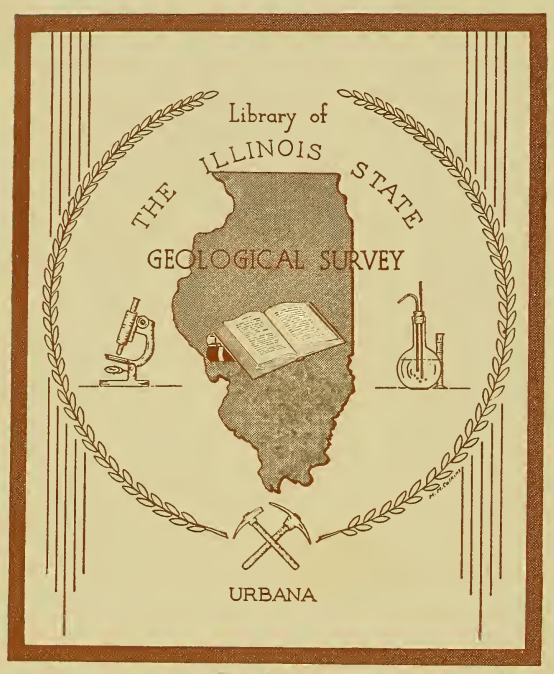
Illinois
State Geological Survey



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THE FLUORSPAR INDUSTRY OF THE UNITED STATES WITH SPECIAL REFERENCE TO THE ILLINOIS-KENTUCKY DISTRICT

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THE FLUORSPAR INDUSTRY OF THE UNITED STATES WITH SPECIAL REFERENCE TO THE ILLINOIS-KENTUCKY DISTRICT [1]

By Paul Hatmaker[2] and Hubert W. Davis[3]

INTRODUCTION

THE FLUORSPAR industry is regarded as one of the smaller nonmetallic mineral industries; nevertheless, the annual domestic production normally is valued at more than $2,000,000. From 1911 to 1936 the annual value has fluctuated from about $600,000 in 1911 to nearly $5,500,000 in 1918; from 1921 to 1930 the average was somewhat less than $2,250,000; from 1931 to 1935 it fell to an average of $1,123,000; and in 1936 the value was more than $3,000,000.

The domestic fluorspar industry represents a capital investment in the neighborhood of $10,000,000 and in years of good demand for fluorspar it gives employment to 1,500 to 2,000 wage earners. In 1929 the industry paid out about $1,500,000 in wages and salaries and about $1,000,000 for supplies, materials, fuel, and machinery, notwithstanding that domestic mines supplied only 73 per cent of the United States demand during that year. A comparison of the relative size on a national scale alone, however, does not illustrate adequately the great importance of fluorspar mining in the economic life of the sections of the states where the mines are located, particularly in the Illinois-Kentucky producing district where there is no other industry except agriculture. Because of its rugged character some of the land is not tillable, and much is rather poor for farming. Steady operation of the mines, therefore, is essential to the livelihood of the labor dependent on them and to the welfare of the communities, which are the center of the fluorspar-producing industry.

About a dozen companies in a small area along the Ohio River in southern Illinois and western Kentucky produce most of the domestic supply. In 1936 this area shipped 161,647 short tons of fluorspar, 92 per cent of the domestic total (figs. 1 and 2).

The status of the steel industry largely determines the prosperity of the producers, as basic open-hearth steel plants use about three-fourths of all fluorspar consumed in the United States (fig. 3). Fluorspar, however, is raw material for a number of other manufacturers.

Imports of fluorspar into the United States were relatively large up to 1930, since which time they have declined sharply. For example, of the 158,597 short

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tons of fluorspar delivered to domestic consumers in 1930, 63,009 tons (about 40 per cent) came from abroad, whereas of the 200,908 tons sold to domestic consumers in 1936, only 24,917 tons (about 12 per cent) were from foreign sources. Exports are negligible. Foreign supplies enter the Atlantic seaboard markets and usually penetrate westward as far as Pittsburgh, the battleground of domestic versus foreign fluorspar; during the World War, however, imports were severely curtailed at a time of great demand (fig. 4).

This paper describes the major features of the domestic industry, from the occurrence of the crude fluorspar to the ultimate utilization of the finished product. The emphasis, however, is placed upon the economic factors. As production is essentially a matter of scientific and engineering skill, technologic

FIGURE 1.—FLUORSPAR PRODUCTION IN THE UNITED STATES, 1900-1936.

problems are mentioned only in sufficient detail to indicate the methods by which they have been solved successfully by the operator. For the technology of production the reader is referred to an earlier United States Bureau of Mines publication[4] and to more recent papers[5] prepared by men intimately associated with the industry.

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4 Ladoo, R. B., Fluorspar, Its mining, milling, and utilization, with a chapter on cryolite: U. S. Bur. Mines, Bull. 244, 1927.

5 Cronk, A. H., Mining methods of the Rosiclare Lead & Fluorspar Mining Co., Rosiclare, Illinois: U. S. Bur. Mines, Inf. Circ. 6384, 1930.

Reeder, E. C., Methods and costs of mining fluorspar at Rosiclare, Illinois: U. S. Bur. Mines, Inf. Circ. 6294, 1930; Milling methods and costs at the Hillside Fluorspar Mines, Rosiclare, Ill.: U. S. Bur. Mines, Inf. Circ. 6621, 1932.

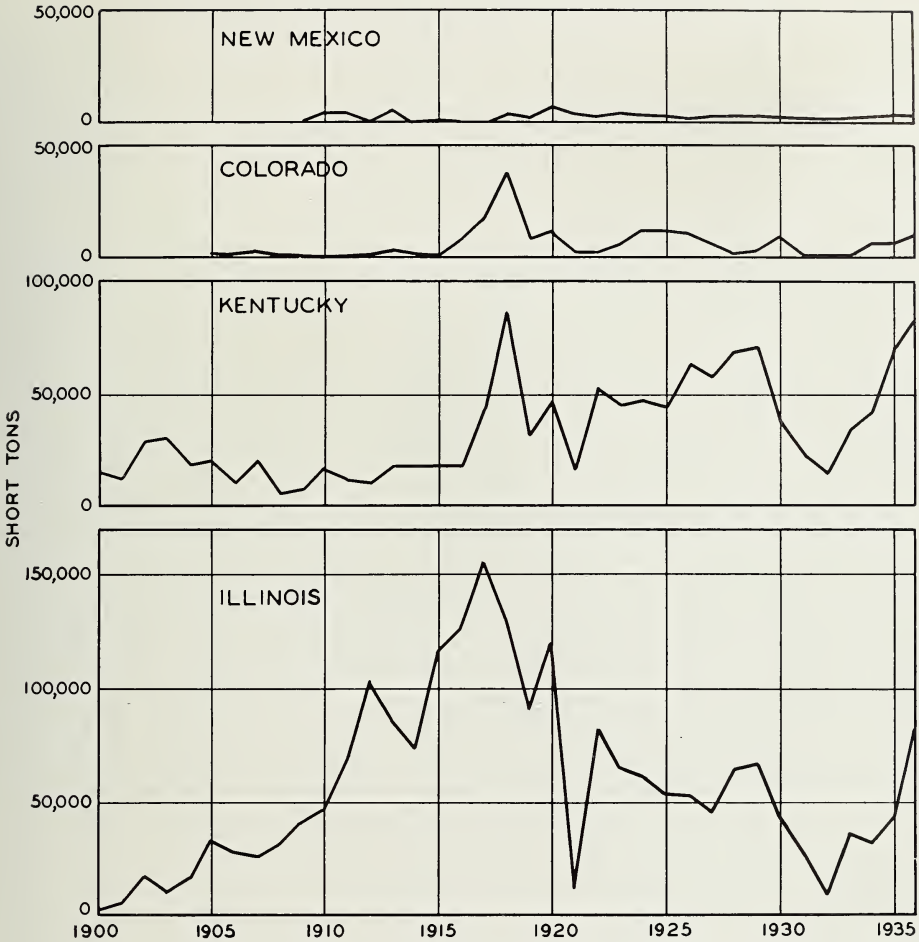

FIGURE 2.—FLUORSPAR PRODUCTION IN THE UNITED STATES, BY CHIEF PRODUCING STATES.

The technology of utilization likewise is described only enough to complete the picture. As utilization methods change rapidly, the producers should acquaint themselves with new conditions and prepare to meet them. The basic open-hearth steel industry, for example, uses less fluorspar per ton of steel than formerly, and the effect upon fluorspar production is obvious. Consumption of fluorspar in glass, enamel, and hydrofluoric acid, however, has been increasing in recent years.

In addition to a discussion of production, marketing, and utilization, certain data bearing on the future of the domestic industry are summarized. The most important of these are ore reserves (from which must come the production of tomorrow) and possible market conditions.

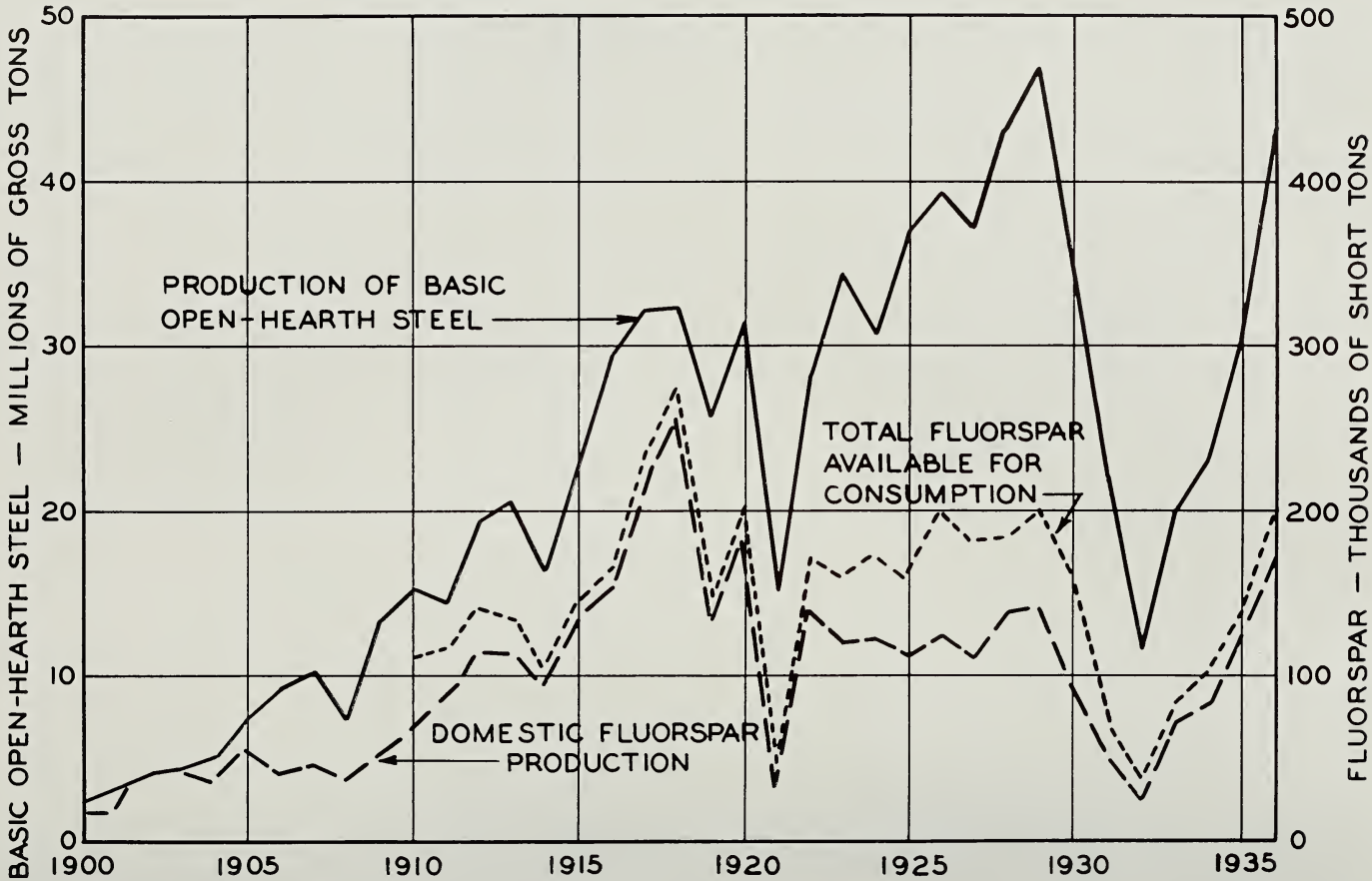

FIGURE 3.—PRODUCTION OF BASIC OPEN-HEARTH STEEL AND FLUORSPAR IN THE UNITED STATES, 1900-1936, AND FLUORSPAR AVAILABLE FOR CONSUMPTION, 1910-1936.

Figure 4.—Fluorspar Imported into and Produced in the United States, 1910-1936.

ACKNOWLEDGMENTS

THE original manuscript of this report was completed in June, 1932, under the auspices of the United States Bureau of Mines. It has since been revised by H. W. Davis of the Bureau, the junior author, in collaboration with W. H. Voskuil, F. H. Reed, and J. E. Lamar of the Illinois Geological Survey.

Acknowledgment is made for review and many helpful suggestions by R. C. Allen and E. L. Brokenshire of Oglebay Norton and Company, John T. Fuller and Roy Miller of Franklin Fluorspar Company, Paul M. Tyler of the United States Bureau of Mines, E. S. Bastin of the University of Chicago, and L. W. Currier of the United States Geological Survey.

In the preparation of this report the authors have drawn freely upon past Mineral Resources and Minerals Yearbook chapters describing the fluorspar in-

dustry; United States Bureau of Mines Bulletin 244, "Fluorspar: Its Mining, Milling, and Utilization," by R. B. Ladoo; and various reports of the United States Tariff Commission. Data on origin, occurrence, and reserves of the Western deposits have been derived mainly from a report by E. F. Burchard of the United States Geological Survey.[6]

The producers and consumers have cooperated in supplying needful data for this report. Their help is deeply appreciated.

DESCRIPTION

NOMENCLATURE

THE term "fluorite" is applied to the mineral composed of calcium fluoride and usually relates to chemically pure crystals or crystal fragments. The term "fluorspar" is now used almost exclusively, both in the commercial and scientific sense. Originally it was called "fluor" from the Latin root *fluo* (signifying *I flow*), but "spar" is a generic name for numerous nonmetallic minerals (especially those lustrous and cleavable), and "fluor" and "spar" were later combined into one word. Fluorspar is commonly called "spar" in the industry, and this term alone is used frequently in this report. However, this term has a more general meaning, being applied also to barite (heavy spar), feldspar, calc-spar (calcite), gypsum, and siderite, depending upon the mining locality.

In England, fluorspar is known as Derbyshire spar or Durham spar, depending upon the locality. "Blue John" is a term applied locally to a fibrous columnar variety found in Derbyshire and used for vases and ornaments. Fluorspar was also called "fluate of lime" in the United States during the early days. The terms "false emerald" and "false amethyst" (or similar designations according to color) also have been applied to finely colored varieties.

PROPERTIES

Fluorspar is a fairly heavy, medium-hard, brittle, glassy mineral composed chiefly of calcium fluoride (CaF_2). It crystallizes in the isometric system, a common form being the cube. Crystals have distinct octahedral cleavage, and fragments can easily be shaped into octahedrons. Cleavage is especially noticeable in well-developed crystals. Certain types are almost perfectly transparent, whereas others are quite opaque. Colors range from delicate tints to deep shades of green, yellow, blue, lavender and old rose; orange, brown and black are rather rare. Massive varieties may be white or colorless.

Fluorspar, fourth in the Mohs scale of hardness, is harder than calcite but softer than apatite or feldspar. Its specific gravity is 3.0 to 3.25. A cubic foot of pure massive fluorspar may weigh 188 to 203 pounds; calcite weighs about 170 pounds and quartz about 166 pounds a cubic foot. Milled gravel spar, containing 10 to 15 per cent calcite and silica, usually weighs 130 to 135 pounds per cubic foot (about 15 cubic feet per ton). Fluorite, being 10 to 20 per cent heavier than calcite and 13 to 22 per cent heavier than quartz, can be separated from these commonly associated minerals by gravity concentration.

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6 Burchard, E. F., Fluorspar deposits in western United States: Amer. Inst. Min. Met. Eng., Tech. Pub. 500, 1933.

The luster is commonly vitreous. The streak is typically white; however, purple varieties may pulverize to a faint lavender or a light pink. Fluorspar is quite brittle and breaks with a conchoidal or splintery fracture.

Flawless transparent fluorspar has a very low index of refraction (that is, it bends light rays only slightly), disperses light faintly, and commonly displays no double refraction. Because of its characteristic optical qualities fluorite is used in optics.

Fluorspar melts at 1,270° to 1,387° C.; pure calcium fluoride melts at 1,378° C. When heated, the mineral usually flies apart or decrepitates. It is virtually insoluble in water but is attacked by strong acids. Some varieties of fluorspar glow in the dark (phosphoresce) after moderate heating. Specimens exhibiting a bluish fluorescence also have been known.

USES

The most important use of fluorspar is as a flux in basic open-hearth steel furnaces. Other metallurgical processes using fluorspar include the manufacture of alloy steel and ferro-alloys in the electric furnace, the preparation of aluminum, and foundry work.

The next most important use at present is in the chemical industry, where fluorspar is used as raw material in the manufacture of hydrofluoric acid and its derivatives, closely followed by the ceramic industries, where fluorspar is used in opal or opaque and colored glass and in various enamels for coating metal ware.

Comparatively little fluorspar is used in the manufacture of cement, calcium carbide and cyanamid, abrasives, heat resistant brick, and carbon electrodes. Small quantities of clear fluorspar crystals are used for optical purposes, and also a small amount of the colored material may find its way into jewelry and stone ornaments.

Utilization of fluorspar is described in greater detail in the section on distribution of domestic consumption by grades and industries, page 63.

Table 1 summarizes the relative importance of domestic shipments for the major uses in 1935 and 1936.

TABLE 1—FLUORSPAR SHIPPED FROM MINES IN THE UNITED STATES, 1935-1936, BY USES.

Use	1935				1936			
	Quantity		Value		Quantity		Value	
	Per cent of total	Short tons	Total	Average	Per cent of total	Short tons	Total	Average
Steel	81.76	101,168	$1,392,661	$13.77	80.36	141,618	$2,296,792	$16.22
Foundry	1.89	2,336	29,068	12.44	1.32	2,326	36,729	15.79
Glass	8.29	10,256	227,917	22.22	6.25	11,014	267,290	24.27
Enamel and vitrolite	3.30	4,087	100,686	24.64	2.98	5,249	129,206	24.62
Hydrofluoric acid and derivatives	2.69	3,333	74,732	22.42	7.16	12,627	326,048	25.82
Miscellaneous	1.82	2,248	30,923	13.76	1.79	3,157	51,124	16.19
	99.75	123,428	1,855,987	15.04	99.86	175,991	3,107,189	17.66
Exported	.25	313	4,651	14.86	.14	240	4,079	17.00
Total	100.00	123,741	1,860,638	15.04	100.00	176,231	3,111,268	17.65

SUBSTITUTES

No other substance appears to be as satisfactory as fluorspar for a general slag thinner and conditioner. Certain furnace charges, such as those containing relatively large ratios of high-manganese ore, high-manganese pig iron, or hematite, may require little or no fluorspar. Such components of the charge, however, can not be considered substitutes for fluorspar, as they merely provide conditions wherein spar is not needed.

Calcium chloride is the best substitute for fluorspar in steel making. Reports indicate, however, that several times as much calcium chloride (50 or more pounds per ton of steel) is required, and the cost at least equals that of fluorspar. Moreover, the chloride is hygroscopic and deliquescent, making it less suitable for storage and handling. Data are not available as to the quantity of calcium chloride now being employed in steel manufacture, but it is believed that it is very small.

Table 2.—Cryolite Imported into the United States, 1922-1936.

Year	Short tons	Value	
		Total	Per ton
1922	4,367	$196,302	$44.95
1923	7,140	319,959	44.81
1924	7,078	320,670	45.30
1925	11,025	690,651	62.64
1926	8,511	557,598	65.51
1927	5,672	410,876	72.44
1928	7,735	529,176	68.41
1929	8,711	670,841	77.01
1930	9,313	695,794	74.71
1931	8,857	580,621	65.56
1932	4,236	291,357	68.78
1933	4,638	298,316	64.32
1934	4,984	376,868	75.62
1935	9,295	646,390	69.54
1936	14,130	1,076,538	76.19

In lieu of the use of fluorspar, furnace slags may be made more liquid by modifying their composition through addition of more lime and other bases, including compounds of sodium and potassium, iron scale, bauxite, and ilmenite. None of these, however, is as easy to manage or has proved, in the long run, as generally efficient or economical; consequently, fluorspar has maintained its popularity among steel men.

In the manufacture of opal glass and in the refining of aluminum the picture is somewhat different. Fluorspar is used in making opal glass as a source of fluorine to produce cloudy or white opaque effects. Cryolite is also an important source of fluorine; this mineral is sodium aluminum fluoride (Na_3AlF_6) containing sodium (Na) 32.8 per cent, aluminum (Al) 12.8 per cent, and fluorine (F) 54.4 per cent. As fluorspar theoretically contains 48.7 per cent of fluorine, a ton of pure fluorspar evidently contains 974 pounds of fluorine, whereas a ton of pure cryolite contains 1,088 pounds.

Cryolite occurs in commercial quantities and is mined at only one locality in the world, Ivigtut, southern Greenland. The greater part of the product is shipped to Copenhagen; the rest is exported to the United States whence some is reexported to Canada. Cryolite imported is used chiefly in the metallurgy of aluminum and in making opaque glass. Synthetic cryolite is invading the field of the natural mineral and the literature indicates that its entrée is in the aluminum, enamel, and insecticide industries.

Table 2 shows the imports of cryolite into the United States from 1922 to 1936.

In making opaque glass and enamels, manufactured fluorine salts such as artificial cryolite, sodium silicofluoride, and sodium fluoride are sometimes used. The mineral lepidolite may also be used as a source of fluorine, although it is commonly used for its content of alumina, potash, and lithia. Bone ash and other calcium phosphates also have been mentioned as fluorspar substitutes. At present it has no substitute in the manufacture of hydrofluoric acid and its derivatives.

HISTORY OF PRODUCTION

Agricola (1529) considered fluorspar a highly useful if not indispensable fluxing agent, but improved metallurgical processes and the fact that it was considered rare and relatively costly, retarded extensive use until just before the beginning of the twentieth century. Rapid growth in basic open-hearth steel manufacture, however, expanded domestic fluorspar production from 15,900 short tons in 1899 to a maximum of 263,817 tons in 1918.

Fluorspar was first used in this country by the Indians or by prehistoric folk who carved ornaments from clear beautifully colored fluorspar. Intricate artifacts have been found, the small turtle being a favorite design.

Occurrences of fluorspar or "fluate of lime" (as it was then called) near Franklin Furnace and Hamburg, New Jersey; Middletown, Connecticut; Rosebrook's Gap, New Hampshire; and Woodstock, Virginia, were recorded as early as 1814[7]. Additional deposits in Maryland on the west side of the Blue Ridge, in New York near Saratoga Springs, in Vermont at Thetford, and in Massachusetts near Southampton were listed in 1816.[8]

The presence of fluorspar in southern Illinois near Shawneetown was recorded as early as 1818.[9] It was noted in 1822[10] on Peters Creek 17 miles from Shawneetown, at the three forks of Grand Pierre Creek 27 miles from Shawneetown, and 30 miles southwest of Cave in Rock, as well as in Smith County, Tennessee; Shepherdstown, West Virginia; Westmoreland, New Hampshire; and elsewhere.

