the President. Premium payments were continued, however, until June 30, 1947. The base price of a pound of zinc was increased to 10.50 cents f.o.b. St. Louis on November 12, 1946, and there it remained throughout 1947.

Under these conditions, the average price paid the miners for a ton of concentrate in 1946 further increased to $117.84, but declined again in 1947 to an average of $105.71 when subsidies ceased, and the base price of zinc under free market conditions declined to $70.35 per ton of 60 per cent concentrate. On May 10, 1949, the price per ton of such concentrate was $79.00, and the metal was quoted for sale at 12.5 cents per pound in East St. Louis.

The Uses of Zinc. The use of zinc is very old. The ancient Egyptians, Phoenicians, and Assyrians used brass and bronze in which zinc was a constituent. This zinc was obtained by smelting copper ores containing zinc minerals. It was not until the 13th century that a Dominican monk, Albertus Magnus, isolated and described zinc and told how he made brass, using the zinc silicate, calamine, in combination with copper.

The first commercial zinc production appears to have been in the Orient. The art of zinc smelting spread to England about 1730 and then to other countries having zinc ores.

In addition to its use in making alloy brass, zinc has many other varied uses. The most important is to galvanize iron and steel products such as pipe, wire, fencing, screen, and sheet metal to prevent rust. Zinc is used in various alloys other than brass. Such alloys as well as the relatively pure metal are used in making die castings, such as automobile door handles, small machine parts, and various items of trim. Zinc also is used in a relatively pure form to make sheeting for roofing and as thinner sheets to form the exterior wall and one electrode of dry cells for flashlight, telephone, and radio batteries. As a fine powder or dust, zinc is added to gold cyanide solutions in the hydro-metallurgy of gold to precipitate the metallic gold so that the gold can be filtered free from the solution. Lead refineries add zinc to molten lead to de-silverize the lead.

The oxide of zinc is an important paint pigment. Although it lacks the covering power of white lead, it has the advantage that the pigment is non-poisonous and does not darken when exposed to hydrogen sulfide. Still another important zinc-containing pigment is lithopone, an intimate mixture of zinc sulfide and barium sulfate. Consumption of both zinc oxide and lithopone increased in 1946 and 1947.

Zinc finds many other uses. As the sulfate, it is used in varnishes and as a mordant in the dye industry. The sulfate when mixed with cobalt nitrate and heated makes the green paint pigment known as Rinman's green. Zinc carbonate is still another paint pigment. Zinc chloride, yet another commercial zinc compound, is a powerful caustic employed to burn off warts and to prevent the growth of horns on cattle.

The Future of Missouri Zinc. The major part of the zinc produced in Missouri since 1941 has been from remnants of ore bodies left in old mines and from low grade deposits that were not profitable at pre-war prices. Subsidy payments, together with improved mining and milling techniques, made the mining of these ores possible during the war; but when premium payments ceased June 30, 1947, production immediately declined and was limited to the richer portion of zinc ore bodies and those that contained lead.

The depletion of the richer portion of the known ores in Southwest Missouri does not mean that mining there will permanently cease, but it does mean that production will not increase until the price is increased or the cost of production declines.

At present the zinc ore reserves of Southwest Missouri are estimated to be approximately 25 millions of tons analyzing about 1.75 per cent zinc and 0.25 per cent lead. Such ore bodies are now marginal; that is, the costs are too high in relation to the worth of the product to permit mining and milling to be an assured success. When favorable price-cost ratios exist, these ore bodies will be mined, and further exploration will be stimulated, which in turn will lead to new discoveries and more mining.

MISCELLANEOUS

Sulfur and Sulfuric Acid. The Laclede Gas and Light Company of St. Louis produced 265 long tons of elemental sulfur in 1946 as a by-product in the liquid purification of gas by the Thylox process. The Thylox processing equipment was installed prior to the war, but production data are available only for 1946. The value of the sulfur cannot be attributed to Missouri, as the gas was not from Missouri wells nor made from Missouri coal.

A considerable amount of sulfuric acid is made at Illinois zinc smelters from zinc sulfide concentrates produced by Missouri mines. The amount and value of this production are not recorded separately, but the value is included under "Miscellaneous" in Table 1 and under "Miscellaneous non-metallics" in Table 3.

Umber, Ocher, and Other Natural Iron Oxide Pigments. Paint pigments made of natural iron or iron and manganese oxide minerals have been produced at various times in Missouri in large amounts. The production figures, however, are usually given in confidence and hence cannot be revealed. This industry which is actually a part of the iron ore mining industry was active during the war, when the demand for iron oxide pigments was increased, owing to the need of that pigment to manufacture olive drab paint for military equipment and establishments.

In the years 1942 through 1944 several mines in Butler, Carter, Dent, Iron, Perry, Texas, and Washington counties produced several thousand tons of paint pigments.

Manufactured or synthetic iron oxide pigments are tending to replace much of the natural product and no umber or ocher have been produced since 1944.

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