Small but unknown quantities were used in the United States during the first half of the nineteenth century. The first recorded use of American fluorspar, so far as known, was in 1823[11] when it was reported that "2 ounces of pure fluorspar from Shawneetown were used (also 4 ounces of sulphuric acid) in

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7 Bruce, Archibald, Mineralog. Jour., vol. 1, pp. 32-33, 1814.

8 Cleaveland, Parker, Elementary treatise on mineralogy and geology, vol. 1, 1st ed., p. 134, 1816.

9 Am. Jour. Sci., vol. 1, pp. 49, 52-53, 1818.

10 Cleaveland, Parker, An elementary treatise on mineralogy and geology, vol. 1, 2d ed., pp. 199-200, 1822.

11 Am. Jour. Sci., vol. 6, pp. 354-356, 1823.

making fluoric acid." In 1837[12] fluorspar, which was sold for $60 a ton and was said to have been used with magnetic iron pyrite in the smelting of copper ores, was mined from a vein near Trumbull, Connecticut. In 1838 Jackson[13] recorded the occurrence of green fluorspar at Long Island in Bluehill Bay, Maine, and stated that it was sold in apothecary shops for 50 cents a pound but that the demand was limited.

Although fluorspar deposits were known in southern Illinois early in the nineteenth century no mining was attempted until 1842 when development was undertaken in Hardin County near the present Rosiclare mine. Since 1842 it was mined more or less continuously, but shipments apparently did not begin until about 1870.

Meanwhile, fluorspar was discovered in western Kentucky. In 1835 an attempt was made to work deposits in Crittenden County. Up to the Civil War other primitive attempts were made, notably in Livingston County near Smithland. In the early seventies prospecting and mining were resumed somewhat generally, chiefly in Crittenden County, and in 1873 the first shipments of Kentucky fluorspar were made from the Yandell mine near Mexico in that county.

In the late sixties the presence of fluorspar in Colorado was recorded, and actual mining began in the early seventies when shipments were made from deposits in Jefferson and Boulder counties.

By the end of the nineteenth century fluorspar associated with other minerals was known to have a broad geographical distribution; but exploitation in the United States had been confined chiefly to Illinois, Kentucky, and Colorado. Although an exact record of production prior to 1880 is not available the total output during the nineteenth century probably did not exceed 165,000 short tons, Illinois contributing about 80 per cent.

Most of the fluorspar produced before 1887 was used in the manufacture of glass, enamels, and hydrofluoric acid; the rest probably was used as a flux in melting iron in foundries and in smelting gold, silver, copper, and lead. By 1887 the annual requirements for these uses had reached about 5,000 short tons.

In 1888, basic open-hearth steel was first made as a commercial product in the United States, and in that year the production of fluorspar increased to 6,000 tons. The progress of steel making apparently was slow for a few years, for in 1893 it was confined virtually to four plants. Considerable advance, however, was made thereafter, and the production in the United States reached the million-ton mark in 1897 and the two-million-ton mark in 1899.

In response to increasing demand the production of fluorspar likewise expanded. In 1891 it reached 10,044 tons, probably half of which was used by steel plants, and by 1899 increased to 15,900 tons, probably two-thirds of which was similarly used. Further increase in the production of basic open-hearth steel during the twentieth century is reflected in the fluorspar industry in that about three-fourths of the total fluorspar now consumed in the United States is used in this type of steel plant.

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12 Shephard, C. U., Connecticut Geol. Survey Rept., p. 80, 1837.
13 Jackson, C. T., Geology of Maine, 2d Rept., p. 125, 1838.

The use of fluorspar in the manufacture of glass, enamels, and hydrofluoric acid also increased substantially during the twentieth century, and additional uses were discovered.

The Rosiclare mine in Illinois continued to furnish most of the domestic supply until 1896. In that year, however, Kentucky again became a producer and from 1898 to 1904 produced more than Illinois due to the exploitation of deposits in Crittenden, Livingston, and Caldwell counties. Meanwhile, considerable development was being carried on in Illinois, and in 1905 when these new properties had reached the productive stage Illinois regained first place.

Arizona and Tennessee were added to the producing States in 1902, and a year later fluorspar mining in Colorado was resumed with the opening of the basic open-hearth steel plant at Pueblo. The first record of fluorspar production in New Mexico was in 1909. Shipments were first reported from New Hampshire in 1911, Utah and Washington in 1918, Nevada in 1919, and California in 1934.

Table 4, pages 42-45, presents statistics of production by States from 1880 to 1936. Data prior to 1880 were not obtained, nor for certain years thereafter were statistics compiled for Kentucky and Colorado, hence the total figures are slightly incomplete. The total unrecorded output is believed to have been about 25,000 short tons. If this amount is added to the 3,824,205 tons reported from 1880 to 1936, the total production since the beginning of operations in the United States may be stated as approximately 3,849,000 tons, of which Illinois has contributed 58.8 per cent, Kentucky 33.8 per cent, and Colorado 5.2 per cent, a total of 97.8 per cent. Most of the remaining 2.2 per cent was furnished by New Mexico.

ORIGIN AND OCCURRENCE

Fluorspar deposits occur in both igneous and sedimentary rocks as veins following faults, fissures, or shear zones; as horizontal or bedding replacement deposits; or as incrustations in vugs or caves. Any such body of fluorspar may weather to gravel spar. Residual gravel spar should not be confused with the milled product for the steel trade, which is known as gravel fluorspar.

Even where fluorspar is enclosed by sedimentary rocks, such as limestone, sandstone, or shale, evidence of igneous activity usually may be found. In the Illinois-Kentucky district, for example, dikes, sills, and plugs of igneous rock have penetrated the sedimentaries typical of that locality. The origin of commercial deposits of fluorspar is believed to be closely connected with igneous activity.

ILLINOIS-KENTUCKY DISTRICT

The Illinois-Kentucky district is in the eastern foothills of the Ozark uplift, which extends across the southern tip of Illinois and western part of Kentucky. The country rock is limestone, shale, and sandstone of diverse kinds and characteristics. The region has been faulted intensely and subsequently the surface has been eroded, partly subduing any inequalities caused by rock movement.

The Illinois and Kentucky fluorspar fields are separated only geographically by the Ohio River. The fluorspar deposits along the Rosiclare fault at Rosiclare, Illinois, have been among the greatest in the world. This vein is nearly vertical, strikes east of north and west of south, and has been productive over a length of

about 3 miles. The Rosiclare fault has been located but not worked extensively south of the river. Fluorspar occurs at an explored depth of 720 feet in the Rosiclare vein in roughly lenticular ore bodies between which the rock walls may enclose masses of calcite or may pinch closely with little or no mineralization. Adjacent to the Rosiclare fault are minor faults which also are mineralized.

FIGURE 5.—FLUORSPAR VEIN AT THE 500-FOOT LEVEL OF THE DAISY MINE, ROSICLARE LEAD & FLUORSPAR MINING CO., ROSICLARE, ILL.

Not much surface gravel spar has been found in the Rosiclare district, except for a comparatively large body between the upper walls of a southern section of the Hillside mine. Such material is the result of weathering of vein and country rock. Fluorspar, being quite resistant to weathering agencies, survives the solution of disintegration of such enclosing softer materials as calcite or limestone and accumulates in gravel-like deposits at or near the surface. The comparative absence of such residual ore bodies at Rosiclare is doubtless explained by their removal by erosion in the area of active erosion bordering the Ohio River.

In the veins just below the surface fluorspar may occur as a rib standing between clay walls. Here the softer wall rocks have been altered, but the fluorspar is virtually undisturbed. As mining progresses downward the walls become more consolidated until a zone of little or no general alteration is reached. In many places calcite is the predominant vein filling, and at some points on produc-

tive veins it is the only mineral present. At other places, on the other hand, it is entirely absent. Progressive or consistent changes in proportions of fluorspar and calcite with increasing depth have not been established for the field as a whole.

Whether calcite ultimately supplants all the fluorspar is a question of much scientific interest but of secondary economic importance, because drainage is the dominant factor in determining practical mining depth. A peculiar condition of the district is the frequent occurrence of watercourses in the limestone country rock and along the faults. These old solution channels, originating when the relative level of the water table was much lower or formed from ground-water circulation below the water table, have been noted at the greatest depths so far explored. These channels add constantly to the water that must be handled. As the workings extend deeper and more ground is opened the water increment rises, adding greatly to mining costs. Ultimately a depth will be reached below which it will be unprofitable to mine at present prices and by known technique.

The watercourses may not persist in depth and very deep ore bodies might be mined by isolating such workings from those connected with the upper water-laden horizons. That problem, however, will concern a future generation of mining engineers.

The ore shoots consist mostly of massive fluorspar, sometimes banded paral lel with the walls, with varying quantities of calcite and other accessory minerals (fig. 5). Shale walls may impart a blue tint to the ore, whereas a white or cream color is common between limestone walls. A center slip often occurs along the middle of the vein filling. Masses of the wall rock lodged as foreign material in the vein filling are frequent.

As a rule galena is more abundant near the surface than at depth. Quartz is common in some places, particularly near sandstone walls. Sphalerite has been found in limited amounts in the Illinois field but in considerable abundance in several areas in Kentucky. Barite appears only in limited quantities. Other accessory minerals include chalcopyrite, marcasite, smithsonite, and petroleum. Considerable quantities of lead and zinc sulfides have been recovered, but these by-products generally have had less importance in recent years.

Near Cave in Rock are extensive and important flat-lying or bedding deposits which have been formed by replacement of the limestone by fluorite. These deposits were formed by mineralizing solutions that rose along joints or minor faults in the country rock and were trapped by the comparatively impervious layers of shale which are found as a significant stratigraphic feature near the base of the Rosiclare sandstone and immediately above the bedding deposits. Below the shale the rising solutions spread out and eventually formed mushroom or flat-lying deposits. The present ground surface is near the horizon where these ore bodies originally were formed so that subsequent erosion has facilitated discovery and exploitation. These deposits contain many vugs in which optical spar, the flawless clear variety of fluorite, frequently is found.

The Kentucky deposits are similar to those in the Rosiclare district. In Kentucky, however, the proved ore bodies are less extensive and smaller, but more numerous. Deposits of gravel or residual spar are more abundant in Kentucky, possibly because they are farther removed from the eroding action of the Ohio River.

WESTERN STATES

In the Western States fluorspar occurs under a wide variety of conditions,—as fillings in fractures and shear zones forming more or less well-defined veins and as replacements of the country rock. Much occurs in igneous formations, whereas in the Illinois-Kentucky district enclosing rocks of sedimentary origin predominate.

In the Castle Dome district, Arizona, fluorspar occurs in fractured and jointed volcanic rocks which intrude and overlie gneisses and slates, probably of pre-Cambrian age. Silver-bearing galena is an accessory vein mineral.

Near Afton, California, fluorspar is present in crevices in andesites and porphyries. Silica and calcite have been noted, but no metallic sulfides.

At Wagon Wheel Gap, Colorado, a large vein of fluorspar cuts rhyolitic tuffs and breccias, following a zone of sheared rhyolite. Accessory minerals include pyrite, barite, quartz, calcite, and clay. In the Jamestown district, which has produced gold, silver, and lead, fluorspar is a common vein filling; in some instances it has replaced the country rock, forming ore bodies capable of producing low-grade lump. At Northgate fluorspar appears as veins and sheets in a faulted and jointed, light-pink, coarse-grained granite. Small quantities of barite and pyrite also have been found.

In New Mexico fluorspar occurs as vein deposits in igneous and sedimentary rocks and as replacements in limestone, in places accompanied by much secondary quartz. Barite, galena, and calcite are other accessory minerals.

The Nevada deposits near Beatty consist of fillings in veins and brecciated zones and replacements in dark-gray limestone country rock which has been intruded by rhyolite.

Fluorspar generally occurs with such associated minerals as calcite, quartz, barite, and metallic sulfides and in diverse geological formations. Individual conditions are important economically and affect the successful development of deposits.

MINING DISTRICTS OF THE UNITED STATES

ILLINOIS-KENTUCKY

The principal known fluorspar deposits in the Illinois-Kentucky district occur in Hardin and Pope counties, Illinois, and in Crittenden, Livingston, and Caldwell counties, Kentucky—an area about 40 miles wide and 60 to 70 miles long in the lower Ohio River country just above Paducah, Kentucky. The industry is centered chiefly in and around Rosiclare and Cave in Rock, Illinois, and Marion, Kentucky.

Both Rosiclare and Marion are served by the Illinois Central Railroad. Rosiclare and Cave in Rock are on the Ohio River and therefore have river transportation facilities. Kentucky producers, however, ship fluorspar by barges on the Ohio and Cumberland rivers. Barge shipments have become important to operators in the district since completion of the dams and locks which maintain a 9-foot stage of water to Pittsburgh, Pennsylvania.

Labor in the district is 100 per cent white native American and relatively abundant. Many workers own small farms and alternate agriculture with mining. The people as a whole have strong personal ties in the locality. Labor

turnover is low. As a whole, the men are characterized by a keen native intelligence. By nature they are extremely loyal if treated with the impartial justice they demand.

Educational facilities in the district are ample, comprising grade and high schools. Many graduates of the high schools have continued their education in colleges and universities.

Rosiclare has a modern well-equipped hospital which provides singularly competent surgical and medical care for the community.

The majority of the operators recognize the value of safety work among the employees. The United States Bureau of Mines periodically conducts classes in first aid and mine rescue work. The men take much interest in it and teams are organized to render immediate aid in case of accident. Safety consciousness is kept vigorous by regular conferences of mine officials with the foremen and the workmen, by the encouragement of suggestions, by contests, by close inspection of all working places, and by the use of safety posters.

Electric power in the district is purchased from utility companies by some operators, but others generate their own power with coal as fuel. Such plants provide power for Rosiclare and Elizabethtown, Illinois. At the smaller operations wood is sometimes used for steam raising. Mines along the Ohio River usually bring in their coal by barge; some, however, use rail facilities.

Much timber is required in the fluorspar mines, and one large company owns extensive timber lands and has its own woods crew.

Illinois—Fluorspar shipments from Illinois amounted to 82,056 short tons in 1936, a noteworthy increase over the 1935 shipments of 44,120 tons. Production came from two principal districts, the Rosiclare and the Cave in Rock districts. The principal mines at Rosiclare are the properties of the Aluminum Ore Co., the Rosiclare Lead & Fluorspar Mining Co., and the Hillside Fluor Spar Mines, which control most of the Rosiclare, Daisy, Blue Diggings, and Argo veins, the Rosiclare being the most important.

The Rosiclare vein is a nearly vertical mineralized fault extending from south of the Ohio River northward across the river into Illinois more than 4½ miles. It has not been explored extensively south of the Ohio River. On the Illinois side it has been developed to a depth of 720 feet and has yielded ore bodies as long as 1,500 feet and as wide as 25 to 30 feet. Between separate ore bodies there may be bodies of calcite or vein pinches.

The chief developments along the Rosiclare vein, beginning at the Ohio River, are the Extension, Annex, Good Hope, and No. 4 workings, belonging to the Aluminum Ore Co.; the Rosiclare mine (developed to the 720-foot level and served by four or more shafts, including the Rosiclare, Plant, Cincinnati, and an air shaft) of the Rosiclare Lead & Fluorspar Mining Co.; the Hillside mine of Hillside Fluor Spar Mines; and the Eureka workings of the Rosiclare Lead & Fluorspar Mining Co.

The Hillside and Eureka mines are the only parts of the Rosiclare vein now being worked to any extent, as many of the older workings have been under water since 1924 when the Rosiclare mine was flooded. High water from the Ohio River, wet weather, flows of water encountered simultaneously in several of the lower levels, and a cave-in at the south end of the mine which allowed an inflow from the Franklin No. 4 workings were too much for the pumps and bailers. Although 3,600 gallons a minute were raised, the dramatic fight to save the mine was a losing one. Small tools and portable equipment were removed

so far as possible, and the levels were successively abandoned only when further salvage work could no longer be done. The pumps were shut down on January 20, 1924. The Rosiclare mine is not lost, however, and much ore will yet be mined when market conditions warrant. Production in the Rosiclare district now comes chiefly from the Hillside mine on the Rosiclare fault and from the Daisy mine on the Daisy and Blue Diggings veins.

The Blue Diggings fault is perhaps a mile long and roughly parallels the Rosiclare fault. Although the latter is nearly vertical or dips steeply westward the Blue Diggings fault dips much more flatly to the east. The Daisy fault appears to be a fracture between the two; the mineralization and throw diminish greatly at the south end near the Blue Diggings vein and at the north end nearest the Rosiclare fault. The Daisy fault is at least three-fourths mile long (it may prove to be much longer) and dips rather steeply westward. The south portion of the Blue Diggings fault is owned by the Aluminum Ore Co., which developed it to the 500-foot level. The shaft at the Blue Diggings mine was recently unwatered, preparatory to sinking it an additional 200 feet in the hope of discovering larger reserves of acid-grade fluorspar. In addition to the Rosiclare, Daisy, and Blue Diggings faults, a fourth fault, the Argo, about 400 feet west of the Blue Diggings vein, has produced small tonnages of spar.

No important veins have been discovered east of the Rosiclare fault or west of the Argo fault in the vicinity of Rosiclare. These two faults are only about 1,500 feet apart, and between them are the Daisy and Blue Diggings veins.

The Daisy mine, one-half mile north of Rosiclare, is the chief present operating unit of the Rosiclare Lead & Fluorspar Mining Co. and since flooding of the Rosiclare mine it has been the largest producer in Illinois. The mine has been developed to a depth of 700 feet by a foot-wall shaft measuring 5½ by 15 feet inside timbers. Crosscuts from the 180, 412, 537, and 640 levels of the Daisy mine have explored and developed the Blue Diggings vein lying to the west. Development, preparatory to exploitation of a new ore body at the 700-foot level of the Blue Diggings vein of the Daisy mine, is now in progress. This discovery, one of the big events in the history of the district, opened an ore body of virtually solid acid-grade fluorspar varying in thickness from 6 to 9 feet up to more than 20 feet. Mining is now carried on principally below the 412-foot level.

Ore from the Daisy mine is hauled in side-dump cars over a standard gage railway to the mill, eight-tenths mile south at the plant and shaft of the Rosiclare mine. This company operates a gravity-concentrating mill and a grinding plant producing fine- and coarse-ground fluorspar for the ceramic trade. A narrow-gage railway from the mill to a river loading station transports incoming coal and outgoing spar for river shipment.

The Hillside mine, just east of the Daisy, is the property of Hillside Fluor Spar Mines, which controls the Rosiclare vein for somewhat less than one-half mile, the productive length having been about 1,800 feet. The mine is developed by a 4-compartment, 6 by 20 foot inside-timber, footwall shaft reaching a depth of 600 feet. Levels have been driven 170, 250, 350, 450, and 550 feet below the collar. Ore from the mine goes direct to a well equipped gravity concentration mill. Additional mill equipment has been added to retreat accumulated tailings. Concentrates are shipped by rail and by barge.

Many smaller mines and prospects near Rosiclare have produced fluorspar from time to time. Literally, the woods are full of old workings, most of them abandoned, which in all have produced appreciable tonnages of fluorspar. The

more important small properties now active include the Empire-Knight-Douglas group (operated by Knight, Knight & Clark) in Pope County near Eichorn; the Hamp mine (owned by the Aluminum Ore Co.) and the Lee mine (owned by Hillside Fluor Spar Mines) both in Hardin County near Karbers Ridge; the Stewart mine (operated by Fluorspar Products Corporation) in Hardin County near Rosiclare; and the Dimick, Rose, Humm, and Preen prospects also in Hardin County near Rosiclare.

The Cave in Rock district of the Illinois-Kentucky fluorspar field is the easternmost producing area in Illinois. It is about 4 miles northwest of the town of Cave in Rock, and adjoins the Rosiclare district. In 1935 L. W. Currier of the United States Geological Survey, acting in cooperation with the Illinois State Geological Survey, made a study of the Cave in Rock district and has provided the following description of the deposits.[14]

> The Cave in Rock deposits are nearly horizontal, tabular and lenticular masses that have replaced certain beds of the Fredonia limestone. The ore bodies are generally elongated in conformity with local minor structural features that apparently controlled the localization of 'ore.' Minor fissures of little or no displacement, genetically connected with regional faults, served as channels of access for rising hydrothermal solutions which, reaching dense or impervious beds through which the fissures failed to extend or in which they were greatly reduced, spread laterally along limestone beds of favorable texture and composition. Such beds became replaced by fluorspar, with preservation of the bedding and cross-bedding of the limestone, and the consequent development of characteristically banded ore. In most places a shale bed at the base of the Rosiclare sandstone forms the roof rock of the deposits, and marks the stratigraphic horizon at which the largest and best ore bodies have been found. Some deposits also have been found at several lower horizons in the Fredonia, below either dense limestone beds, or a lower, thin, calcareous sandstone bed known locally as the 'sub-Rosiclare' sandstone.
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> The exploited bedding deposits underlie a broad, low, plateau-like eminence known as 'Spar Mountain,' and an isolated remnant to the southwest known as 'Lead Hill.' Spar Mountain is bordered along the south and southeast sides by an escarpment about 100 feet high, part way up the slope of which the Rosiclare sandstone crops out. The same horizon is exposed at the south end of Lead Hill near the top. A general north and northeast regional dip of the formation brings the ore horizon progressively lower to the north, so that in a distance of about 1 mile it passes entirely below the surface.
>
> The deposits are penetrated by opencuts, adits, and shafts, according to their topographic positions. Underground developments consist of drifts from which crosscuts, rooms, and pillars are developed irregularly, according to the economic limits of the ore bodies. The main drifts commonly follow lines of greatest mineralization, many of which coincide with the directions of local structural axes or mineralized fissures. Mining costs are low, as the ore breaks easily, the roof requires but little timbering, and very little underground water is encountered.
>
> Owing to its purity and general freedom from deleterious minerals the ore requires only simple milling operations. Washing in a log washer or trommel, hand picking, crushing, sizing, and jigging are practised. At a few points abundant quartz forbids exploitation, but this mineral appears to be closely restricted and is practically absent from the chief ore bodies. Calcite and barite are present in spots but are not general in distribution. Galena is prominent at a few places but is not present in most of the ore bodies; sphalerite is rarely found.

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[14] Published by permission of the Director of the United States Geological Survey.

Some of the material mined from the bedding deposits is exceptionally high in fluorspar and low in silica. In places selective mining can produce run-of-mine material carrying in excess of 90 per cent fluorspar with silica much less than 5 per cent, the industrial silica limit for standard fluxing spar, but it is general practice to remove 'ore' that, with simple milling, will easily give a product that meets the industrial specifications. Material from some of the 'ore' bodies can be readily milled to meet the strict requirements for 'acid' fluorspar.

The principal operators in the district are (1) Benzon Fluorspar Co., (2) Victory Fluorspar Mining Co., (3) Crystal Fluorspar Co., and (4) Fluorspar Products Corporation.

The Benzon Fluorspar Co., post office address Cave in Rock, operates the original 'Spar Mountain' mines on the south and southeast escarpment. The mines include the Oxford pits, West Morrison, Lead adit, 32 cut, Cleveland, Green, and Defender. Both opencut work and underground mining are practised. Several adits have been driven on the 'ore' horizon, and from them drifts and rooms are developed irregularly according to the economic limits of the mineral bodies. The company is also prospecting the horizon below the 'sub-Rosiclare sandstone', south and east of the escarpment, where fluorspar bodies of undetermined extent have been discovered. The company also operates a mill for cleaning and concentrating the fluorspar. The greater part of the marketable product is then delivered to storage bins at a wharf on the Ohio River at Cave in Rock. Some, however, is shipped by rail.

The Victory Fluorspar Mining Co., post office address Elizabethtown, operates two shafts about 1,000 feet apart on the flat summit of Spar Mountain, and about 500 feet north of the escarpment. An irregular system of drifts and rooms has been developed, but the workings of the two mines are not yet connected. A small mill had been operated at the original shaft, but in 1935 a new mill, having a capacity of 160 tons of mill feed per shift, was erected at No. 2 shaft, and replaced the older plant. The marketable fluorspar is transported by motor trucks to loading bins on the Ohio River at Cave in Rock and to the railroad at Rosiclare.

The Crystal Fluorspar Co., post office address Rosiclare, operates a mine at the base of the escarpment in the eastern part of the field, about half a mile from the Benzon mines. The mine is entered by a low incline, and a shallow shaft is used for hoisting ore to the surface, at the level of the feeding platform of a 50-ton concentrating mill. The marketable product is transported by motor trucks to the Illinois Central Railroad at Rosiclare.

The Fluorspar Products Corporation, post office address Elizabethtown, operates several adits on the south end of Lead Hill. The workings are at several levels, not connected. Run-of-mine material is hand picked in part, and in part is milled at a plant at the Stewart mine, about 10 miles west of Lead Hill. This plant is situated on a railroad spur.

Kentucky—Adjacent to and separated from the Illinois field only by the Ohio River is the western Kentucky fluorspar district. The ore bodies occur primarily in fissure veins and are similar to the vein deposits of Illinois, except that they appear to be more numerous and of smaller dimensions. Weathering of the deposits has been more severe, or erosion has been less, so that residual or secondary deposits of gravel spar have had more economic importance in Kentucky.

Production has come chiefly from Crittenden County, but Livingston and Caldwell counties also have been important producers; a comparatively small output has come from Mercer and Woodford counties, in central Kentucky. As in Illinois the hills of western Kentucky contain many old, abandoned workings, some of which are active from time to time.

The Tabb vein system, the most important in Kentucky, embodies the Tabb, Wheatcroft, Haffaw, Pogue, Blue & Marble, Pigmy, and other mines. The

Columbia vein system also has major importance; it includes the Franklin, Mary Belle, Ada Florence, Memphis, and Keystone mines among its properties. Many other major and minor fault systems occur, in which have been developed such mines as the Lucile, Beard, Brown, Big Four, Davenport, and Watson, in Crittenden County; the Bonanza, Guill, Klondike, C. R. Babb, and Nancy Hanks in Livingston County; and the Crook, Crider, and Marble, in Caldwell County.

Other Kentucky mines and prospects include: Bachelor, Loveless, and Two Brothers, in Crittenden County; Green, Gossage, Hudson, Lola, Mitchell, Mineral Ridge (John-Jim), and Split Nickel in Livingston County; and the Tyrie, Hollowell & Hobby, and Walker in Caldwell County.

An improved demand for Kentucky fluorspar which began in 1933 resulted in the shipment of 80,241 short tons in 1936, a tonnage exceeded only in 1918. Most of the output came from mines of the fissure-vein type, which employ mechanical equipment, but a considerable quantity was reclaimed from mill ponds, waste dumps, and old workings of abandoned mines. The same situation existed in 1935. A number of the relatively small producers log-wash their crude material and sell the product to the local mills for further beneficiation. Others, without log washers, sell direct to local mills.

The Aluminum Ore Co. owns or controls among other properties, the Franklin, Mary Belle, Brown, Ebby Hodge, Memphis, Susie Beeler, Beard, Haffaw, Split Nickel, and Cross mines, and operates a well equipped concentration and grinding mill at Marion, Kentucky, and a concentration and flotation mill at Rosiclare, Illinois. The company suspended active mining operations during the first half of 1930. Since then, however, many of the mines have been operated by lessees and contractors.

The Lafayette Fluorspar Co. operates mines near Mexico, Kentucky, on the Tabb vein system and owns the Big Four mine on the La Rue fault system. The Tabb vein property is developed to the 400-foot level by shafts. A modern concentrating mill produces metallurgical-grade fluorspar only. Power is purchased from the Kentucky Utility Power Co.

The Kentucky Fluor Spar Co. operates a mill at Marion, Kentucky, and buys most of its crude supply, thereby furnishing a local market for many small mines and prospects. The equipment includes complete concentrating and grinding facilities.

Among other important mines in western Kentucky from the standpoint of past, present, and future production are the Watson (Eagle), Lucile, Holly, Davenport, Pigmy, Keystone, Blue & Marble, Bachelor, and Pogue in Crittenden County; the Crook, Crider, Marble, Hollowell & Hobby, and Walker in Caldwell County; and the Klondike, Nancy Hanks, Bonanza, C. R. Babb, and John-Jim in Livingston County.

In recent years deposits of fluorspar averaging 5 to 6 feet wide have been discovered in Livingston County, across the Ohio River from the Fairview-Rosiclare deposits in Illinois.

Fluorspar also occurs in Mercer and Woodford counties in central Kentucky, and a relatively small and irregular production was made prior to 1923. No output was reported from 1922 to 1935. In 1936, however, the Faircloth mine, in Woodford County, was reopened.

CALIFORNIA

Shipments of fluorspar from California, amounting to 181 short tons, were reported from a deposit near Afton, San Bernardino County, during the fiscal year ending June 30, 1934. The fluorspar was hand sorted and shipped to steel plants. No fluorspar was produced or shipped in 1935 and 1936.

COLORADO

Colorado has produced about 200,000 short tons of fluorspar between the early seventies, when mining began, and the close of 1936. Shipments increased from 742 short tons in 1933 to 6,537 tons in 1934 and 9,412 tons in 1936. Greatly increased production from mines in Chaffee County and renewed production in Mineral County are chiefly responsible for the larger shipments since 1934. Most of the fluorspar was sold for metallurgical purposes.

The Colorado Fuel & Iron Corporation operates the Wagon Wheel Gap mine 1¼ miles southwest of Wagon Wheel Gap, Mineral County, Colorado. The output is consumed in the company steel plant, at Pueblo, Colorado. The mine has been developed systematically and to 1936 had produced 110,000 tons of spar (55 per cent of the total recorded production of the State up to that time).

Production of fluorspar near Salida in Chaffee County from 1929, when the deposits were opened, through 1936 was about 11,400 tons, of which 5,100 tons were mined in 1936. The movement of considerable fluorspar from Chaffee County to eastern markets indicates low production costs.

Comparatively small mines have been operated intermittently in the Jamestown district, Boulder County. Production from the county through 1936 totaled about 58,000 tons (29 per cent of that for the State through 1936).

Jackson County near Northgate had some importance as a producer between 1922 and 1926, but recent production has been small. The county's output has been about 15,000 tons (7.5 per cent of the State total through 1936).

Other counties producing small tonnages include Custer, El Paso, Gilpin, Jefferson, Ouray, and Park.

NEW MEXICO

New Mexico has produced 64,595 short tons of finished spar from 1909, the first year of production, through 1936. Distribution by counties follows: Dona Ana County 39 per cent, Luna County 37 per cent, Grant County slightly less than 12 per cent, and Sierra County somewhat over 12 per cent. In 1936, 2,126 tons, chiefly flotation concentrates, were shipped. Present production is derived mainly from near Deming, Luna County, and Lordsburg, Grant County. Ore from the Deming area is treated in the flotation mill near Deming, which makes high-grade concentrates from a highly siliceous feed.

Other chief activities have been reported at the Tortugas and Heathden mines near Las Cruces, Dona Ana County, the Hot Springs mine 4½ miles south of Hot Springs in Sierra County, at and near the Nakaye mine about 5 miles north of Derry in Sierra County, at the Alamo mine near Derry in Sierra County, at the Sadler mine in Luna County 8 miles north of Nutt, and at the Great Eagle mine near Red Rock, Grant County.

NEVADA

Present fluorspar operations in Nevada are confined to the Daisy mine 4½ miles southeast of Beatty in Nye County and to the Baxter mine 5½ miles from Broken Hills in Mineral County. There is a concentrating and grinding mill at Beatty.

NEW HAMPSHIRE

Fluorspar mines near Westmoreland, Cheshire County, which have been idle since 1923, were reopened in 1934 and small quantities of fluorspar were produced and shipped in 1935 and 1936. A concentrating plant was completed in 1935.

OTHER STATES

Shipments of fluorspar have been reported from Arizona, Tennessee, Utah, and Washington, and some fluorspar has been mined in Texas. The known deposits in these States, however, are now unimportant economically.

Fluorspar of mineralogic or scientific interest only occurs in many other States, including New York and Virginia. Whether or not these minor occurrences will ever have economic importance is problematical. It seems unlikely that any large new fluorspar-producing district remains undiscovered; however, scientific prospecting is progressing too rapidly to say that no new commercial deposits will ever be uncovered.

PROSPECTING AND EXPLORATION

Fluorspar is widely distributed in minute quantities but occurrences of commercial value in the United States are not numerous; and new deposits are not discovered easily even in districts where it is known to occur. Some operators in the Illinois-Kentucky district, however, have been able to find more than enough new ore to balance depletion.

New ore is located both by surface and subsurface work. The more important indications guiding surface prospecting in the Illinois-Kentucky district are gravel-spar showings in the soil or subsoil, the trace or location of faults, and characteristic iron stains in soil or clay overburden. It is likewise significant that in Illinois commercial quantities of fluorspar generally have not been found in the strata above the Rosiclare sandstone and that, as pointed out by Bastin, in the case of the bedding deposits the "maximum mineralization occurs nearest the shale parting between the Rosiclare sandstone and the Fredonia limestone." A knowledge of stratigraphic geology therefore also aids prospecting.

Obviously, finding gravel or lump fluorspar at the surface indicates ore. However, due to slumping and spreading of the original vein filling during weathering of the less resistant enclosing rock material, the extent of a gravel deposit is not a reliable guide to the size of the ore body in place below. Many productive deposits of gravel spar have been found overlying a vein too narrow to be worked profitably when solid walls were reached. On the other hand, important ore bodies have been found, the upper horizons of which consisted only of a rib of solid or lump spar between clay walls, not showing at the surface and with no development of gravel spar. The presence of gravel spar therefore should be used cautiously in predicting ore bodies beyond the limits of the actual workings.

Faults are the most common sources of ore bodies and the most important geologic features for which to look. They are the result of tremendous stresses in the rock formations which have produced breaks or fractures along which a differential movement of the opposing faces has occurred. Consequently, at the present erosion surface a fault may be marked by juxtaposition of two different kinds of rock at the same level.

Many faults show topographic features such as scarps, perhaps having a bluff or ridge of sandstone along one side, whereas the opposite side, being a softer rock, has become eroded. Other faults show no such topographic features, both sides of the fault being at the same elevation. Sink holes may characterize one side of a fault, perhaps because solution along the fracture has facilitated the formation and determined the frequency and trend of a series of sinks. Certain faults are characterized by sharply tilted rock that has been displaced or dragged down by the movement.

Soil, loess, or clay near a vein or above a mineralized fissure may be stained vivid red from iron-bearing solutions. With practice faults can be traced across country by noting exposures in highway or railroad cuts and carefully interpreting geological and topographical features.

More precise locations of faults may be made by the use of the Gish-Rooney earth resistivity apparatus, which has recently been used by the United States Geological Survey and the Illinois State Geological Survey in their cooperative work in Hardin County, Illinois. A report on this work is in preparation for separate publication.

Shallow prospect shafts (usually served by a hand windlass), pits, and trenches ordinarily follow preliminary reconnaissance. The endeavor is to learn the exact trace of a fault and to explore it to depths of about 50 feet, usually the economic limit to which a prospect shaft can be sunk by windlass.

Churn drilling may determine the exact location or presence of a fault and often is of considerable help in gathering exact knowledge of rock conditions before shaft sinking. Holes may be drilled along a line about at right angles with the direction of the fault. The exact elevations of key horizons, such as an easily recognizable sandstone or shale stratum, are correlated, allowance being made for normal dip of the strata between the holes. If elevations of a particular horizon, taken from two holes far apart, are very different, additional holes may be drilled in the intervening territory until the break in rock sequence is found. Where the faults are nearly vertical, churn-drill holes yield little information on mineralization.

Much diamond drilling has been done in the Illinois-Kentucky district, but it has unsatisfactory features. Many ore bodies are erratic in shape and size; the diamond drill may miss ore by a narrow margin, thus unwarrantably condemning territory. The drill may encounter a flat-lying stringer or seam of spar a few inches thick and of no appreciable extent, but the core may contain the same amount of ore as one which cuts a stringer from an ore body containing thousands of tons of spar. Mud pockets and solution channels cause loss of the bit through caving and at best are a constant menace and source of annoyance. Properly interpreted, however, diamond drilling has been found useful to pilot rock crosscuts underground, to locate faults, or to explore territory that would be too costly or otherwise inexpedient to invade with winzes, shafts, or crosscuts.

Vertical exploration is commonly by shafts, winzes, or raises and lateral work by drifts. Rock pinches along the fault must be followed by barren drifts to reach such ore as may be beyond the present workings. Bodies of calcite may occur be-

tween ore shoots. In all such exploration work it is important at all times to be sure that the drift is following the true wall, for a false wall may mask an ore body. As horses and minor slips are common along many faults it is easy to misinterpret conditions and misdirect the drift. In exploration headings complete data on the kind and character of the wall rock should be available at all times. Such information may be obtained by short test holes or by occasional short crosscuts. These precautions prevent a barren rock drift from skirting blindly an unobserved ore body.

If the distance between parallel faults is not too great, crosscuts may be driven from one to the other. If there is a reasonable chance of mineralization it is usually considered better practice to open up the ground by a rock drift without preliminary diamond drilling. Under ordinary conditions it costs only four or five times as much per foot for a crosscut as for a drill hole. One crosscut will yield much more satisfactory data than several holes, and if ore is found the crosscut provides the means for immediate development or further exploration.

Ore occurrences of each mining district have their individual peculiarities. The bedding deposits near Cave in Rock, for example, differ considerably from other Illinois-Kentucky ore bodies. These horizontal lenses of ore, some of which are mushroom shaped, may be connected by extremely thin vertical cracks or fractures in the beds of limestone. These cracks appear insignificant to one unfamiliar with the local deposits, nevertheless they are important guides to new ore bodies.

Certain New Mexico deposits outcrop as conspicuous ridges, due to the siliceous nature of the ore. Others show little or no relief. It is reported that one western occurrence was overlooked for some time because the spar resembled quartz, for which it was mistaken.

Recently, considerable interest has been manifested in geophysical prospecting as applied to fluorspar deposits. Preliminary experimental work in the Illinois-Kentucky district has checked the location of known faults and known ore bodies. This method of prospecting undoubtedly will have considerable if not vital importance in the future when it becomes necessary to locate ore bodies not now in sight. Many faults appear barren on the surface, but it seems reasonable to suppose that some of them will be mineralized at depth. Below the zone of calcite dominance of known veins additional bodies of fluorspar may occur at levels perhaps below the downward extension of the watercourses and solution channels. Moreover, horizontal or bedding deposits, such as are mined near Cave in Rock, may be found by geophysical means. Geophysical science may shed considerable light upon these and other problems of exploration and prospecting that no large operator can afford to neglect indefinitely.

Keeping accurate and complete records of all geological data is most important. Mine maps should show both the plan and section of mine workings, the nature and character of the rock, and the presence of minor slips or fractures. Strike, dip, and character of the vein or fault fillings and widths of ore should be plotted. Where the vein filling consists of fluorspar mixed with calcite or other gangue material the full stope width and the width of actual fluorspar should be measured. These data are absolutely necessary for intelligent estimation of ore reserves and are extremely valuable in outlining both exploration and development work.

The character of the wall rock should be noted so that geological cross-sections can be made. Many faults are the hinge variety with maximum displacement at one point, diminishing away from the zone of greatest movement. Vertical cross-sections at intervals provide information on the probable longitudinal extent of the fault. Many faults feather out, and whereas it is good mining practice to drive through pinches or barren spots on the vein, ultimately the fault movement becomes so slight that no further exploration is justified. Geological data of this character also are valuable in predicting the character of the ground in prospect in projected development work. Drifting costs depend considerably upon the character of the ground encountered. As such work commonly is done on contract a forecast of conditions assists the mine superintendent in letting such contracts upon a sound basis.

Complete maps and mine workings are vital in a catastrophe. Although excellent safety records are now being achieved by operators, serious mine catastrophes have occurred, caused by unexpected falls of ground in some section of the mine or by the sudden inrush of mud runs or water. In such emergencies exact knowledge of the position of all mine workings is absolutely essential to rescue work. Neglecting to keep detailed and up-to-date mine maps because of the expense involved is nothing short of criminal.

MINING

Mining methods and costs at two mines in southern Illinois are described in detail in Information Circulars 6384 and 6294,[15] United States Bureau of Mines. These papers are available in many libraries. General data on mining methods are given in United States Bureau of Mines Bulletin 244.[16] It is not within the scope of this paper to repeat a detailed description of mining practice as applied to the fluorspar deposits. A brief outline of such methods will give some understanding of the problems involved.

Fluorspar mining is somewhat like the mining of valuable metal deposits which occur as isolated or detached bodies of ore sharply contrasted with the enclosing country rock in rather definite structural form along faults, fractures, or shear zones or in flat-lying lens-shaped beds.

Much fluorspar has been mined at shallow depths. Surface operations include opencuts, prospect pits, and trenches and often require no other tools than picks, shovels, and crowbars. In the Illinois-Kentucky district the walls at or near the top of the ground are generally dirt and clay, and after removal of overburden the fluorspar can readily be loosened by hand and shoveled into trucks. Light blasting is frequently employed to break bowlders and loosen chunks of solid spar.

Opencut operations, especially along steep ore bodies, require certain precautions. The walls must be supported to avoid caving during wet weather. Records should be kept to guide future work, as surface gouging may interfere with underground mining operations later.

Workings from prospect shafts not more than 50 feet deep may proceed with little other hoisting equipment than a windlass and a bucket. The simplest possible mining method may be employed, with only sufficient timber to hold

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[15] See footnote 5, p. 8.

[16] Ladoo, R. B., Fluorspar: Its mining, milling, and utilization: U. S. Bur. Mines, Bull. 244, pp. 27-35, 1927.

the walls (and back) long enough to extract the ore. Two men generally operate the windlass.

At small mines more than 50 feet deep single-compartment shafts with wood headframes are used. The ore is hoisted in buckets which are loaded at the face and trammed by hand on narrow-gage tracks to the shaft. Hoisting is by gasoline engine.

FIGURE 6.—METHOD OF DRIVING DRIFT, DAISY MINE, ROSICLARE, ILLINOIS.

Underground mining methods depend considerably upon the character of the ore body and the nature of the walls. Mines that exploit fissure-vein deposits generally use shrinkage stopes, overhand stopes with stulls, or some system of square-sets. Bedding deposits such a those near Cave in Rock, Illinois, are generally worked by a room-and-pillar system.

Steeply inclined ore bodies are commonly developed by shafts sunk in the footwall or the vein, by crosscuts leading to the ore body, and by drifts along the veins at convenient levels (fig. 6). These drifts may be spaced vertically 100 to 200 feet apart, but 100-foot intervals are probably most convenient.

At larger mines the main shafts usually contain two hoisting compartments and a ladderway to provide space for air and water pipes and electric power conduits. Steel headframes generally have been adopted, and hoisting is done with double-drum electric hoists pulling skips or cages. At the various station levels ore and waste pockets facilitate handling of broken ore and rock, which are trammed by hand or by storage-battery locomotives.

After drifts have opened the ore body vertical raises may be driven to explore and develop the upper extension of the ore shoot. Winzes are sometimes employed to develop the ore below the level, but where conditions permit it is usually more convenient and less costly to carry the mining scheme up from a given level or horizon.

Square-set mining generally is used at the upper levels of the ore bodies, because the walls there are usually clay, mud, or other soft, unconsolidated material. Here the ore may be gravel spar or a rib that has not been disintegrated appreciably by weathering. Such ore bodies generally are mined by removing vertical slices from the top of the ore shoot and placing square-sets of heavy oak timbers to hold the soft wall material, which is kept from falling into the stope by lagging. As one vertical slice is removed and timbered a second is started; if the open ground shows signs of taking undue weight back filling with waste may become necessary.

Where wall conditions permit, shrinkage stopes are used at lower levels. If the ore shoot has been developed by drifting, one overhand stope is taken out along the back and shot into the level. Heavy stulls are placed at short intervals to form the roof of the level and the floor of the shrinkage stope. Stout poles are placed tightly together upon these stulls, and ore chutes are installed. Raises are started at the end of the stope to provide a manway, and stoping is begun. The fluorspar is drilled with stopers, jackhammers, or mounted machines and shot on to the poles. Just enough ore is drawn through the chutes to provide a working space between the top of the broken ore and the back of the stope. Air and water lines follow along the footwall as stoping progresses. Manways are cribbed off the broken ore. As the back of the stope approaches the level above raises may be punched through to provide air circulation. A floor pillar perhaps 10 to 15 feet thick is usually left. When the stope is completed, broken ore is drawn off as required; when the level is to be abandoned, some or all of the floor pillar may be recovered.

Crude ore as delivered from the mines contains minerals associated with the fluorspar and a certain amount of waste country rock. The actual fluorspar content varies with the character of the ore body, and often as much as 50 or more per cent of the crude ore must be eliminated by milling.

MILLING

MECHANICAL SEPARATION

Milling separates the impurities or foreign substances and reduces the fluorspar particles to the proper size for ultimate utilization. Impurities are separated by hand picking, washing with water, gravity concentration by jigs and tables, and flotation,—a new development in the industry. For most uses reduction in size amounts to beneficiation, because the ore must be broken to free

the particles of spar from the gangue. Size reduction is by hand sledges, gyratory or jaw crushers, and rolls. For certain uses a finely ground product is desired, and size reduction is carried much beyond complete unlocking of the impurities.

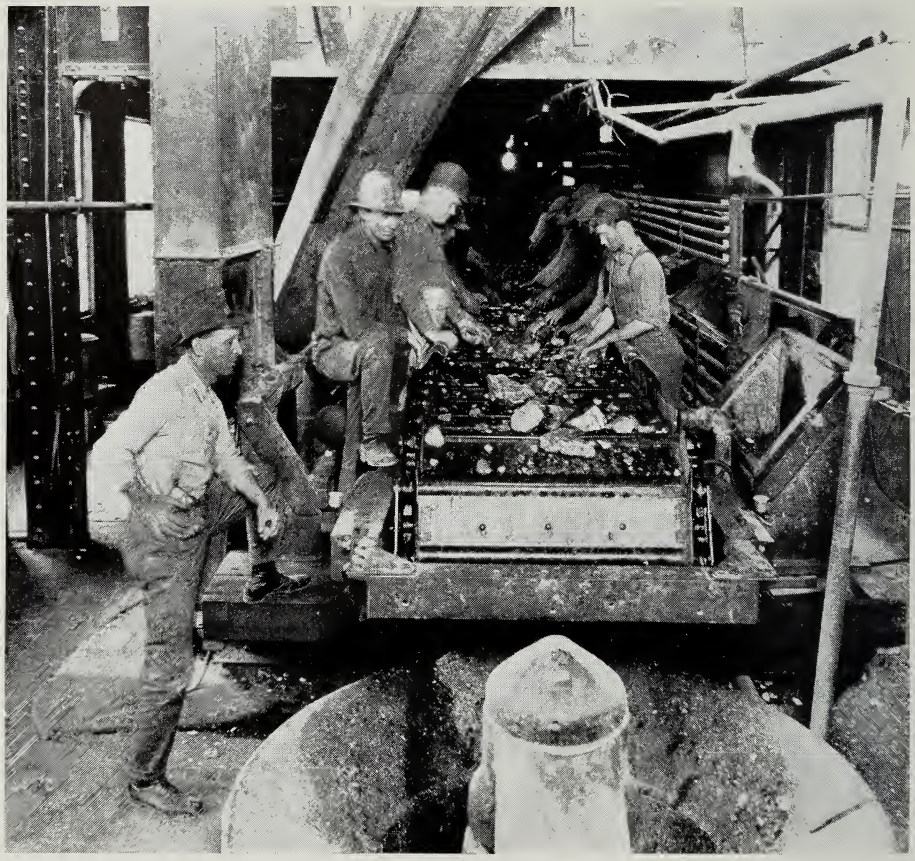

FIGURE 7.—PICKING BELT AND GYRATORY CRUSHER, FLUORSPAR MILL, ROSICLARE, ILLINOIS.

Some residual deposits of gravel spar yield metallurgical grades by crushing and washing, but many surface deposits which are most amenable to such treatment have been worked out. These deposits consist of small pieces of fluorspar in a matrix of clay or dirt, which are fairly pure because calcite or limestone, the usual gangue material, has been removed by weathering.

The bulk of the fluorspar marketed requires much more thorough finishing. Selection begins at the working faces underground, where as much waste as possible is left in place and care is taken to shoot the ore lightly to avoid excess of fines. Larger chunks of ore, not passing the grizzlies at the shaft ore pockets, are

washed with a hose and waste bowlders discarded. At the mill ore coarser than about three-fourths inch is cleansed with water jets and fed mechanically to a long, slow, endless belt where acid and No. 1 lump, No. 2 lump, possible optical crystals, and coarse waste are picked off by hand and consigned to the several bins for further disposal (fig. 7). Tramp iron may be removed by a magnetic pulley.

High-grade spar from the picking belt may be stocked ready for shipment as lump material or dried by steam coils, pulverized, and carefully screened for the ceramic trade. Additional mill treatment (other than flotation) produces fluxing grades, although in some instances high-grade concentrates suitable for grinding are drawn from jigs.

Primary breaking of coarse material from the end of the picking belt is done usually by a gyratory or jaw crusher set to discharge about a minus 1-inch material. The product is then crushed by rolls to minus three-fourths inch and joins the undersize, which by-passes the picking belt. The pulp at one mill is dewatered at this point by a chain drag, and the overflow goes to a sludge pond.

The pulp is now clean, washed material ranging in size from three-fourths inch to very fine sand. Three types of fragments are present,—practically pure fluorspar, gangue material containing no appreciable fluorspar, and pieces of interlocked ore and waste. Fluorite has a specific gravity of 3 to 3.25; the gangue material is about 2.7. As the difference is small the pulp must be sized very closely to insure efficient separation by gravity methods.

First sizing generally is done by a scalping screen (either revolving or vibrating) which removes any material coarser than about three-fourths inch. Such oversize is sent through rolls for further reduction. The pulp is then divided into two main parts—that finer than three-fourths inch and coarser than about 2 mm, and that finer than 2 mm. The minus three-fourths inch plus 2-mm material is carefully separated into perhaps four or five different sizes, each of which goes to a separate jig (fig. 8). The minus 2-mm pulp (sand size) is conveyed to the table section of the mill.

Pulp less than about 2 mm in size, from the mill circuit, is generally treated on tables. Hydraulic classifiers may be employed to prepare the feed for the different tables. As galena is very brittle, it shatters readily into comparatively fine particles. Considerable galena therefore is recovered from the tables. A fluorite concentrate is also produced. At one mill the first set of four tables produces lead concentrates, fluorspar concentrates, and a middling product which is reclassified and passed to a second set of tables where lead, fluorspar, and waste are further separated.

Milling practice is much the same in principle as in the Illinois-Kentucky district. Decrepitation (the heating of fluorspar to about 1,200° F., when it tends to fly apart and can be separated from gangue which is not so affected) has been used at the Rock Candy mill, British Columbia, and at several plants in New Mexico with some success.

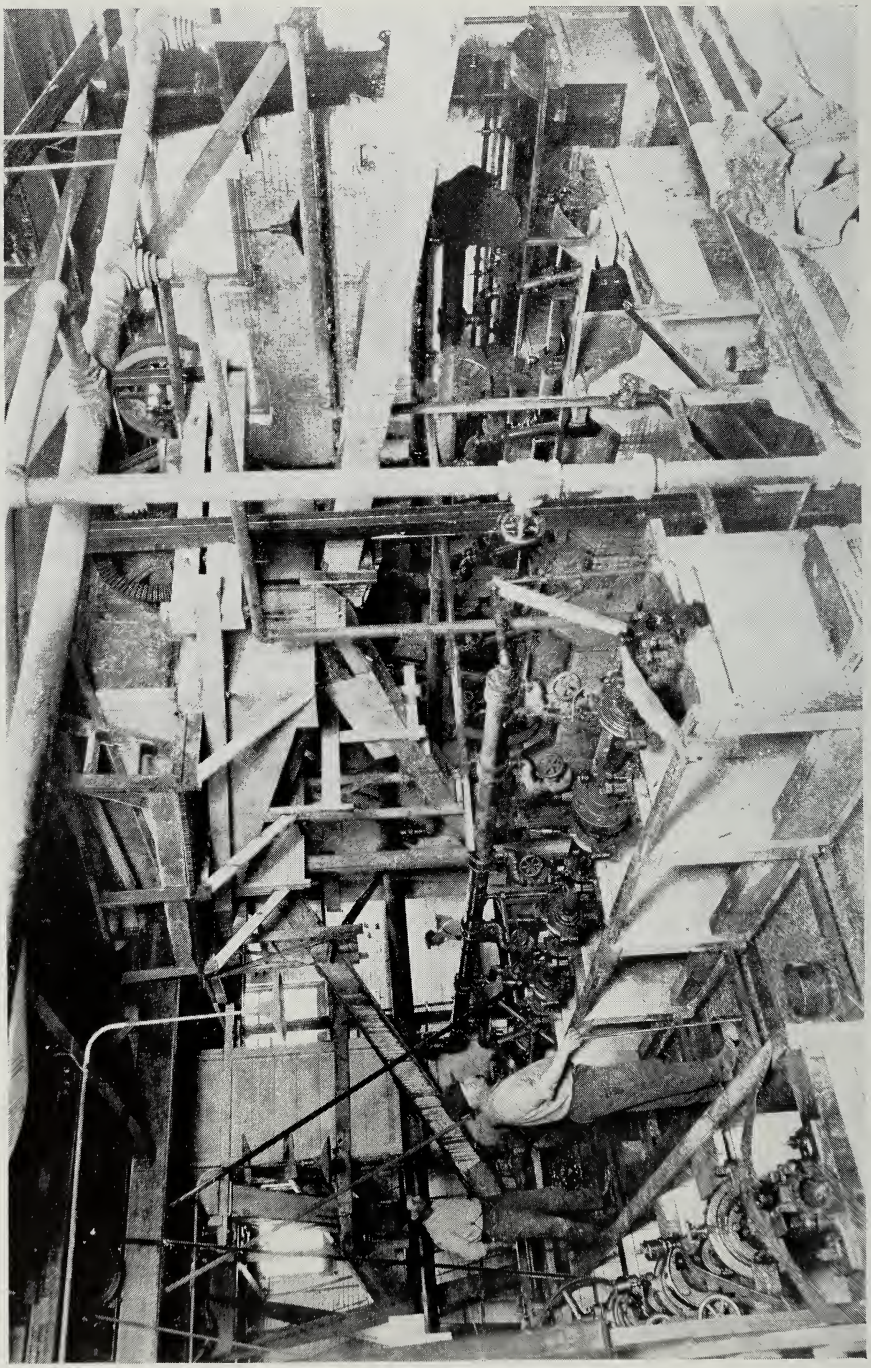

FIGURE 8.—JIG ROOM OF FLUORSPAR MILL, ROSICLARE, ILLINOIS.

FLOTATION

The flotation of fluorspar ores is the subject of United States Patent 1785992, issued December 23, 1930, to J. C. Williams and O. W. Greeman, assignors to the Aluminum Co. of America, of which the Aluminum Ore Co. is a subsidiary. The United States Bureau of Mines made preliminary studies of the flotation of fluorspar at its Mississippi Valley Experiment Station, Rolla, Missouri.[17]

Merchantable fluorspar is now recovered by this process, the Aluminum Ore Co. mill having been placed in commercial operation at Rosiclare, Illinois, March 18, 1929, after much preliminary laboratory work. The prime object of this plant is to produce acid-grade concentrates. From 1929 to 1931, this mill treated 37,439 short tons of fluorspar-bearing materials, which yielded 12,341 tons of No. 1 acid-grade concentrates and 1,398 tons of No. 2 concentrates for use chiefly in the manufacture of cement. The mill was inactive from 1932 to 1935, but resumed operations in 1936.

At the Aluminum Ore Co. flotation mill four reagents are used—a depressant, a collector, a frother, and a froth conditioner. Essentially the process reduces the ore pulp to minus 65 and plus 325 mesh with a minimum of fines. Colloidal material is removed, as it has an adverse effect upon the recovery of fluorspar. Lead, silica, and calcite are depressed, and the fluorspar is floated. The consistency of the float-feed pulp averages 1 part of ore to 7 parts of water. This pulp is prepared for the flotation machines in a conditioner where the collecting and frothing agents are added and is warmed by steam. Depressing and froth-conditioning agents are added in the flotation machines.

The percentage of mill recovery varies in direct proportion to the CaF_2 content of the pulp, other factors being equal. It also varies with the particle size of the pulp, the horizons in the mine from which the ore is taken, and the silica and calcite content.

Although good results have already been obtained by this process, much work remains. The flow sheet of the present mill is constantly being changed as experience indicates the need of major or minor improvements.

WORLD PRODUCTION

Complete data on world production of fluorspar are not available, but table 3 gives information on the principal producing countries from 1913 to 1935.

The United States produced more fluorspar annually than any other country from 1913 through 1926. Germany captured the lead in 1927, since which time it has alternated between the United States and Germany. The rapid growth of the industry in Germany and France since the World War and in Russia in 1934 and 1935 is strikingly revealed. The industry in Great Britain has declined somewhat, but not as much as her exports to the United States.

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17 Coghill, W. H., and Greeman, O. W., Flotation of fluorspar ores for acid spar: U. S. Bur. Mines, Rept. Investigations 2877, 1928.

TABLE 3.—WORLD PRODUCTION OF FLUORSPAR, 1913-1935, IN METRIC TONS.
(Compiled in part by M. T. Latus, of the United States Bureau of Mines.)

Country[1]	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
Argentina[2]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Australia:												
New South Wales	.....	.....	424	1,407	1,326	2,315	2,046	1,213	.....	.....	.....	478
Queensland	.....	.....	.....	.....	72	.....	.....	613	545	.....	.....	1,894
South Australia	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Victoria	.....	.....	.....	.....	.....	102	319	13	199	.....	.....	.....
Canada	.....	.....	.....	1,165	3,855	6,679	4,593	10,192	5,007	4,085	126	69
China	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	165	(a)
Chosen	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
France	7,524	(a)	(a)	(a)	(a)	(a)	4,894	8,997	5,776	9,251	12,913	23,047
Germany:												
Anhalt	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Baden	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Bavaria	4,731	3,729	1,500	4,198	6,470	6,011	6,396	6,272	7,210	13,221	10,543	21,663
Prussia	16,977	12,316	7,874	9,333	7,856	9,387	10,444	7,339	11,989	8,630	10,810	13,078
Saxony	3,260	3,725	3,045	2,763	1,410	2,332	2,906	2,918	4,763	8,509	5,761	9,032
Thuringia	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Great Britain	54,522	34,357	33,653	55,607	65,912	54,357	37,452	55,561	23,508	33,878	49,818	50,286
Italy	.....	.....	.....	800	800	876	900	810	1,600	1,395	3,362	6,831
Mexico	(a)	(a)	(a)	(a)	(a)	(a)	(a)	[b]500	[b]500	[b]500	[b]500	[b]500
Newfoundland (shipments)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Norway	.....	.....	180	140	.....	155	560	.....	.....	.....	.....	.....
Russia	.....	.....	.....	.....	.....	.....	.....	.....	.....	[c]42	[c]14	[c]215
South-West Africa	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(a)
Spain	351	79	370	277	250	350	280	416	176	392	.....	4,474
Switzerland	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(a)	(a)
Union of South Africa	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	10,975	10,192
United States	104,853	86,289	124,230	141,282	198,519	239,333	125,454	169,441	31,715	128,453	109,939	113,378
Estimated total	217,000	160,000	198,000	244,000	327,000	356,000	196,000	270,000	97,000	218,000	224,000	269,000

1 In addition to the countries listed, Japan produced 36 tons in 1922.
2 Railroad shipments.

[a] Data not available; estimate included in total.
[b] Estimated.
[c] Data for year ended Sept. 30.

TABLE 3.—WORLD PRODUCTION OF FLUORSPAR, 1913-1935, IN METRIC TONS, *Cont'd.*
(Compiled in part by M. T. Latus, of the United States Bureau of Mines.)

Country[1]	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Argentina[2]	.....	.....	24	.....	.....	.....	.....	10	200	311	(a)
Australia:											
New South Wales	.....	.....	.....	.....	96	205	12	.....	51	203	420
Queensland	4,295	2,348	1,050	1,143	602	763	529	1,240	749	1,328	815
South Australia	.....	.....	.....	.....	.....	.....	.....	41	201	234	91
Victoria	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Canada	3,525	.....	.....	.....	16,211	73	36	29	66	136	204
China	4,498	(a)	3,436	(a)	(a)	(a)	7,100	3,510	4,800	5,050	(a)
Chosen	.....	.....	.....	950	1,470	2,297	2,648	7,577	9,076	12,099	9,722
France	24,430	41,670	44,210	46,650	52,968	58,660	23,800	15,200	15,050	14,100	22,750
Germany:											
Anhalt	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	7,357	8,068
Baden	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	6,527	3,941
Bavaria	31,454	32,475	51,001	48,552	50,797	48,063	26,780	21,915	26,364	29,661	31,277
Prussia	24,101	29,729	36,607	37,365	37,717	30,272	12,842	7,794	10,653	21,555	24,618
Saxony	16,141	17,442	22,027	16,422	18,491	11,871	6,937	2,656	3,672	4,945	6,938
Thuringia	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	23,572
Great Britain	39,706	36,459	40,362	47,614	42,432	30,266	20,242	15,675	28,508	34,765	31,646
Italy	7,770	6,320	5,577	4,520	5,740	6,655	5,850	6,450	7,714	9,668	9,500
Mexico	.....	937	(a)	(a)	(a)	(a)	[b]900	[b]900	[b]900	[b]900	[b]900
Newfoundland (shipments)	.....	.....	.....	.....	.....	.....	.....	.....	1,451	2,535	4,082
Norway	.....	.....	.....	(a)	(a)	821	630	571	507	673	(a)
Russia	[c]1,211	[c]3,765	[c]840	[c]3,100	[c]5,700	16,900	16,600	11,200	19,300	27,000	49,100
South-West Africa	(a)	(a)	995	872	565	.....	.....	610	.....	.....	.....
Spain	2,436	14,011	757	2,082	13,478	11,296	6,017	7,018	3,564	6,365	(a)
Switzerland	(a)	(a)	[b]1,000	[b]1,000	[b]1,000	[b]1,000	[b]1,000	[b]1,000	[b]1,000	[b]1,000	.....
Union of South Africa	4,883	8,403	7,582	5,582	2,715	1,520	2,197	1,317	445	1,393	1,955
United States	103,118	116,715	102,099	127,450	132,847	86,952	48,520	22,907	66,161	77,823	112,255
Estimated total	286,000	311,000	339,000	374,000	416,000	335,000	194,000	135,000	214,000	286,000	354,000

DOMESTIC PRODUCTION STATISTICS AND MINE STOCKS

Table 4 gives data on production of fluorspar in the United States from 1880 to 1936. Except for figures prior to 1906, which represent actual production, these data apply to tonnages shipped from the mines as reported by operators. Stocks of crude ore and finished products provide discrepancies when figures in the table are considered as production, but such differences are adjusted by succeeding years. For all practical purposes shipments may be said to approximate production.

Stocks at the mines, however, are important because they may be liquidated at any time. The magnitude of the tonnage of fluorspar in stock from 1927 to 1936, chiefly in the Illinois-Kentucky district, is revealed in table 5.

IMPORTS

Since 1910, the first year for which complete data on imports are available, an average of about 1 ton of fluorspar has come into the United States for every 4 tons shipped from domestic mines. This ratio has fluctuated widely for individual years, however, as is evident from table 6. Figure 4, page 11, shows this relationship graphically.

Before August 1909, when a duty of $2.68 per short ton became effective, fluorspar was imported into the United States duty free, but a record of the quantity is not available. However, virtually all imports had come from England, mostly after 1906, when it was found that fluorspar could be obtained easily and cheaply from the tailings of old Derbyshire lead mines. In consequence the production from these waste dumps, most of which was shipped to the United States, increased rapidly from about 1,100 short tons in 1906 to 17,000 tons in 1909. Mines in Derbyshire and Durham also increased their yield rapidly, and up to August 1909 about 150,000 short tons had been exported to the United States. The effect of the duty was not apparent immediately, as the total imports into the United States in 1910 were 42,488 short tons (38 per cent of the fluorspar available for consumption in the United States in that year). In 1911 imports dropped to 32,764 tons (27 per cent of the total available for consumption). The ratio of imports to domestic requirements fell to 18 per cent in 1912 and to 16 per cent in 1913 after which, due chiefly to the interruptions to commerce caused by the World War, imports decreased until 1919, when the ratio to domestic requirements was 5 per cent, notwithstanding a decrease to $1.34 a short ton in duty effective October, 1913.

In 1920 a substantial increase was noted, the ratio of imports to domestic requirements rising to 12 per cent. The ratio increased steadily to 1927, when it was 39 per cent, in spite of an increase in duty from $1.34 to $5 a short ton effective September 22, 1922. The ratio of imports to domestic requirements declined to 25 and 27 per cent, respectively, in 1928 and 1929 but increased to 40 per cent in 1930, the highest ratio since statistics of imports have been recorded. Since 1932 the ratio has declined sharply and fell to 13 per cent in 1936.

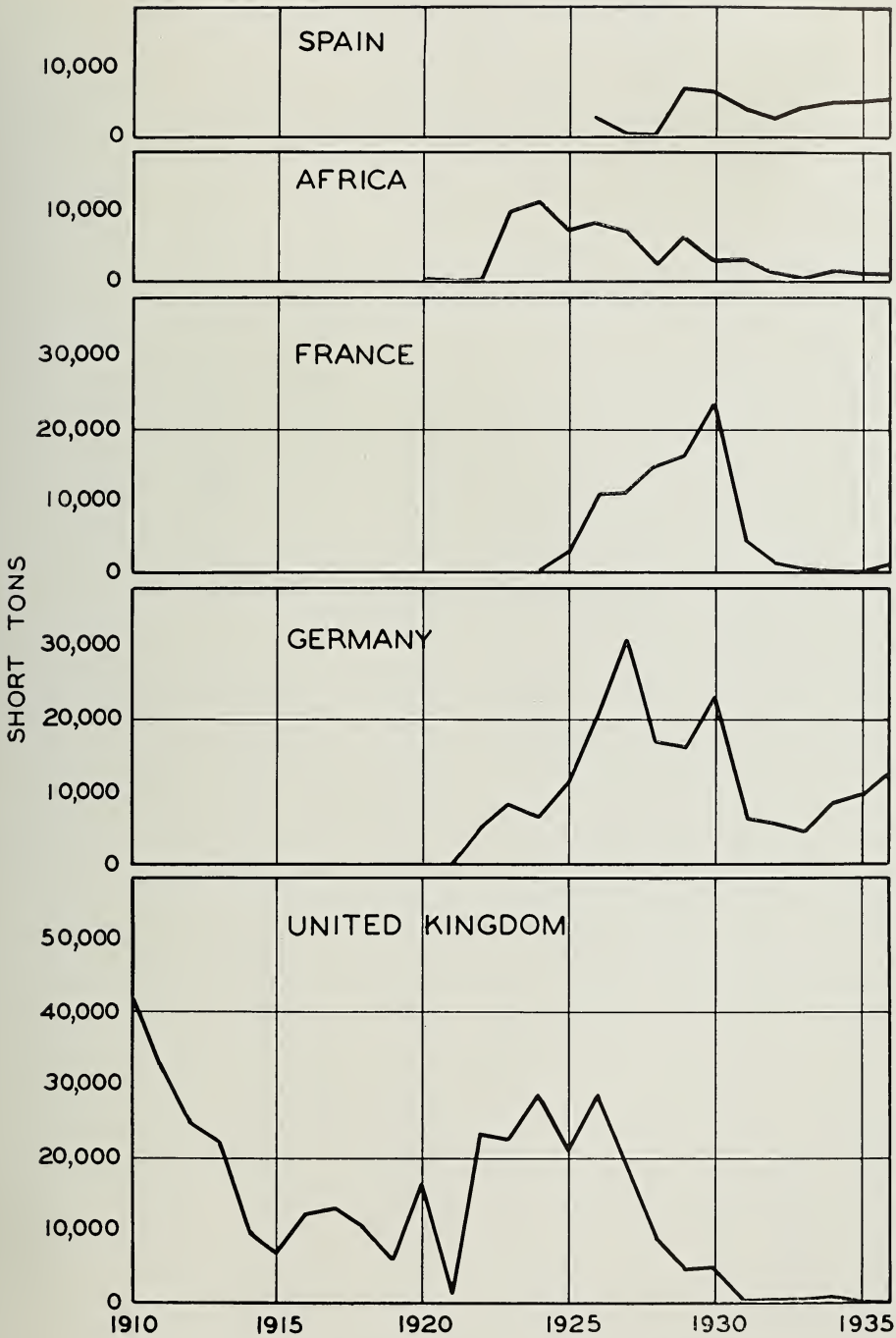

FIGURE 9.—FLUORSPAR IMPORTED INTO THE UNITED STATES FROM CHIEF FOREIGN SOURCES, 1910-1936.

TABLE 4.—FLUORSPAR PRODUCED IN THE

Year	Arizona			California			Colorado		
	Short tons	Value		Short tons	Value		Short tons	Value	
		Total	Average		Total	Average		Total	Average
1880	.....	.....	.....	.....	.....	.....	.....	.....	.....
1881	.....	.....	.....	.....	.....	.....	.....	.....	.....
1882	.....	.....	.....	.....	.....	.....	.....	.....	.....
1883	.....	.....	.....	.....	.....	.....	.....	.....	.....
1884	.....	.....	.....	.....	.....	.....	.....	.....	.....
1885	.....	.....	.....	.....	.....	.....	.....	.....	.....
1886	.....	.....	.....	.....	.....	.....	.....	.....	.....
1887	.....	.....	.....	.....	.....	.....	.....	.....	.....
1888	.....	.....	.....	.....	.....	.....	.....	.....	.....
1889	.....	.....	.....	.....	.....	.....	.....	.....	.....
1890	.....	.....	.....	.....	.....	.....	.....	.....	.....
1891	.....	.....	.....	.....	.....	.....	.....	.....	.....
1892	.....	.....	.....	.....	.....	.....	.....	.....	.....
1893	.....	.....	.....	.....	.....	.....	.....	.....	.....
1894	.....	.....	.....	.....	.....	.....	.....	.....	.....
1895	.....	.....	.....	.....	.....	.....	.....	.....	.....
1896	.....	.....	.....	.....	.....	.....	.....	.....	.....
1897	.....	.....	.....	.....	.....	.....	.....	.....	.....
1898	.....	.....	.....	.....	.....	.....	.....	.....	.....
1899	.....	.....	.....	.....	.....	.....	.....	.....	.....
1900	.....	.....	.....	.....	.....	.....	.....	.....	.....
1901	.....	.....	.....	.....	.....	.....	.....	.....	.....
1902	500			.....	.....	.....	.....	.....	.....
1903	79	$6,593	$10.08	.....	.....	.....	.....	.....	.....
1904	75			.....	.....	.....	.....	.....	.....
1905	.....	.....	.....	.....	.....	.....	1,156	$ 8,200	$ 7.09
1906	.....	.....	.....	.....	.....	.....	300	1,800	6.00
1907	.....	.....	.....	.....	.....	.....	3,300	11,400	3.45
1908	34	252	7.41	.....	.....	.....	701	4,266	6.09
1909	30	435	14.50	.....	.....	.....	350	2,100	6.00
1910	.....	.....	.....	.....	.....	.....	268	1,608	6.00
1911	.....	.....	.....	.....	.....	.....	721	4,226	5.86
1912	.....	.....	.....	.....	.....	.....	1,639	9,834	6.00
1913	100	800	8.00	.....	.....	.....	4,432	26,592	6.00
1914	.....	.....	.....	.....	.....	.....	1,978	12,992	6.57
1915	.....	.....	.....	.....	.....	.....	247	1,482	6.00
1916	199	2,587	13.00	.....	.....	.....	8,669	42,457	4.90
1917	135	1,080	8.00	.....	.....	.....	17,104	196,633	11.50
1918	364	5,537	15.21	.....	.....	.....	38,475	416,780	10.83
1919	45	450	10.00	.....	.....	.....	9,687	150,739	15.56
1920	181	3,264	18.03	.....	.....	.....	12,852	251,308	19.55
1921	.....	.....	.....	.....	.....	.....	3,143	39,907	12.70
1922	.....	.....	.....	.....	.....	.....	2,309	20,169	8.73
1923	.....	.....	.....	.....	.....	.....	6,044	59,710	9.88
1924	.....	.....	.....	.....	.....	.....	12,301	135,411	11.01
1925	.....	.....	.....	.....	.....	.....	11,776	153,707	13.05
1926	.....	.....	.....	.....	.....	.....	10,440	128,211	12.28
1927	.....	.....	.....	.....	.....	.....	6,432	82,503	12.83
1928	.....	.....	.....	.....	.....	.....	1,815	18,040	9.94
1929	.....	.....	.....	.....	.....	.....	4,808	56,607	11.77
1930	.....	.....	.....	.....	.....	.....	9,248	101,758	11.00
1931	.....	.....	.....	.....	.....	.....	529	5,921	11.19
1932	.....	.....	.....	.....	.....	.....	333	3,330	10.00
1933	.....	.....	.....	.....	.....	.....	742	6,778	9.13
1934	.....	.....	.....	.....	.....	.....	6,537	83,132	12.72
1935	.....	.....	.....	181	(b)	(b)	6,978	88,454	12.68
1936	40	(b)	(b)	.....	.....	.....	9,412	109,411	11.62
Total	1,782	b20,988	c12.05	181	(b)	(b)	194,726	2,235,466	11.48

[a] Beginning with 1906 figures represent shipments from mines.
[b] Value for Nevada in 1933; California and Nevada in 1934; Nevada, New Hampshire, and Utah in 1935; and Arizona, Nevada, New Hampshire, and Utah in 1936 included with New Mexico.

United States, 1880-1936, by States[a].

Illinois			Kentucky			Nevada		
Short tons	Value		Short tons	Value		Short tons	Value	
	Total	Average		Total	Average		Total	Average
4,000	$ 16,000	$ 4.00	.....	.....	.....	.....	.....	.....
4,000	16,000	4.00	.....	.....	.....	.....	.....	.....
4,000	20,000	5.00	.....	.....	.....	.....	.....	.....
4,000	20,000	5.00	.....	.....	.....	.....	.....	.....
4,000	20,000	5.00	.....	.....	.....	.....	.....	.....
5,000	22,500	4.50	.....	.....	.....	.....	.....	.....
3,500	15,400	4.40	1,500	$ 6,600	$4.40	.....	.....	.....
3,500	14,000	4.00	1,500	6,000	4.00	.....	.....	.....
6,000	30,000	5.00	.....	.....	.....	.....	.....	.....
9,500	45,835	4.82	.....	.....	.....	.....	.....	.....
8,250	55,328	6.71	.....	.....	.....	.....	.....	.....
10,044	78,330	7.80	.....	.....	.....	.....	.....	.....
12,250	89,000	7.27	.....	.....	.....	.....	.....	.....
12,400	84,000	6.77	.....	.....	.....	.....	.....	.....
7,500	47,500	6.33	.....	.....	.....	.....	.....	.....
4,000	24,000	6.00	.....	.....	.....	.....	.....	.....
5,000	40,000	8.00	1,500	12,000	8.00	.....	.....	.....
3,562	25,159	7.06	1,500	12,000	8.00	.....	.....	.....
.....	.....	.....	7,675	63,050	8.21	.....	.....	.....
3,300	23,000	6.97	12,600	73,650	5.85	.....	.....	.....
3,000	12,600	4.20	15,450	81,900	5.30	.....	.....	.....
6,086	37,405	6.15	13,500	76,398	5.66	.....	.....	.....
18,360	121,550	6.62	29,030	143,410	4.94	.....	.....	.....
11,413	57,620	5.05	30,835	153,960	4.99	.....	.....	.....
17,205	122,172	7.10	19,096	111,499	5.84	.....	.....	.....
33,275	220,206	6.62	22,694	132,362	6.83	.....	.....	.....
28,268	160,623	5.68	11,868	79,802	6.72	.....	.....	.....
25,128	141,971	5.65	21,058	133,971	6.36	.....	.....	.....
31,727	172,838	5.45	6,323	48,642	7.69	.....	.....	.....
41,852	232,251	5.55	7,800	53,233	6.82	.....	.....	.....
47,302	277,764	5.87	17,003	124,574	7.33	.....	.....	.....
68,817	481,635	7.00	12,403	96,574	7.79	.....	.....	.....
103,937	695,467	6.69	10,473	61,186	5.84	.....	.....	.....
85,854	550,815	6.42	19,622	113,903	5.80	.....	.....	.....
73,811	426,063	5.77	19,077	128,986	6.76	.....	.....	.....
116,340	624,040	5.36	19,219	129,873	6.76	.....	.....	.....
126,369	746,150	5.90	19,698	123,596	6.27	.....	.....	.....
156,676	1,373,333	8.77	43,639	697,566	15.98	.....	.....	.....
132,798	2,887,099	21.74	87,604	2,069,185	23.62	.....	.....	.....
92,729	2,430,361	26.21	32,386	883,171	27.27	400	$5,600	$14.00
120,299	3,096,767	25.74	46,091	1,246,942	27.05	532	8,672	16.30
12,477	315,767	25.31	15,266	294,513	19.29	.....	.....	.....
83,855	1,493,188	17.81	52,484	970,059	15.48	.....	.....	.....
65,045	1,443,490	22.19	45,441	945,402	20.81	.....	.....	.....
62,067	1,288,310	20.76	47,847	988,940	20.67	.....	.....	.....
54,428	1,024,516	18.82	44,826	833,794	18.60	.....	.....	.....
53,734	1,012,879	18.85	62,494	1,167,129	18.68	.....	.....	.....
46,006	863,909	18.78	57,495	1,040,338	18.09	.....	.....	.....
65,884	1,154,983	17.53	69,747	1,426,766	20.46	455	6,603	14.51
67,009	1,284,834	19.17	70,827	1,390,603	19.63	1,357	23,400	17.24
44,134	836,473	18.95	39,181	763,370	19.48	974	14,267	14.65
28,072	468,386	16.69	23,462	437,642	18.65	395	5,697	14.42
9,615	156,279	16.25	14,725	225,052	15.28	49	882	18.00
36,075	543,060	15.05	34,614	469,451	13.56	505	([b])	([b])
33,234	567,396	17.07	43,163	690,990	16.01	631	([b])	([b])
44,120	685,794	15.54	68,679	1,017,451	14.81	1,040	([b])	([b])
82,056	1,525,606	18.59	80,241	1,409,433	17.56	2,126	([b])	([b])
2,242,863	30,219,652	$13.47	1,301,636	20,934,966	$16.08	8,464	[b]65,121	[d] 15.65

[c] Average for 1902-1920. [d] Average for 1919-1932.
[e] Average for 1911-1923. [f] Average for 1918-1924.

TABLE 4.—

Year	New Hampshire			New Mexico			Tennessee		
	Short tons	Value		Short tons	Value		Short tons	Value	
		Total	Average		Total	Average		Total	Average
1880	...	...	...	...	...	...	...	...	...
1881	...	...	...	...	...	...	...	...	...
1882	...	...	...	...	...	...	...	...	...
1883	...	...	...	...	...	...	...	...	...
1884	...	...	...	...	...	...	...	...	...
1885	...	...	...	...	...	...	...	...	...
1886	...	...	...	...	...	...	...	...	...
1887	...	...	...	...	...	...	...	...	...
1888	...	...	...	...	...	...	...	...	...
1889	...	...	...	...	...	...	...	...	...
1890	...	...	...	...	...	...	...	...	...
1891	...	...	...	...	...	...	...	...	...
1892	...	...	...	...	...	...	...	...	...
1893	...	...	...	...	...	...	...	...	...
1894	...	...	...	...	...	...	...	...	...
1895	...	...	...	...	...	...	...	...	...
1896	...	...	...	...	...	...	...	...	...
1897	...	...	...	...	...	...	...	...	...
1898	...	...	...	...	...	...	...	...	...
1899	...	...	...	...	...	...	...	...	...
1900	...	...	...	...	...	...	...	...	...
1901	...	...	...	...	...	...	...	...	...
1902	...	...	...	...	...	...	128		
1903	...	...	...	...	...	...	196	$3,400	$8.50
1904	...	...	...	...	...	...	76		
1905	...	...	...	...	...	...	260	1,720	6.62
1906	...	...	...	...	...	...	360	1,800	5.00
1907	...	...	...	...	...	...	...	...	...
1908	...	...	...	...	...	...	...	...	...
1909	...	...	...	710	$3,728	$5.25	...	...	...
1910	...	...	...	4,854	26,250	5.41	...	...	...
1911	800	$6,400	$8.00	4,307	22,612	5.25	...	...	...
1912	300	1,500	5.00	196	1,176	6.00	...	...	...
1913	200	1,200	6.00	5,372	42,976	8.00	...	...	...
1914	250	2,000	8.00	...	...	...	...	...	...
1915	650	5,200	8.00	485	3,880	8.00	...	...	...
1916	800	7,864	9.83	...	...	...	...	...	...
1917	1,274	19,110	15.00	...	...	...	...	...	...
1918	1,059	21,243	20.06	3,437	64,348	18.72	...	...	...
1919	531	12,826	24.15	2,346	37,643	16.05	...	...	...
1920	202	4,040	20.00	6,353	101,460	15.97	...	...	...
1921	567	13,721	24.20	3,507	60,186	17.16	...	...	...
1922	690	15,353	22.25	2,180	30,992	14.22	...	...	...
1923	142	3,160	22.25	4,328	50,861	11.75	...	...	...
1924	...	...	...	2,580	35,178	13.63	...	...	...
1925	...	...	...	2,639	40,325	15.28	...	...	...
1926	...	...	...	1,989	33,058	16.62	...	...	...
1927	...	...	...	2,613	47,978	18.36	...	...	...
1928	...	...	...	2,589	50,162	19.38	...	...	...
1929	...	...	...	2,438	35,682	14.64	...	...	...
1930	...	...	...	2,312	30,775	13.31	...	...	...
1931	...	...	...	1,026	13,629	13.28	...	...	...
1932	...	...	...	529	6,956	13.15	...	...	...
1933	...	...	...	994	[b]19,889	[b]13.27	...	...	...
1934	...	...	...	2,040	[b]49,887	[b]17.49	...	...	...
1935	12	([b])	([b])	2,726	[b]68,823	[b]17.39	6	116	19.33
1936	257	([b])	([b])	2,045	[b]66,818	[b]14.78	...	...	...
Total	7,734	[b]113,617	[c]15.22	64,595	[b]945,272	[b]13.58	1,026	7,036	6.86

Concluded.

Utah			Washington			Total		
Short tons	Value		Short tons	Value		Short tons	Value	
	Total	Average		Total	Average		Total	Average
.....	.....	.....	.....	.....	.....	4,000	$16,000	$4.00
.....	.....	.....	.....	.....	.....	4,000	16,000	4.00
.....	.....	.....	.....	.....	.....	4,000	20,000	5.00
.....	.....	.....	.....	.....	.....	4,000	20,000	5.00
.....	.....	.....	.....	.....	.....	4,000	20,000	5.00
.....	.....	.....	.....	.....	.....	5,000	22,500	4.50
.....	.....	.....	.....	.....	.....	5,000	22,000	4.40
.....	.....	.....	.....	.....	.....	5,000	20,000	4.00
.....	.....	.....	.....	.....	.....	6,000	30,000	5.00
.....	.....	.....	.....	.....	.....	9,500	45,835	4.82
.....	.....	.....	.....	.....	.....	8,250	55,328	6.71
.....	.....	.....	.....	.....	.....	10,044	78,330	7.80
.....	.....	.....	.....	.....	.....	12,250	89,000	7.27
.....	.....	.....	.....	.....	.....	12,400	84,000	6.77
.....	.....	.....	.....	.....	.....	7,500	47,500	6.33
.....	.....	.....	.....	.....	.....	4,000	24,000	6.00
.....	.....	.....	.....	.....	.....	6,500	52,000	8.00
.....	.....	.....	.....	.....	.....	5,062	37,159	7.34
.....	.....	.....	.....	.....	.....	7,675	63,050	8.21
.....	.....	.....	.....	.....	.....	15,900	96,650	6.08
.....	.....	.....	.....	.....	.....	18,450	94,500	5.12
.....	.....	.....	.....	.....	.....	19,586	113,803	5.81
.....	.....	.....	.....	.....	.....	48,018	271,832	5.66
.....	.....	.....	.....	.....	.....	42,523	213,617	5.02
.....	.....	.....	.....	.....	.....	36,452	234,755	6.44
.....	.....	.....	.....	.....	.....	57,385	362,488	6.32
.....	.....	.....	.....	.....	.....	40,796	244,025	5.98
.....	.....	.....	.....	.....	.....	49,486	287,342	5.81
.....	.....	.....	.....	.....	.....	38,785	225,998	5.83
.....	.....	.....	.....	.....	.....	50,742	291,747	5.75
.....	.....	.....	.....	.....	.....	69,427	430,196	6.20
.....	.....	.....	.....	.....	.....	87,048	611,447	7.02
.....	.....	.....	.....	.....	.....	116,545	769,163	6.60
.....	.....	.....	.....	.....	.....	115,580	736,286	6.37
.....	.....	.....	.....	.....	.....	95,116	570,041	5.99
.....	.....	.....	.....	.....	.....	136,941	764,475	5.58
.....	.....	.....	.....	.....	.....	155,735	922,654	5.92
.....	.....	.....	.....	.....	.....	218,828	2,287,722	10.45
20	$ 465	$23.25	60	$824	$13.73	263,817	5,465,481	20.72
166	4,784	28.82	.....	.....	.....	138,290	3,525,574	25.49
268	6,094	22.74	.....	.....	.....	186,778	4,718,547	25.26
.....	.....	.....	.....	.....	.....	34,960	724,094	20.71
78	1,404	18.00	.....	.....	.....	141,596	2,531,165	17.88
188	3,196	17.00	.....	.....	.....	121,188	2,505,819	20.68
184	3,292	17.89	.....	.....	.....	124,979	2,451,131	19.61
.....	.....	.....	.....	.....	.....	113,669	2,052,342	18.06
.....	.....	.....	.....	.....	.....	128,657	2,341,277	18.20
.....	.....	.....	.....	.....	.....	112,546	2,034,728	18.08
.....	.....	.....	.....	.....	.....	140,490	2,656,554	18.91
.....	.....	.....	.....	.....	.....	146,439	2,791,126	19.06
.....	.....	.....	.....	.....	.....	95,849	1,746,643	18.22
.....	.....	.....	.....	.....	.....	53,484	931,275	17.41
.....	.....	.....	.....	.....	.....	25,251	392,499	15.54
.....	.....	.....	.....	.....	.....	72,930	1,039,178	14.25
.....	.....	.....	.....	.....	.....	85,786	1,391,405	16.22
180	(b)	(b)	.....	.....	.....	123,741	1,860,638	15.04
54	(b)	(b)	.....	.....	.....	176,231	3,111,268	17.65
1,138	b19,235	f21.28	60	824	13.73	3,824,205	54,562,187	14.27

TABLE 5.—STOCKS OF FLUORSPAR AT MINES OR SHIPPING POINTS IN THE UNITED STATES, 1927-1936, IN SHORT TONS.

Year	Crude[1]	Ready-to-ship	Total
1927	47,956	23,122	71,078
1928	60,456	12,162	72,618
1929	55,773	18,128	73,901
1930	51,464	56,201	107,665
1931	43,186	62,541	105,727
1932	41,999	55,211	97,210
1933	42,008	44,777	86,785
1934	33,326	50,586	83,912
1935	24,185	40,043	64,228
1936	24,023	29,958	53,981

1 The greater part of this crude (run-of-mine) fluorspar must be beneficiated before it can be marketed.

TABLE 6.—FLUORSPAR IMPORTED INTO THE UNITED STATES, AND RATIO OF IMPORTS TO IMPORTS PLUS DOMESTIC SHIPMENTS, 1910-1936.

Year	Domestic shipments, short tons	Imports for consumption into the United States, short tons	Ratio of imports to imports plus domestic shipments, per cent
1910	69,427	42,488	37.96
1911	87,048	32,764	27.35
1912	116,545	26,176	18.34
1913	115,580	22,682	16.41
1914	95,116	10,205	9.69
1915	136,941	7,167	4.97
1916	155,735	12,323	7.33
1917	218,828	13,616	5.86
1918	263,817	12,572	4.55
1919	138,290	6,943	4.78
1920	186,778	24,612	11.64
1921	34,960	6,229	15.12
1922	141,596	33,108	18.95
1923	121,188	42,226	25.84
1924	124,979	51,043	29.00
1925	113,669	48,700	29.99
1926	128,657	75,671	37.03
1927	112,546	71,515	38.85
1928	140,490	47,183	25.14
1929	146,439	54,345	27.07
1930	95,849	64,903	40.37
1931	53,484	20,709	27.91
1932	25,251	13,236	34.39
1933	72,930	10,408	12.49
1934	85,786	16,705	16.30
1935	123,741	16,340	11.66
1936	176,231	25,504	12.64

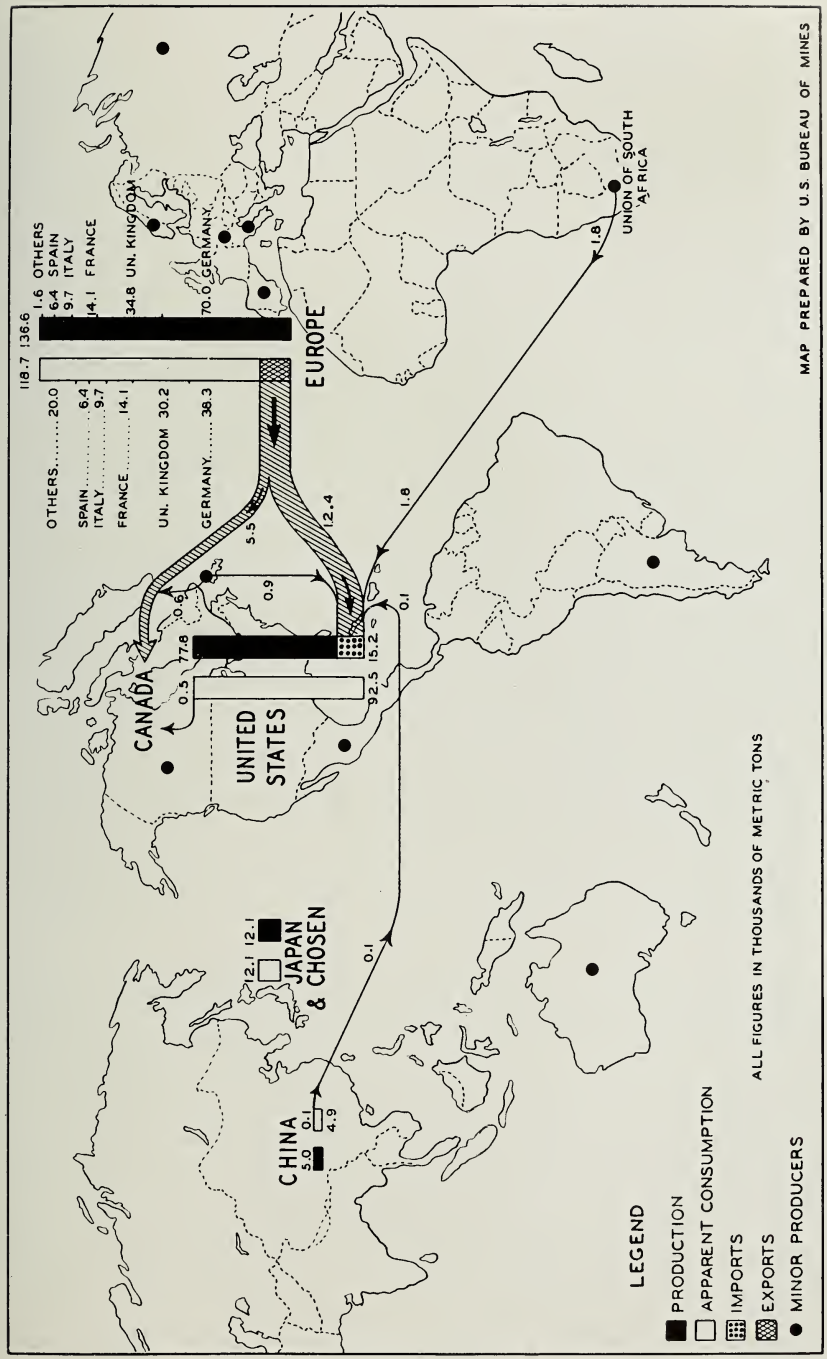

FIGURE 10.—WORLD PRODUCTION AND INTERNATIONAL TRADE IN FLUORSPAR IN 1934 AND FLOW TO UNITED STATES MARKETS FROM PRINCIPAL PRODUCING DISTRICTS.

TABLE 7.—FLUORSPAR IMPORTED INTO THE

Year	Africa		Argentina		Australia		Austria-Hungary	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1910	...	...	...	...	...	...	11	$50
1911	...	...	...	...	...	...	...	...
1912	...	...	...	...	...	...	...	...
1913	...	...	...	...	...	...	...	...
1914	...	...	...	...	...	...	...	...
1915	...	...	...	...	...	...	...	...
1916	...	...	...	...	...	...	...	...
1917	...	...	...	...	...	...	...	...
1918	...	...	...	...	...	...	...	...
1919	...	...	...	...	...	...	...	...
1920	30	$1,080	...	...	11	$426	...	...
1921	...	...	...	...	...	...	...	...
1922	486	8,415	...	...	...	...	...	...
1923	10,380	157,625	...	...	...	...	...	...
1924	11,125	147,977	...	...	...	...	...	...
1925	7,906	108,647	...	...	...	...	...	...
1926	8,506	136,502	...	...	...	...	...	...
1927	7,069	90,966	...	...	...	...	...	...
1928	2,661	36,471	20	$360	...	...	...	...
1929	6,387	75,856	...	...	...	...	...	...
1930	2,712	31,069	...	...	...	...	...	...
1931	3,672	40,375	...	...	...	...	...	...
1932	1,587	14,809	...	...	[c]	196	...	...
1933	712	12,449	...	...	...	...	...	...
1934	1,997	31,872	...	...	...	...	...	...
1935	1,347	23,739	...	...	...	...	...	...
1936	948	19,424	...	...	...	...	...	...
Total	67,525	937,276	20	360	11	622	11	50

[a] Imports Aug. 1 to Dec. 31, 1909, 6,971 tons, valued at $26,377; not recorded separately prior to Aug. 1, 1909.
[b] Quantity not recorded.

Table 7 shows the relative importance of the various countries that have supplied fluorspar to the United States from 1910 to 1936. The United Kingdom, Germany, France, Africa and Spain have provided the largest quantities. The country named is not always that in which the fluorspar was originally mined. For instance, the fluorspar imported from Australia was mined in South Africa, and the fluorspar credited to Belgium presumably was mined in Germany.

Imports of fluorspar into the United States from the United Kingdom decreased from an average of 19,300 short tons for the 18 years 1910-1927 to an average of 6,600 tons from 1928 to 1930. Since the latter year this movement has almost ceased. The United Kingdom maintained her position as the main foreign source of supply for the United States through 1920 and from 1922 to 1926. The predominance of the United Kingdom as a source of imported fluorspar is shown by comparison of her share with the total recorded from 1910 to 1936; the United Kingdom contributed 367,987 short tons (45

United States, 1910-1936, by countries[a].

Belgium		Canada		China		Czechoslovakia		France	
Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	618	$ 3,813	.....	.....	.....	.....	.....	.....
.....	.....	913	21,973	.....	.....	.....	.....	.....	.....
.....	.....	902	13,532	.....	.....	.....	.....	.....	.....
.....	.....	7,068	110,532	.....	.....	.....	.....	.....	.....
.....	.....	4,370	52,855	.....	.....	.....	.....	.....	.....
71	$1,187	2,877	32,679	.....	.....	34	$ 761	.....	.....
35	712	([b])	5	90	$1,183	.....	.....	.....	.....
6	75	213	3,216	506	5,089	.....	.....	232	$2,782
78	1,624	.....	.....	559	5,816	27	591	2,537	20,887
31	566	1,109	10,310	645	5,992	.....	.....	11,163	90,737
21	449	560	4,250	449	3,961	.....	.....	11,711	86,279
.....	.....	.....	.....	756	8,200	.....	.....	15,072	141,434
21	519	.....	.....	1,345	11,534	.....	.....	16,850	159,059
.....	.....	.....	.....	739	7,957	.....	.....	23,313	184,238
11	170	280	2,313	202	1,811	.....	.....	4,462	33,646
.....	.....	.....	.....	112	671	.....	.....	1,578	9,588
.....	.....	.....	.....	27	413	.....	.....	204	1,247
.....	.....	187	2,962	112	990	.....	.....	.....	.....
.....	.....	1	14	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	1,595	16,039
274	5,302	19,098	258,454	5,542	53,617	61	1,352	88,717	745,936

[c] Less than 1 ton of optical fluorspar.
[d] Optical fluorspar.

(Table 7 concluded on pages 50 and 51)

per cent) out of 809,373 short tons. If a record were available of the fluorspar imported into the United States prior to 1910, her share possibly would be 54 per cent of the total imports.

Imports of fluorspar into the United States from Germany were small before the World War, ranging from 100 to 300 tons annually prior to 1913. Immediately after the war the imports remained insignificant, amounting to 407 short tons in 1920 and 215 tons in 1921. In 1922, however, the imports jumped to 5,804 short tons, and Germany thus became an important source of imported fluorspar. In 1930 she contributed 23,797 tons to United States markets. Since 1927 Germany has been the chief source of imported fluorspar. The total imports from Germany for 1910 to 1936 were 192,603 short tons (24 per cent of the total imported during this period from all sources).

TABLE 7.—

Year	Germany		Italy		Netherlands		Newfoundland	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1910	142	$ 1,386	.....	.....	.....	.....	.....	.....
1911	198	1,919	.....	.....	.....	.....	.....	.....
1912	256	2,444	.....	.....	.....	.....	.....	.....
1913	320	3,073	.....	.....	.....	.....	.....	.....
1914	184	1,818	.....	.....	.....	.....	.....	.....
1915	127	1,154	.....	.....	.....	.....	.....	.....
1916	.....	.....	.....	.....	.....	.....	.....	.....
1917	.....	.....	.....	.....	.....	.....	.....	.....
1918	.....	.....	.....	.....	.....	.....	.....	.....
1919	.....	.....	.....	.....	.....	.....	.....	.....
1920	407	9,450	.....	.....	.....	.....	.....	.....
1921	215	4,420	.....	.....	.....	.....	.....	.....
1922	5,804	49,196	.....	.....	.....	.....	.....	.....
1923	8,580	67,595	268	$ 2,471	11	$ 180	.....	.....
1924	6,834	69,357	1,585	14,804	1,177	13,951	.....	.....
1925	11,680	103,845	4,278	32,208	.....	.....	.....	.....
1926	20,465	171,769	1,379	15,434	.....	.....	.....	.....
1927	31,829	230,821	449	5,969	.....	.....	.....	.....
1928	17,601	150,872	1,033	9,600	.....	.....	.....	.....
1929	16,488	140,860	1,258	10,528	.....	.....	.....	.....
1930	23,797	189,587	1,802	17,198	.....	.....	.....	.....
1931	6,491	77,067	1,523	24,267	.....	.....	.....	.....
1932	5,842	70,294	1,457	11,848	.....	.....	.....	.....
1933	4,333	54,836	533	4,533	.....	.....	320	$ 2,646
1934	8,224	98,565	60	587	.....	.....	745	10,460
1935	9,843	119,275	55	589	.....	.....	.....	.....
1936	12,943	160,937	.....	.....	.....	.....	4,317	31,497
Total	192,603	1,780,540	15,680	150,036	1,188	14,131	5,382	44,603

Imports of fluorspar into the United States from France were first recorded in 1923, when 232 short tons were imported. Thereafter imports from France increased successively, reaching 23,313 short tons in 1930. France has been the third largest source of imported fluorspar, contributing 88,717 short tons (11 per cent of the total imported) from 1910 to 1936.

Thus, the United Kingdom, Germany, and France have supplied 649,307 short tons of fluorspar (80 per cent of the total imported) from 1910 to 1936. Africa, Spain, Canada, and Italy, in the order named, have been smaller but important sources of imported spar.

Figure 10 shows the flow of fluorspar from foreign countries to the United States markets in 1934 and the approximate location of the major world deposits.

TARIFF HISTORY

Prior to 1909, fluorspar was not specifically mentioned in the tariff law; it was included in the blanket provision for crude minerals which were free of duty under various acts.

Concluded.

Soviet Russia in Asia		Spain		United Kingdom		Total	
Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
.....	.....	.....	.....	42,335	$133,716	42,488	$135,152
.....	.....	.....	.....	32,566	78,673	32,764	80,592
.....	.....	.....	.....	25,920	69,172	26,176	71,616
.....	.....	.....	.....	22,362	68,390	22,682	71,463
.....	.....	.....	.....	10,021	37,125	10,205	38,943
.....	.....	.....	.....	7,040	21,724	7,167	22,878
.....	.....	.....	.....	12,323	54,000	12,323	54,000
.....	.....	.....	.....	12,998	110,785	13,616	114,598
.....	.....	.....	.....	11,659	147,391	12,572	169,364
.....	.....	.....	.....	6,041	94,099	6,943	107,631
.....	.....	.....	.....	17,096	144,142	24,612	265,630
.....	.....	.....	.....	1,644	12,031	6,229	69,306
.....	.....	.....	.....	23,836	206,950	33,108	299,188
.....	.....	.....	.....	22,862	202,548	42,226	432,319
.....	.....	.....	.....	29,365	298,391	51,043	555,642
.....	.....	.....	.....	21,635	195,229	48,700	468,847
18	$277	2,948	$ 33,915	29,407	281,735	75,671	747,237
.....	.....	978	3,650	18,449	168,840	71,515	595,185
.....	.....	680	5,178	9,360	56,585	47,183	408,700
.....	.....	7,168	52,039	4,828	30,580	54,345	480,975
.....	.....	6,784	53,612	5,756	60,995	64,903	544,656
.....	.....	4,068	31,786	.....	.....	20,709	211,435
.....	.....	2,659	24,881	[d]1	378	13,236	132,665
.....	.....	4,262	28,690	17	229	10,408	105,043
.....	.....	4,914	35,316	466	2,534	16,705	183,286
.....	.....	5,094	35,432	.....	.....	16,340	179,049
.....	.....	5,701	31,365	.....	.....	25,504	259,262
18	277	45,256	335,864	367,987	2,476,242	809,373	6,804,662

The rates of duty on fluorspar beginning with 1909 have been as follows:

Act of 1909, effective August 1909, $3 per long ton (equivalent to $2.68 per short ton).

Act of 1913, effective October 1913, $1.50 per long ton (equivalent to $1.34 per short ton).

Act of 1922, effective September 22, 1922, $5.60 per long ton (equivalent to $5 per short ton).

Act of 1922, effective November 16, 1928, $8.40 per long ton (equivalent to $7.50 per short ton) on fluorspar containing not more than 93 per cent of calcium fluoride. The rate of duty on fluorspar containing more than 93 per cent of calcium fluoride remained $5 per short ton.

Act of 1930, effective June 18, 1930, $8.40 per long ton (equivalent to $7.50 per short ton) on fluorspar containing not more than 97 per cent of calcium fluoride. The rate of duty on fluorspar containing above 97 per cent remained $5 per short ton.

EXPORTS

Exports of domestic fluorspar have never had major importance. Most of the fluorspar exported from the United States is shipped to Canada. The bulk of it is of metallurgical grade, but some ground spar for the ceramic trade is exported.

TABLE 8.—FLUORSPAR REPORTED BY PRODUCERS AS EXPORTED FROM THE UNITED STATES, 1922-1936.

Year	Short tons	Value		Year	Short tons	Value	
		Total	Average			Total	Average
1922....	2,296	$40,966	$17.84	1929..	506	$11,621	$22.97
1923....	1,144	25,312	22.13	1930..	281	6,160	21.92
1924....	617	14,489	23.48	1931..	311	5,599	18.00
1925....	1,055	17,574	16.66	1932..	25	553	22.12
1926....	2,132	34,915	16.38	1933..	71	967	13.62
1927....	385	7,507	19.50	1934..	522	8,602	16.48
1928....	398	6,586	16.55	1935..	313	4,651	14.86
				1936..	240	4,079	17.00

DOMESTIC CONSUMPTION

The total tonnage of fluorspar available for consumption in the United States can be approximated by adding domestic shipments to imports and deducting exports. Table 9 shows this quantity from 1922 to 1936.

TABLE 9.—FLUORSPAR AVAILABLE FOR CONSUMPTION IN THE UNITED STATES, 1922-1936.

Year	Short tons	Year	Short tons
1922	172,408	1929	200,278
1923	162,270	1930	160,471
1924	175,405	1931	73,882
1925	161,314	1932	38,462
1926	202,196	1933	83,267
1927	183,676	1934	101,969
1928	187,275	1935	139,768
		1936	201,495

In effect the foregoing figures represent the current market demand, whether for immediate utilization or for consumers' stocks. These tonnages show the actual quantity moving to domestic consumers, both from domestic mines and from ports of entry; the quantity of spar consumed varies somewhat from these figures. More detailed data on the quantities of spar actually consumed by the various industries in the United States for the period 1932 to 1936 are given in table 10.

The relative amounts of spar moving from the several points of origin to the different industries are affected to no small degree by problems and costs of transportation.

TABLE 10.—CONSUMPTION OF FLUORSPAR IN THE UNITED STATES, BY PURITY AND USE. [AVERAGE FOR 1932-1936.]

Purity and use	Short tons	Percentage of total	Purity and use	Short tons	Percentage of total
Acid:			Metallurgical:		
Hydrofluoric acid and derivatives	11,800	10.33	Basic open-hearth steel	82,400	72.15
Ceramic:			Electric-furnace steel	4,400	3.85
Glass	8,800	7.71	Ferro-alloys	500	.44
Enamel	3,900	3.42	Foundry	1,400	1.23
Cement	300	.26	Other	700	.61
			Total	114,200	100.00

TRANSPORTATION

Not much fluorspar is consumed near the domestic producing districts. Except for Baltimore, New York, and Philadelphia the bulk of both domestic and imported spar must be transported considerable distances to markets. The question of distance is even more acute with material from western deposits.

Pittsburgh is nearer ports of entry on the Atlantic coast than it is to the Illinois-Kentucky district. For example, it costs $1.77 more to ship a ton of fluorspar by rail to Pittsburgh from Rosiclare, Illinois, than from Baltimore. As competition in the industry is very keen, a slight difference in transportation cost may determine where an order for spar is placed.

Shipments of fluorspar move by rail, by water, and by a combination of rail and water. Table 11 lists railroad freight rates from the principal points of origin to the chief consuming centers. The rates were in effect April 5, 1932, except from Salida, Colorado, which were in effect August 10, 1937. Rates in effect at present may be obtained from the Interstate Commerce Commission, Washington, D. C., or local freight agents.

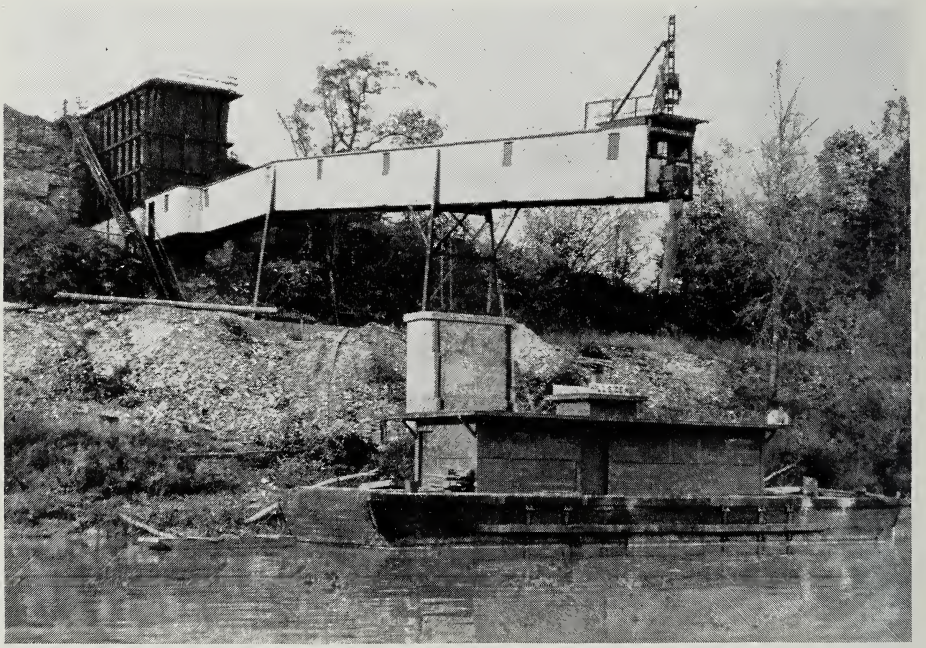

Figure 11.—Loading Station on the Ohio River near Rosiclare, Illinois, for Barge Transportation, Hillside Fluor Spar Mines.

The Ohio River is the means of transporting considerable fluorspar in barges from the Illinois-Kentucky district to Pittsburgh and other steel areas (fig. 11). Completion of the river system of locks and dams provided such an impetus to river movement that 46,895 short tons of spar were transported in 1936 compared with 23,000 tons in 1935.

Independent barge lines and transportation barge lines owned by certain steel companies participate in this river movement. The fluorspar is loaded in barges on the return up-bound trip after the tows have taken their cargoes of various commodities to down-bound trans-shipping points.

Rates by independent barge lines are fairly uniform and the cost per short ton at present is as follows:

$2.05 to Portsmouth, Ohio.
2.10 to Steubenville, Ohio.
2.20 to Freedom and Pittsburgh, Pa.
2.30 to Monessen, Pa.

The unloading charge at up-river points is 25 cents per ton, and the cargo insurance rates approximate 5 cents a ton.

The barges are loaded rarely with less than 300 tons and usually with not more than 600 tons, depending upon river stage conditions. Loading into the barge is done by the shipper and unloading by the buyer. All transportation costs beyond the loading dock at Kentucky-Illinois points are charged to the buyer.

The combination river and rail rates per short ton from Rosiclare, Illinois, to Youngstown, Ohio, follow:

Barge rate, Rosiclare, Illinois, to Freedom, Pa.	$2.20
Unloading charge from barge to railroad car at Freedom	.25
Insurance, approximate	.05
Rail rate, Freedom, Pa., to Youngstown, Ohio	1.20
Surcharge	.06
River-rail rate, total	3.76
All-rail rate	5.25

Methods and costs of transportation therefore are important factors in the ultimate price for which fluorspar is sold and must be considered carefully by both buyers and sellers in negotiating contracts.

MARKETS AND PRICES

PRICES

The average price of all fluorspar produced in the United States from 1880 to 1916, inclusive, was $6.07 per short ton. During this time the average price per ton for any year was never less than $4 nor more than $8.21. From 1917 to 1931 inclusive, however, the average price per ton for all domestic spar sold was $19.17, with a low of $10.45 in 1917 and a high of $25.49 in 1919. For the 5 years 1932-1936 the average price dropped to $16.11 a ton, with a low of $14.25 in 1933 and a high of $17.65 in 1936. The average price for the pre-war years 1909 to 1913, inclusive, was $6.39, whereas for 1926 to 1930 the price was $18.49.

Among the causes of this tripling of fluorspar prices were (1) stimulated war demand and (2) higher war and postwar production costs, which have never dropped to pre-war levels.

During the war imports of foreign spar were greatly curtailed, although steel production was keyed to a high pitch. Materials which facilitated steel production in any way generally were used lavishly and were bought without regard for price. In contrast with the stagnation in the fluorspar industry from 1931 to 1933, it is interesting to recall that during the World War rep-

TABLE 11.—RAILROAD FREIGHT

From: / To:	DOMESTIC PRODUCING CENTERS									
	Arizona	Colorado				Illinois		Kentucky	Nevada	
	Dome	Boulder	Northgate	Salida	Wagon Wheel Gap	Rosiclare	Shawneetown	Marion	Beatty	Fallon
Alabama: Birmingham	$10.80	$ 9.80	$16.90	$12.40	$12.10	$ 3.80	$ 3.40	$ 3.40	$16.80	$10.80
California:										
Los Angeles	4.60	10.00	10.00	8.70	12.30	17.00	.....	17.60	4.50	7.00
San Francisco	6.60	10.00	10.00	8.70	12.30	17.00	.....	17.60	6.50	5.00
Colorado: Pueblo	9.56½	4.60	11.90	4.60	2.30	7.00	7.90	7.60	14.00	9.56½
Delaware: Wilmington	.....	.....	.....	.....	16.70	7.50	7.20	7.50	18.00	.....
Georgia: Atlanta	12.60	.....	.....	13.00	12.70	4.40	4.00	4.00	.....	.....
Illinois:										
Chicago	10.80	7.60	8.00	7.20	9.90	3.50	3.10	3.60	15.00	10.80
East St. Louis	10.80	5.90	7.50	6.00	8.20	2.40	2.00	2.40	15.00	10.80
Peoria	.....	.....	.....	7.20	9.10	3.50	3.10	3.60	.....	.....
Indiana:										
Gary	10.80	7.60	8.00	7.20	9.90	3.50	3.10	3.60	16.80	10.80
Indianapolis	.....	.....	.....	.....	13.30	3.35	.....	3.35	.....	.....
Kokomo	.....	.....	.....	.....	13.30	3.75	.....	3.75	.....	.....
Muncie	.....	.....	.....	.....	13.50	3.90	.....	3.90	.....	.....
Kentucky:										
Ashland	.....	.....	.....	.....	14.30	4.25	3.95	4.25	.....	12.60
Newport	.....	.....	.....	.....	16.50	3.65	3.35	3.65	.....	12.60
Maryland: Baltimore	.....	.....	.....	.....	16.50	7.30	7.00	7.20	.....	.....
Michigan: Detroit	.....	.....	.....	.....	16.10	5.25	4.95	5.25	.....	12.60
Minnesota: Duluth	.....	.....	.....	.....	9.90	5.70	5.30	5.70	15.00	.....
Missouri:										
Kansas City	10.80	4.60	7.50	5.10	6.80	5.00	5.60	5.10	15.00	10.80
St. Louis	10.80	5.90	7.50	6.00	8.20	2.40	2.00	2.40	15.00	10.80
New York:										
Buffalo	.....	.....	.....	.....	15.10	5.25	4.95	5.25	.....	.....
New York	.....	.....	.....	.....	16.70	7.90	.....	7.90	.....	.....
Ohio:										
Cleveland	.....	.....	.....	.....	14.50	5.25	4.95	5.25	.....	.....
Columbus	12.60	.....	.....	.....	13.90	4.70	4.40	4.70	.....	12.60
Mansfield	.....	.....	.....	.....	14.10	5.25	4.95	5.25	16.80	.....
Youngstown	12.60	12.40	13.40	11.20	14.70	5.25	4.95	5.25	16.80	12.60
Oklahoma:										
Okmulgee	16.10	14.40	14.80	7.70	15.70	8.80	.....	9.00	15.00	18.10
Sand Springs	15.80	14.40	15.50	5.10	15.70	8.40	.....	8.80	15.00	17.80
Pennsylvania:										
Johnstown	.....	.....	.....	.....	15.10	5.55	5.25	5.55	.....	.....
Newell	.....	.....	.....	.....	15.10	5.55	5.25	5.55	.....	.....
Philadelphia	.....	.....	.....	.....	16.70	7.50	7.20	7.50	.....	.....
Pittsburgh	12.60	12.40	13.80	11.60	14.70	5.25	4.95	5.25	16.80	12.60
Washington	.....	.....	.....	.....	14.70	5.25	7.00	5.25	.....	.....
Tennessee: Chattanooga	10.80	.....	.....	12.20	12.10	3.80	3.40	3.40	.....	10.80
Washington:										
Youngstown (Seattle)	18.70	10.00	19.80	9.70	14.00	.....	.....	.....	15.80	13.40
West Virginia:										
Parkersburg	12.60	12.20	.....	11.20	14.50	5.25	4.95	5.25	16.80	.....
Wisconsin: Milwaukee	10.80	7.60	8.00	7.20	9.90	4.10	4.30	4.30	15.00	10.80

Note: All rates are per net ton of 2,000 pounds. Rates furnished by the Interstate Commerce Commission, Apr. 5, 1932, except from Salida, Colorado, which were supplied August 10, 1937.

RATES ON FLUORSPAR.

New Mexico			Ports of Entry								
Engle	Hatch	Mesilla Park	Baltimore	Buffalo	Los Angeles	Mobile	New Orleans	New York	Philadelphia	San Francisco	Seattle
$10.20	$10.20	$10.20	$12.00	$12.80	.....	$2.90	$8.00	$13.00	$12.40	.....	.....
8.00	8.00	8.40	.....	.....	.....	.....	.....	.....	.....	$7.70	$14.10
8.00	8.00	8.40	.....	.....	$7.70	.....	.....	.....	.....	.....	9.30
3.15	3.15	3.15	14.00	12.80	11.25	16.40	16.40	14.60	14.40	11.25	22.00
.....	.....	11.40	2.80	5.60	.....	.....	.....	3.40	1.24	.....	.....
.....	.....	10.20	10.60	13.10	.....	8.00	9.40	11.60	11.20	.....	.....
8.00	8.00	8.00	6.16	6.00	13.20	6.20	6.20	6.70	6.34	13.20	27.40
8.40	8.40	8.40	7.30	7.40	13.20	4.02	4.02	7.84	7.48	13.20	26.00
.....	.....	8.40	6.83	6.80	.....	[a]10.00 [b] 8.60	[a]10.00 [b] 8.60	7.37	7.01	.....	.....
8.00	8.00	8.00	6.16	6.00	13.20	[a]9.00 [b]7.60	[a]9.00 [b]7.60	6.70	6.34	13.20	27.40
.....	.....	10.20	5.70	5.80	.....	5.54	5.54	6.23	5.87	.....	.....
.....	.....	10.20	5.76	5.60	.....	12.20	12.80	6.29	5.94	.....	.....
.....	.....	10.20	5.49	5.40	.....	12.20	13.00	6.03	5.67	.....	.....
.....	.....	10.20	4.96	5.40	.....	12.20	12.80	5.49	5.13	.....	.....
.....	.....	10.20	5.29	5.40	.....	[a]7.30 [b]5.90	[a]7.30 [b]5.90	5.83	5.47	.....	.....
.....	.....	11.40	.....	5.60	.....	.....	.....	4.20	1.69	.....	.....
.....	.....	10.20	4.69	4.40	.....	.....	14.40	5.22	4.87	.....	.....
.....	.....	8.40	9.40	7.80	.....	.....	[a]13.00 [b]11.50	9.60	9.60	13.20	.....
5.00	5.00	5.00	9.20	8.20	13.20	[a]7.20 [b]7.20	[a]7.20 [b]7.20	9.80	9.60	13.20	25.00
8.40	8.40	8.40	7.30	7.40	13.20	[a]10.50 [b]9.10	[a]10.50 [b]9.10	7.84	7.48	13.20	26.00
.....	.....	10.20	3.66	.....	.....	.....	.....	3.66	3.66	.....	.....
.....	.....	11.40	2.81	.....	.....	.....	.....	.....	2.25	.....	.....
.....	.....	10.20	4.22	3.60	.....	13.60	14.60	4.76	4.40	.....	.....
.....	.....	10.20	4.69	4.80	.....	12.80	13.60	5.22	4.87	.....	.....
.....	.....	10.20	4.55	4.60	.....	13.20	14.00	4.96	4.73	.....	.....
10.20	10.20	10.20	3.96	3.60	15.00	14.20	14.80	4.49	4.13	15.00	30.20
7.60	7.60	7.60	13.20	.....	20.50	.....	9.80	13.60	13.60	20.50	26.00
5.35	5.35	5.35	13.20	.....	20.20	.....	9.80	13.60	13.60	20.20	26.00
.....	.....	10.56	4.60	4.60	.....	.....	.....	5.20	4.80	.....	.....
.....	.....	.....	3.48	.....	.....	.....	.....	4.02	3.66	.....	.....
.....	.....	.....	1.69	.....	.....	.....	.....	3.00	.....	.....	.....
10.20	10.20	10.20	3.48	4.40	15.00	14.40	14.80	4.02	3.66	15.00	30.20
.....	.....	.....	2.40	.....	.....	.....	.....	4.40	2.93	.....	.....
10.20	.....	10.20	10.80	.....	14.40	8.80	9.40	11.80	11.20	.....	.....
13.20	13.20	13.20	.....	30.20	14.10	.....	.....	.....	.....	9.30	.....
.....	10.20	10.20	4.15	5.20	15.00	13.20	14.20	4.69	4.33	.....	.....
8.40	.....	8.40	6.16	6.00	13.20	[a]9.00 [b]7.60	[a]9.00 [b]7.60	6.70	6.34	13.20	27.40

[a] Applies on traffic from Panama Canal Zone, Cuba, insular possessions of U. S., all foreign countries except Canada, Newfoundland, Island of Miquelon, and St. Pierre, Europe, and Africa.
[b] Applies on all traffic from all foreign countries except as provided in footnote (a).

resentatives of the larger consumers were stationed at the mines for the sole purpose of seeing that their companies were shipped their proper quota. Under stress of these conditions domestic production and price of fluorspar increased to record heights.

Even after the war, when increased imports of foreign spar appeared in domestic markets, prices did not return to former levels. Many factors have contributed to higher prices since the war. Wholesale commodity prices in general were 50 per cent higher in 1926 than in 1913; also labor costs had increased. Such advances in cost of labor and supplies, moreover, have been enlarged in the total cost of the finished product, as the grade of crude domestic ore has generally been lower since the war.

Local changes in costs of production may also affect price levels. Because competition is keen in the industry, sporadic production of fluorspar that can be mined and sold profitably at a lower price than that from established sources of supply may be offered to consumers at price concessions to get the business. Such a condition naturally forces down all prices, as each operator desires to obtain his share of the trade. Under normal conditions the market for metallurgical fluorspar is a buyers' market, with the purchasing agents generally cracking the whip in regard to prices, specifications, and terms of sale and delivery. With any change in world conditions curtailing imports, the market, as during the World War, becomes a sellers' market, and the seller can dictate prices, specifications, and terms of sale.

Market quotations in the Pittsburgh district usually set the price level for metallurgical fluorspar in the United States because this region is both a leading market and the meeting ground of domestic and foreign material. Based on Pittsburgh transactions, price quotations are made on domestic fluorspar

Table 12.—Quoted Prices per Short Ton of Fluxing-gravel Fluorspar in the United States, 1932-1936.

Month	Illinois–Kentucky (f. o. b. mines)				
	1932	1933	1934	1935	1936
January	$15.00	$ 9.00	$15.00	$13.00	$17.00
February	15.00	10.25	15.50	13.00	17.50
March	14.00	9.00	16.00	13.00	17.00–18.00
April	12.50	9.75	17.00	13.00	18.00
May	11.50	11.75	17.00	13.00	17.00–18.00
June	11.25	12.25	17.00	13.00	17.50–16.50
July	10.25	14.00	15.00	13.00	17.00
August	10.25	14.50	16.00	14.00	17.00
September	9.50	14.75	16.00	14.00	18.00
October	9.75	14.50	16.00	14.50	18.00
November	9.00	15.00	16.00	16.00	18.00
December	9.00	15.75	15.00	16.00	18.00

(Continued on p. 59)

f. o. b. the nearest shipping point to the mines or mills or f. o. b. at ports of entry. Location of deposit or country of origin is seldom a factor to the buyer except that experience may have associated certain definite desirable or objectionable qualities with material from a given source. Prices are based on the short ton and usually apply to material loaded in railway cars. In the Illinois-Kentucky district, however, prices are also quoted on spar loaded in barges for transportation on the Ohio River.

Prices quoted for small lots are generally somewhat higher than prices for large tonnages sold on contracts. Such transactions, negotiated usually by the producer or his sales agent and the purchasing agent of the consumer, may also involve price concessions contingent upon general industrial conditions, stocks on hand at consuming plants, and the current state of foreign supplies. Heavy stocks at the mines tend to depress prices and are always a threat to the general price level until liquidated.

Ground spar is quoted in bulk and bags or barrels. Table 12 gives monthly price quotations of fluxing-gravel fluorspar at Illinois-Kentucky mines and at seaboard from 1932 to 1936 inclusive. The actual average selling prices of all grades of domestic fluorspar sold from 1880 to 1936 are shown graphically in figure 12.

The value assigned to foreign fluorspar in table 7 is the foreign or export value, whichever is higher. The cost to consumers in the United States includes, in addition, the duty, loading charges at the docks, ocean freight, insurance and consular fee, and freight from docks to manufacturers' plants. Information concerning ocean freight and loading and other charges on fluorspar imported from the various countries into the United States is not available;

TABLE 12.—*Concluded.*

Month	Imported (at seaboard, duty paid)				
	1932	1933	1934	1935	1936
January	$17.00	$16.52–16.96	$18.50	$19.00	$20.00
February	17.00–17.40	16.52–16.96	18.50	19.00	20.00
March	17.00–17.40	16.52–16.96	18.50–19.00	19.00	20.00–21.50
April	17.00–17.40	16.52–16.96	19.00	19.00	21.50
May	17.00–17.40	16.07–16.96	19.00	19.00	21.50
June	17.00–17.40	16.07–16.96	19.00	19.00	21.50
July	16.00–17.40	16.07–16.96	19.00	19.00–18.50	21.50
August	16.00–16.75	17.86–18.30	19.00	18.50	21.50
September	16.00–16.75	18.08–18.53	19.00	18.50	21.50
October	16.00–16.75	18.08–18.53	19.00	18.50–20.00	22.00
November	16.00–16.75	18.08–18.53	19.00	20.00	22.00
December	16.00–16.75	18.08–18.53	19.00	20.00	22.00–23.00

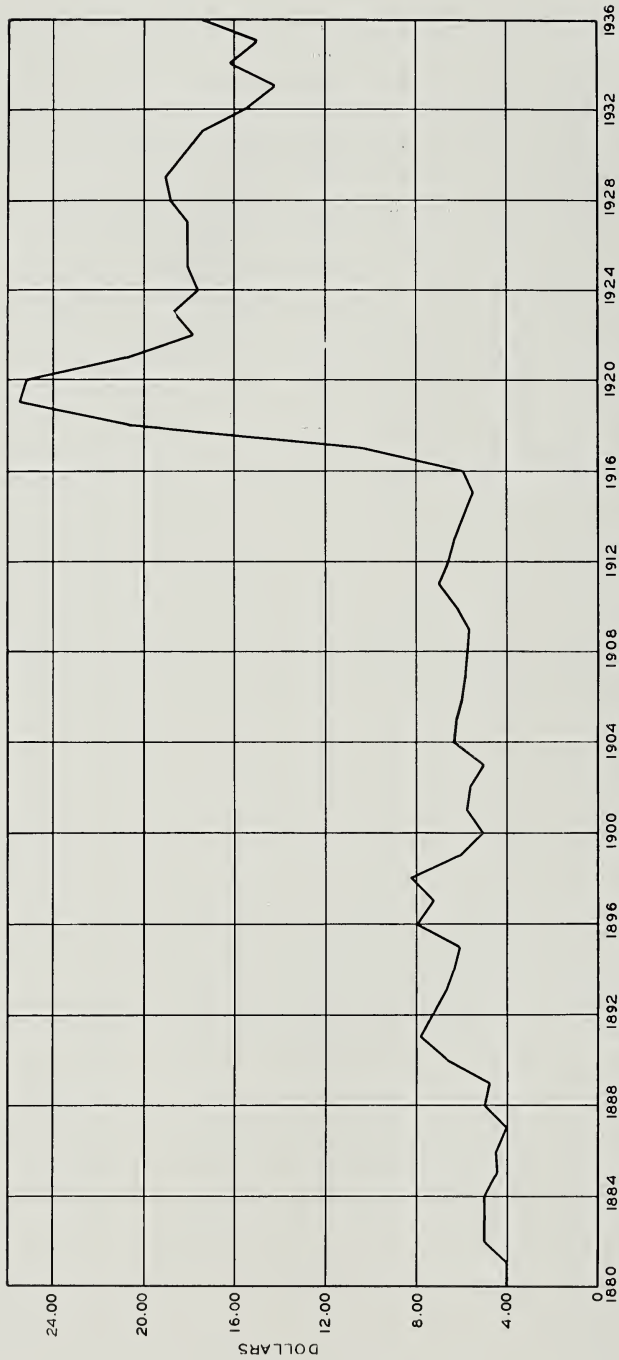

FIGURE 12.—AVERAGE PRICES PER TON OF FLUORSPAR AT MINES IN THE UNITED STATES, 1880-1936.

however, the detailed charges for a cargo of 200 long tons of metallurgical fluorspar shipped from St. Raphael, France, to the United States in 1930 were as follows:

Duty at $8.40 a long ton	$1,680.00
Ocean freight at $3.16 a ton	632.00
Insurance	5.00
Loading charges at 75 cents a ton	150.00
Consular fee	2.50
	$2,469.50

According to reports to the United States Bureau of Mines by importers, the selling price at tidewater, duty paid, of the imported fluorspar sold to steel manufacturers averaged $19.04 a short ton in 1936; the selling price at tidewater, duty paid, of imported ground fluorspar sold to manufacturers of glass and enamel averaged $27.53 a short ton; and the selling price of fluorspar sold for use in making hydrofluoric acid averaged $25.15.

TYPICAL CONTRACTS AND TERMS

Large consumers buy the bulk of their fluorspar on contract, generally covering a definite tonnage to be delivered within a stated time and specifying the minimum content of calcium fluoride and the maximum content of impurities that will be accepted. The contract generally includes penalties for excesses of impurities above the specified limits. Premiums are seldom paid for unusual purity. By mixing and grading, therefore, producers endeavor to ship a product containing the minimum calcium fluoride content specified and the maximum content of impurities tolerated.

In times of excessive competition, however, producers may ship material higher in grade than specified to maintain good will. Such practice of course amounts to a slight shading of price.

A sample contract form used by one of the important fluorspar agents is given on page 62.

Metallurgical gravel fluorspar is generally shipped in bulk in open-top cars, which may be dumped or unloaded with crane or clamshell bucket, or in barges, which also may be unloaded with crane or clamshell bucket. Acid-lump fluorspar is generally shipped in box cars. Ground fluorspar is shipped in bulk in box cars lined with heavy paper and packed in bags holding 125 pounds or in barrels holding 450 to 500 pounds. An extra charge is made for packing in bags and barrels, the amount depending on the nature of the container. Bags in good condition may be returned for repacking, when the usual allowance of 10 cents a bag is made. Freight on bags to the mine must be paid by consumer. Barrels are not returnable.

DISTRIBUTION METHODS

Much of the domestic fluorspar of commerce is sold through established sales agencies, who handle other raw materials used in the iron, steel, ceramic, and chemical industries and are thus in close contact with the consumers. Such sales agencies either operate their own mines or have contracts with producers whereby the producer agrees to supply and the sales agency agrees to handle the entire output of the producer. A sales agent may even be bound by contract to market only the products of a single operator.

ORIGINAL FLUORSPAR CONTRACT

issued from the office of

.....

No. .....

Buyer's No. .....

Date .....

Seller: .....

By: .....

Buyer: .....

Quantity: .....

Grade: .....

Price: Per ton of 2,000 lbs. $..... ..... f.o.b.....
Washed gravel and No. 2 lump fluorspar to average not less than 85% calcium fluoride and not more than 5% silica, the buyer to have the right to reject any shipment less than 80% calcium fluoride or more than 7% silica. On completion of contract the buyer may deduct 1/85th of the delivered price for each per cent of calcium fluoride less than 85%, but in determining calcium fluoride content, 2½% shall be added or subtracted therefrom for each per cent by which the silica content shall be less or more than 5%, and fractions in proportion.

Payment: Cash on 15th of each month, to....., for shipments during preceding calendar month. If the buyer fails to make any payment when due, ..., as such agent, shall have the right to cancel the contract or to postpone shipment of undelivered balances until prior shipments are paid for by buyer. Railroad weights, nearest shipping point of origin, shall govern both buyer and seller.

Shipment: .....

Route: Via.....
If shipment is to be made in installments, this contract for all purposes shall be treated as separate for each installment.
The seller shall not be liable in damages for failure to deliver caused by strikes, accidents or other causes beyond its reasonable control. The contract is completely set forth herein.

Not valid until accepted by an officer of..... Buyer .....

By ..... By .....

Buyer's Copy

Small producers who do not have selling connections and who are unable to guarantee a definite tonnage or to make delivery over a stated period generally find it difficult to sell direct to consumers. In the Illinois-Kentucky district, however, larger producers frequently purchase the product of their smaller neighbors.

Most of the fluorspar imported into the United States is handled by brokers, agents, or dealers who make selling contacts, negotiate contracts, and handle the detail of passing the fluorspar through the customs at the port of entry and on to the customer. Representatives of both domestic and foreign producers are commonly in close touch with purchasing agents of the larger consumers. All concerned are specialists in such commodity markets and each must have knowledge not only of the broader phases of production but also of the distribution of fluorspar to the various consuming industries.

DISTRIBUTION OF DOMESTIC CONSUMPTION

DISTRIBUTION BY GRADES

Commercial fluorspar is graded according to (1) purity as acid, ceramic, and metallurgical fluorspar and (2) particle size as lump, gravel and ground fluorspar. Distribution by purity of acid, ceramic, and metallurgical fluorspar from 1932 to 1936, is indicated in table 13.

TABLE 13.—CONSUMPTION OF FLUORSPAR IN THE UNITED STATES, 1932 TO 1936, BY PURITY.

Purity	1932		1933		1934		1935		1936	
	Short tons	Per cent of total	Short tons	Per cent of total	Short tons	Per cent of total	Short tons	Per cent of total	Short tons	Per cent of total
Acid.....	7,000	12.50	7,800	9.22	11,000	9.94	12,900	9.39	20,100	11.02
Ceramic....	9,500	16.96	10,300	12.17	11,500	10.40	16,100	11.72	17,400	9.54
Metallurgical	39,500	70.54	66,500	78.61	88,100	79.66	108,400	78.89	144,900	79.44
Total.....	56,000	100.00	84,600	100.00	110,600	100.00	137,400	100.00	182,400	100.00

During the 5-year period 1932-1936 acid fluorspar consumption ranged from 9.2 to 12.5 per cent of the total, ceramic fluorspar from 9.5 to 17.0 per cent, and metallurgical fluorspar from 70.5 to 79.4 per cent.

Distribution of domestic shipments from 1932 to 1936, according to purity and size, is shown in table 14.

Table 14 shows that 83 per cent of the fluorspar shipped from domestic mines during the five years 1932-1936 was of metallurgical grade and that during the same period 84 per cent of the total was gravel fluorspar. Distribution of acid, ceramic, and metallurgical fluorspar from domestic mines fluctuates considerably from year to year. During the 5-year period 1932-1936 shipments of acid fluorspar ranged from 1.3 to 7.2 per cent of the total, of ceramic fluorspar from 9.2 to 19.2 per cent, and of metallurgical fluorspar from 76.9 to 84.1 per cent.

TABLE 14.—DISTRIBUTION OF SHIPMENTS OF FLUORSPAR FROM MINES IN THE UNITED STATES, 1932-1936, BY PURITY AND SIZE, PER CENT.

Year	Purity				Size		
	Acid	Ceramic	Metal-lurgical	Miscel-laneous	Lump	Gravel	Ground
1932	2.9	19.2	76.9	1.0	5.1	75.8	19.1
1933	1.3	13.5	84.1	1.1	3.0	83.9	13.1
1934	1.9	11.6	84.1	2.4	3.7	86.5	9.8
1935	2.7	11.6	83.7	2.0	4.3	85.2	10.5
1936	7.2	9.2	81.7	1.9	6.8	83.4	9.3
Average	4.0	11.4	82.7	1.9	4.9	84.3	10.8

Table 15 shows the distribution of imported fluorspar for 1935 and 1936 (and the selling price at tidewater, duty paid). Data were compiled chiefly from information courteously furnished the United States Bureau of Mines by importers.

TABLE 15.—DISTRIBUTION OF FLUORSPAR IMPORTED INTO THE UNITED STATES, 1935-1936.

Industry	1935			1936		
	Short tons	Selling price at tidewater, including duty		Short tons	Selling price at tidewater, including duty	
		Total	Average		Total	Average
Steel	5,702	$102,635	$18.00	15,096	$287,454	$19.04
Glass	1,969	49,803	25.29	394	10,397	26.39
Enamel	920	24,447	26.57	544	15,428	28.36
Hydrofluoric acid	7,715	189,794	24.60	8,883	223,419	25.15
Total	16,306	366,679	22.49	24,917	536,698	21.54

In 1931 a striking change occurred in the relative distribution of fluorspar imported into the United States. Previous to that year the steel industry had been the chief purchaser of foreign fluorspar, but since 1931 this industry has accounted for less than one-half of the total imports.

DISTRIBUTION BY INDUSTRIES

BASIC OPEN-HEARTH STEEL

Purpose—Fluorspar is used as a flux or slag conditioner in the basic open-hearth process of steel making. It is added to the furnace charge in the form of gravel to increase the fluidity of the slag, to assist in the purification of the molten metal, and to decrease the time necessary for producing steel from the metallic charge.

Extent of market—Formerly about 80 per cent of the fluorspar mined in the United States and 80 to 90 per cent of that imported was used in the steel

industry, chiefly in the basic open-hearth process. Since 1931, however, chiefly due to the low rate of steel operations and increased duty, only about 45 per cent of the total spar imported was sold as fluxing spar.

Shipments of fluorspar from domestic sources to steel plants from 1922 to 1936 are shown in table 16.

TABLE 16.—FLUORSPAR SHIPPED FROM DOMESTIC MINES FOR USE IN THE MANUFACTURE OF STEEL, 1922-1936.

Year	Short tons	Average value	Year	Short tons	Average value
1922	122,403	$16.24	1929	118,904	$17.08
1923	96,713	18.23	1930	76,837	16.13
1924	104,349	17.72	1931	39,832	14.16
1925	91,760	16.16	1932	18,881	12.13
1926	105,614	16.51	1933	60,279	12.77
1927	93,196	16.35	1934	70,672	15.03
1928	108,064	15.19	1935	101,168	13.77
			1936	141,618	16.22

Table 17 shows the total consumption of fluorspar in basic open-hearth steel furnaces, the consumption of fluorspar per ton of steel, and the stocks at steel plants from 1922 to 1936, inclusive.

The principal feature of this table is the almost gradual decrease in amount of fluorspar used per ton of steel until 1933. In 1934, however, the quantity increased considerably, but tended downward again in 1935 and 1936.

Table 18 shows the variation in average consumption of fluorspar per ton of basic open-hearth steel, over a period of five years, in plants that make about 88 per cent of the total.

The cost of fluorspar is a relatively small item in the total cost of making a ton of steel. In the Chicago district, for example, the average cost at all plants of fluorspar used in the production of a ton of steel in 1936 was about 5.6 cents, based on $16.50 a ton for fluorspar at Illinois-Kentucky mines, $3.50 for freight to Chicago, and $1.50 for handling, interest, and other charges. Similarly, the cost of fluorspar per ton of steel in the Pittsburgh district was about 6.1 cents. All-rail freight to Pittsburgh is figured at $5.25 a ton.

It is evident that even major fluctuations in the market price of fluorspar have a very slight effect upon the total cost of making a ton of steel.

Steel ingots and castings are produced by the several processes known as basic open-hearth, acid open-hearth, Bessemer, crucible, and electric, depending upon the type of furnace used. In the United States about 90 per cent of all steel ingots and castings produced in 1936 was by the basic open-hearth process.

Domestic production of steel ingots and castings by the basic open-hearth process, from 1898 to 1936, is shown in table 19.

Figure 3, page 10, shows graphically the rapid growth in the output of basic open-hearth steel and its relationship to the fluorspar industry.

Utilization in steel.—In the basic open-hearth furnace limestone is spread upon the bottom, the metallic charge is added, and the heat is started. As the charge melts the limestone rises to the top and floats on the surface of the molten bath. Fluorspar may be added at this stage in amounts usually not less than 6 pounds per ton of steel or 200 to 600 pounds per heat; it is shoveled into the furnace by hand as needed according to the judgment of the furnace operator or helper.

TABLE 17.—CONSUMPTION AND STOCKS OF FLUORSPAR AT BASIC OPEN-HEARTH STEEL PLANTS, 1922-1936.

Year	Consumption of fluorspar in basic open-hearth steel plants (Short tons)	Consumption of fluorspar per ton of steel (Pounds)	Stocks of fluorspar on hand at end of year (Short tons)	Year	Consumption of fluorspar in basic open-hearth steel plants (Short tons)	Consumption of fluorspar per ton of steel (Pounds)	Stocks of fluorspar on hand at end of year (Short tons)
1922	104,000	7.4	65,000	1929	155,600	6.6	70,700
1923	140,000	8.1	49,900	1930	109,000	6.3	89,000
1924	119,800	7.8	64,000	1931	66,200	6.0	67,600
1925	137,700	7.4	49,400	1932	36,300	6.2	55,000
1926	142,000	7.2	70,000	1933	61,300	6.1	56,000
1927	138,000	7.4	85,000	1934	81,000	6.9	45,500
1928	152,000	7.0	76,000	1935	99,600	6.5	47,500
				1936	133,900	6.1	59,200

TABLE 18.—AVERAGE CONSUMPTION OF FLUORSPAR PER TON OF STEEL BY VARIOUS STEEL PLANTS, 1932-1936, IN POUNDS.

1932	1933	1934	1935	1936	1932	1933	1934	1935	1936
14.176	18.944	14.443	13.243	13.187	5.302	5.659	7.488	7.048	6.734
4.572	3.864	4.766	4.182	4.792	6.646	6.754	6.584	9.347	10.495
5.122	4.687	5.141	4.803	4.541	6.056	8.148	9.820	8.168	5.104
6.136	5.731	9.958	8.452	10.519	6.356	5.386	5.900	5.236	5.027
6.281	6.871	6.195	7.027	4.105	6.118	6.590	6.429	6.764	6.357
5.171	5.858	5.768	5.658	5.160	6.260	6.099	6.780	5.257	5.917
6.842	4.289	5.046	6.857	7.416	5.366	6.601	7.348	7.088	6.671

TABLE 19.—PRODUCTION OF BASIC OPEN-HEARTH STEEL INGOTS AND CASTINGS, 1898-1936.

Year	Long tons	Year	Long tons
1898	1,569,412	1917	32,087,507
1899	2,080,426	1918	32,476,571
1900	2,545,091	1919	25,719,312
1901	3,618,993	1920	31,375,723
1902	4,496,533	1921	15,082,564
1903	4,734,913	1922	28,387,171
1904	5,106,367	1923	34,665,021
1905	7,815,728	1924	30,719,523
1906	9,658,760	1925	37,087,342
1907	10,279,315	1926	39,653,315
1908	7,140,425	1927	37,144,268
1909	13,417,472	1928	43,200,483
1910	15,292,329	1929	47,232,419
1911	14,685,932	1930	34,268,316
1912	19,641,502	1931	22,130,398
1913	20,344,626	1932	11,742,682
1914	16,271,129	1933	20,057,146
1915	22,308,725	1934	23,440,000
1916	29,616,658	1935	30,447,000
		1936	43,615,000

FIGURE 13.—BASIC OPEN-HEARTH STEEL FURNACE BEING CHARGED WITH MOLTEN IRON.

In figure 13, molten iron is being poured into a basic open-hearth furnace. Piles of miscellaneous fluxing materials, such as fluorspar, are shown on the charging floor.

The chemical reactions that occur when fluorspar is used in steel making are not well understood, and authorities differ not only as to the chemical reactions but also as to the rôle fluorspar plays in smelting and the nature of the results obtained. One authority states that the chief functions of the fluorspar are to render the slag fluid enough to hasten the transfer of heat from the flame to the steel beneath the slag, which reduces the time or duration of the heat, and to enable the slag to flow readily when the furnace is tapped. Many open-hearth slags when tapped are only partly liquid. Fluorspar lowers the melting point of the solid portion of the slag to an extent depending upon the amount added and therefore renders it more fluid.

Fluorspar is also held to eliminate sulfur through volatilization from the slag. The importance of this is in question, however, and Schwerin[18] has made an excellent review of this problem. Fluorspar is also believed to be an effective agent in removing phosphorus from the molten metal, although calcium is regarded as the chief phosphorus remover.

At some furnaces fluorspar is added from the time the lime has risen from the bottom to the surface of the bath until the heat is tapped and sometimes shortly before tapping. One authority states, however, that fluorspar, when used, should be added shortly after the open-hearth charge is melted and all the lime has risen from the bottom. The fluorspar is introduced in varying amounts only if the slag contains an excessive amount of free lime or is too viscous. If one addition does not bring about the desired fluidity or fusion of free lime another addition of like amount is made. However, fluorspar is never added within one-half hour prior to tapping of the heat, a precaution taken to guard against the possibility of fluorides entering the finished product as a result of reactions between calcium fluoride in the slag and certain elements in the metal.

Good steel can be made without fluorspar, but the benefits gained by its use far outweigh the few cents cost per ton of steel, and fluorspar will doubtless maintain its favor among steel men for many years to come.

Although fluorspar is used at all basic open-hearth steel plants it is not used in all furnace heats. Fluorspar is not required where considerable iron ore must be added to eliminate carbon, as in such heats the oxide of iron in the slag insures enough fluidity. For high-manganese pig iron less fluorspar is needed than for ordinary pig iron. Also, less fluorspar is required when steel is made by the duplex process. On the other hand, considerably more fluorspar is usually necessary when dolomite, which may make a viscous slag, is used instead of limestone, or when scrap, which requires a high-lime charge, is the chief furnace burden instead of pig iron; therefore, the average quantity of fluorspar used per ton of basic open-hearth steel varies widely among the various steel plants, usually ranging from 1 to 50 pounds. In general, the average is 5 to 8 pounds of fluorspar per ton of steel, or a very small proportion of the furnace charge.

Chemical specifications.—Most basic open-hearth steel manufacturers specify that fluorspar shall analyze not less than 85 per cent calcium fluoride, not more than 5 per cent silica, and not more than 0.3 per cent sulfur. However, fluorspar carrying as little as 80 per cent calcium fluoride and 6 to 7 per cent silica is sometimes accepted, especially by western steel plants, and some consumers do not

[18] Schwerin, L., Metals and alloys, vol. 5, pp. 61-66, 83-88, 118-123, 1934.

object to a larger amount of sulfur. As a rule, content of other elements is not guaranteed, but the consumer prefers the absolute minimum of lead and zinc. Representative analyses of fluorspar used in steel plants appear in table 20.

TABLE 20.—ANALYSES OF GRAVEL FLUORSPAR USED IN STEEL PLANTS, PER CENT.

CaF_2	SiO_2	$CaCO_3$	Fe_2O_3	Al_2O_3	S	$BaSO_4$
86.59	4.83	7.70	0.40	0.43	Trace	Trace
87.50	4.00	7.20	.60	.55	.12	.....
86.70	4.80	7.50	.....	.....	.....	.....
88.92	3.07	1.23	.....	1.96	.....	4.16
87.80	3.10	.....	3.06		.....	.....

A minimum of silica is specified because, as generally computed, one part of silica requires 2½ parts of fluorspar to flux it; a fluorspar containing 85 per cent calcium fluoride and 5 per cent silica would be equivalent to 72½ units of net calcium fluoride. With some manufacturers a sliding scale is acceptable, and for each 2½ units of calcium fluoride above 85 per cent the silica is allowed to go up 1 point. A fluorspar containing 87½ per cent calcium fluoride and 6 per cent silica is therefore equivalent to one containing 85 per cent calcium fluoride and 5 per cent silica; however, when the fluorspar contains less than 72½ units of net calcium fluoride the contract usually provides for an adjustment in price, as shown by the first paragraph of the sample contract form on page 62.

Physical requirements.—Manufacturers of basic open-hearth steel generally require that fluorspar be in the form of gravel, all of which will pass through a 1-inch square opening; the fines are to be not less than 15 per cent of the total. However, variation in size requirements is not uncommon, and fluorspar in lumps several inches in diameter is sometimes used. A screen analysis of typical gravel fluorspar is given in table 21.

TABLE 21.—SCREEN ANALYSIS OF GRAVEL FLUORSPAR[1].

Opening, inches	Mesh	On or between sieves, percent	Total Percentage		Opening, inches	Mesh	On or between sieves, percent	Total Percentage	
			On	Passing				On	Passing
0.371	..	6.25	6.25	93,75	0.0328	20	8.33	64.78	35.22
0.263	3	11.62	17.87	82.13	0.0232	28	7.30	72.08	27.92
0.185	4	8.61	26.48	73,52	0.0164	35	9.62	81.70	18.30
0.131	6	6.41	32.89	67.11	0.0116	48	8.07	89.77	10.23
0.093	8	6.91	39.80	60.20	0.0082	65	4.48	94.25	5.75
0.065	10	8.34	48.14	51.85	0.0058	100	3.28	97.53	2.47
0.046	14	8.31	56.45	43.55					

[1] These data are averaged from four typical screen analyses of No. 2 gravel. By courtesy of the Rosiclare Lead & Fluorspar Mining Co.

Too great a percentage of fines or dust is objectionable because it may be lost in the furnace draft or it settles reluctantly in the molten bath. On the other hand, material one-half to 1 inch in size may not be assimilated readily by the slag; therefore, the bulk of the material should be under one-half inch to about 48-mesh.

Objectionable impurities.—In basic open-hearth steel practice calcium carbonate is the least objectionable impurity in fluorspar because calcium carbonate is itself a flux; however, it is uneconomical to buy limestone at fluorspar prices. Silica is much more objectionable because it requires a certain amount of fluorspar or limestone to flux it and to preserve the necessary basicity of the slag.

The sulfur content must be as low as possible, usually less than 0.3 per cent. Sulfur may be derived from any zinc or iron sulfides (sphalerite or pyrite) or from barite ($BaSO_4$) present in the ore. Such impurities should be (and usually are) eliminated from the fluorspar product during the milling process. Barite is probably objectionable more because it is a diluent than because of its sulfur content. Sulfur is very objectionable in steel, but its importance as an impurity in fluorspar is often over-emphasized. As only a fraction of 1 per cent of spar is actively employed, no appreciable quantity of sulfur would be added to the finished metal even though the fluorspar contained as much as 5 per cent of barite.

Basic open-hearth steel markets.—Approximately 78 per cent of the fluorspar sold in the United States in 1936 was shipped to 100 basic open-hearth steel plants in 24 States. Most of these plants, however, are in the eastern part of the United States and are more or less centralized in certain well-known districts.

The six specific market areas for metallurgical fluorspar in basic open-hearth steel plants in the eastern United States follow.

1. The Pittsburgh-Johnstown-Steubenville-Butler area, which in 1936 consumed 32,500 short tons of fluorspar (24.3 per cent of the total consumed in basic open-hearth steel plants). Steel plants in this region comprise the largest single market in the United States. Of the 32,500 tons consumed in this area in 1936, 22,100 tons were used in the Pittsburgh district.
2. The Youngstown-Canton-Farrell area, which in 1936 consumed 19,200 short tons of fluorspar (14.3 per cent).
3. The Harrisburg-Philadelphia-Claymont-Baltimore area, which in 1936 consumed 15,000 short tons of fluorspar (11.2 per cent).
4. The Cleveland-Lorain area, which in 1936 consumed 7,400 short tons of fluorspar (5.5 per cent).
5. The Buffalo area, which in 1936 consumed 5,600 short tons of fluorspar (4.2 per cent).
6. The Bridgeport-Phillipsdale-Worcester area, which in 1936 consumed 1,100 short tons (0.8 per cent).

Thus, the steel plants in the above areas consumed 80,800 short tons of fluorspar in 1936, (60.3 per cent of the total consumed in the basic open-hearth steel industry).

Costs of production and transportation limit the markets in which sellers of fluorspar can profitably compete; the import duty further limits the markets for imported fluorspar. The cost of producing fluorspar in France, Germany, Newfoundland, and Spain (the principal countries which now export to the

United States), is relatively much lower than in the Illinois-Kentucky district. Fluxing grade fluorspar imported from these sources, notwithstanding a duty of $7.50 a short ton, is sold in western Pennsylvania and to a smaller extent in eastern Ohio and the Panhandle of West Virginia in competition with that from the Illinois-Kentucky district. Previous to 1931 the market in this area was divided between domestic and imported fluorspar. Since 1931, however, the greater part of the fluorspar sold in this area has come from the Illinois-Kentucky district.

Since basic open-hearth steel plants near the Atlantic coast in eastern Pennsylvania, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, and Maryland are farther from domestic mines and relatively nearer to the ports of entry for imported spar, the greater part of the spar sold to steel plants in this area comes from foreign sources. In 1936 about 16,000 short tons of fluorspar were consumed by basic open-hearth steel plants in this area.

In the Middle West the chief markets for fluorspar are at steel plants in the Chicago district (which includes Gary and Indiana Harbor, Indiana); the St. Louis district (which includes Granite City and Alton, Illinois); Peoria, Illinois; Kokomo, Indiana; Duluth, Minnesota; and Kansas City, Missouri. The total consumption in this area in 1936 amounted to 30,800 short tons (23 per cent of the total consumed in basic open-hearth steel).

The Chicago district, the largest market in the Middle West, consumed 22,400 short tons of fluorspar in 1936 (16.7 per cent of the total consumed in the basic open-hearth steel industry). In fact, the consumption of metallurgical fluorspar in this district in 1936 slightly exceeded the consumption of fluorspar in steel plants located strictly in the Pittsburgh district.

The second largest market in the Middle West is the St. Louis district, which in 1936 consumed 4,000 short tons of fluorspar. Although the consumption of fluorspar in basic open-hearth steel plants at Kansas City, Kokomo, Peoria, and Duluth aggregated 4,400 short tons in 1936 the consumption at each locality is comparatively small, ranging from 600 to 1,600 tons.

In general, all fluorspar used in steel plants in Illinois, Indiana, Minnesota, and St. Louis, Missouri, is from the Illinois-Kentucky district, although some fluorspar from the Colorado-New Mexico district is used in steel plants in these areas. Most of the fluorspar used at Kansas City is from the Colorado-New Mexico district.

In the South important markets for fluorspar are Birmingham and Alabama City, Alabama, and Atlanta, Georgia. This area consumed 4,500 short tons of fluorspar in 1936 (3.4 per cent of the total consumed in the basic open-hearth steel industry). All the fluorspar sold in this market is from the Illinois-Kentucky district.

In the West the largest market for fluorspar is the steel works in Pueblo, Colorado, which obtains its supply chiefly from Colorado. On the Pacific coast the chief consumers of fluorspar are the steel plants at Los Angeles, San Francisco, Pittsburg, and Torrance, California; and Youngstown, Washington. The quantity consumed annually is comparatively small and is supplied mainly by mines in New Mexico and Nevada and by imported fluorspar, chiefly from Germany and Spain.

In 1936 the total consumption of metallurgical fluorspar in the West, including the Pacific coast, was 5,500 short tons (4.1 per cent of the total consumed in the basic open-hearth steel industry).

Other important markets are Dearborn and Ecorse, Michigan; Ashland and Newport, Kentucky; and Mansfield, Middletown, and Portsmouth, Ohio. Smaller markets are Lima, Marion, and South Columbus, Ohio; Sand Springs, Oklahoma; South Milwaukee, Wisconsin; and Bettendorf, Iowa. In 1936 the total consumption of fluorspar in basic open-hearth steel plants at Lima, Mansfield, Marion, Middletown, Portsmouth, and South Columbus, Ohio, and Ashland and Newport, Kentucky was 7,800 short tons.

Stocks.—Steel companies generally keep several months' supply of fluorspar in stock at their plants. At the end of 1936, for example, 59,200 tons of spar, equivalent to 44 per cent of the 1936 consumption in basic open-hearth steel plants, was so reported. Based on the amount consumed in 1936 this amount was sufficient to last over 5 months. Such a large tonnage represents a considerable investment, and the interest charges are correspondingly high. On the other hand, this insures consumers against sudden fluctuations in supply and price, enabling them to take advantage of price declines and to buy when general market conditions are most favorable.

Table 17, page 66, shows stocks of fluorspar at basic open-hearth steel plants and the annual consumption of fluorspar at these plants from 1922 to 1936, inclusive. During this period stocks at the steel plants have averaged nearly a 7-month supply for the furnaces.

ELECTRIC-FURNACE STEEL

Metallurgical-grade fluorspar is used in certain electric-furnace plants, chiefly in making alloy steels. It is used in the same manner as in the basic open-hearth furnace but by no means as universally. The quantity of spar used by individual plants per ton of steel ranges from a few pounds to 50 pounds. The general average is about 20 pounds. Electric furnaces for steel manufacture provided a market for about 4 per cent of the fluorspar sold in 1936.

TABLE 22.—CONSUMPTION OF FLUORSPAR AT ELECTRIC-FURNACE STEEL PLANTS, 1927-1936, SHORT TONS.

Year	Consumption	Year	Consumption
1927	4,700	1932	2,100
1928	6,100	1933	3,400
1929	6,500	1934	4,300
1930	3,600	1935	5,400
1931	3,100	1936	6,900

Chemical requirements are generally the same as those for basic open-hearth furnaces. Special nut size (one-half to 1 inch and free from fines) is usually required. However, variation in size is not uncommon.

The chief markets afforded by electric-furnace steel plants are in Illinois, Ohio, New York, and Pennsylvania; plants in these States consumed 89 per cent of the total fluorspar consumed in electric-furnace steel plants in 1936. The largest consumers of fluorspar in the manufacture of electric-furnace steel also manufacture steel by the basic open-hearth process. In fact, 63 per cent of the total fluorspar consumed in electric-furnace steel plants (table 22) in 1936 was used by manufacturers who also made basic open-hearth steel.

FERRO-ALLOYS

Fluorspar is used to a small extent as a flux in making ferro-alloys by the electric-furnace process. For this purpose a fluorspar comparatively high in calcium fluoride and low in silica is usually required. It should be fine enough to insure good distribution in the furnace.

The average quantity of fluorspar used per ton of ferro-alloys varies widely and irregularly from year to year and depends greatly upon the nature of the alloys. For instance, in 1936 the average consumption at different plants ranged from 0.7 pound to 260 pounds and in 1927 from 1.2 to 190 pounds. The chief markets are at Niagara Falls, New York, Keokuk, Iowa, and Langeloth and Bridgeville, Pennsylvania. Consumption and stocks from 1927 to 1936 follow.

TABLE 23.—CONSUMPTION OF FLUORSPAR IN THE MANUFACTURE OF FERRO-ALLOYS AND STOCKS, 1927-1936, SHORT TONS.

Year	Consumption	Stocks	Year	Consumption	Stocks
1927	500	100	1932	200	100
1928	800	400	1933	300	200
1929	1,100	200	1934	500	200
1930	1,100	300	1935	700	300
1931	300	200	1936	800	200

FOUNDRIES

The function of fluorspar in iron foundries is also that of a flux. It is valuable chiefly in the production of the finer grades of castings, such as automobile cylinders and blocks, and in heating and plumbing equipment. The market consumes only about 1 per cent of the fluorspar used annually in the United States. Most of the larger foundries using fluorspar are in Illinois, Indiana, Michigan, and New York. Shipments from domestic mines to foundries from 1922 to 1936 follow.

TABLE 24.—FLUORSPAR SHIPPED FROM DOMESTIC MINES FOR USE IN FOUNDRIES, 1922-1936.

Year	Short tons	Average value	Year	Short tons	Average value
1922	2,998	$19.02	1929	3,498	$19.93
1923	3,748	21.20	1930	2,209	18.69
1924	7,138	22.35	1931	1,123	16.10
1925	6,275	19.31	1932	524	14.57
1926	6,212	19.55	1933	1,039	13.27
1927	4,533	18.69	1934	1,489	15.99
1928	3,694	17.93	1935	2,336	12.44
			1936	2,326	15.79

In foundry practice a small quantity of fluorspar helps to melt the lime accumulation at the air inlets, to produce a more liquid slag, and to promote the removal of such impurities as phosphorus and sulfur from the iron. It may be added in the cupola or in the ladle before the molten iron is poured and has

particular value for continuous melting practice and for handling iron having a relatively high sulfur content. If fluorspar is used in the cupolas the charge melts more rapidly and with a thinner slag; and the iron can be maintained at a higher temperature, which results in sharper castings. It is reported that 3 per cent by weight of ground fluorspar placed in the bottom of the ladle slags off the impurities and thus produces a more malleable iron with greater tensile strength. Cleaner castings are also obtained. The quantity of fluorspar used in cupolas varies considerably but probably averages 15 to 20 pounds per ton of metal.

Chemical requirements for cupola use are virtually the same as those for basic open-hearth steel practice, although fluorspar containing as little as 82 per cent of calcium fluoride and as much as 8 per cent silica is sometimes accepted. Typical analyses of fluorspar used in cupolas follow.

TABLE 25.—ANALYSES OF FLUORSPAR USED IN CUPOLAS, PER CENT.

CaF_2	SiO_2	$CaCO_3$
87.0	4.5	7.5
88.5	4.3	6.0
92.0	3.5	3.67
82.0	8.0	1.3
88.4	4.0	7.1

Fluorspar for cupola use is usually sold in lumps from nut size to about 12 inches in diameter. However, variation in size requirements is not uncommon, as fluorspar of gravel size and ground material are sometimes used.

Consumption and stocks of fluorspar in foundry practice from 1927 to 1936 are shown in the following table. Special attention is directed to the decline in consumption during the last few years.

TABLE 26.—FLUORSPAR CONSUMED AND IN STOCK AT FOUNDRIES, 1927-1936, SHORT TONS.

Year	Consumption	Stocks	Year	Consumption	Stocks
1927	3,400	1,000	1932	600	500
1928	3,300	1,000	1933	900	600
1929	2,700	700	1934	1,600	500
1930	1,600	800	1935	1,900	800
1931	1,000	600	1936	1,900	700

OTHER METALLURGICAL USES

Small quantities of fluorspar are used in other metallurgical operations, such as the production of nickel and monel metal, reducing aluminum, smelting refractory ores of gold, silver, and copper, refining lead and silver, and extracting various rare metals from their ores. The quality and size of fluorspar depend on the particular use. For instance, in the production of nickel and monel metal a lump fluorspar high in calcium fluoride and absolutely free from lead is required. In reducing aluminum a ground fluorspar showing by analysis 98.5 per cent calcium fluoride, 0.62 per cent silica, and 0.74 per cent calcium carbonate is generally used.

Although nonferrous smelters afford a comparatively small market for fluorspar, the gain in shipments from 868 tons in 1935 to 1,931 tons in 1936 was noteworthy.

GLASS

Purpose—Fluorspar is used in the manufacture of opal or opaque glass and colored glass. It provides a source of fluorine which is regarded as essential or desirable in the manufacture of such glass products as lamp globes, shades, bulbs, soda fountain tops and accessories, table and counter tops, liners for fruit jars, containers for toilet and medicinal preparations, tableware, novelties, and bars and rods for lavatories.

Extent of market—The glass industry is not a large market for fluorspar on a tonnage basis. Shipments of fluorspar from domestic mines for use in glass manufacture from 1924 to 1936 follow.

TABLE 27.—FLUORSPAR SHIPPED FROM DOMESTIC MINES FOR USE IN GLASS MANUFACTURE, 1924-1936.

Year	Short tons	Average value	Year	Short tons	Average value
1924	6,094	$35.16	1930	3,158	$32.92
1925	6,767	31.23	1931	5,279	30.74
1926	7,507	32.01	1932	3,596	28.30
1927	5,968	30.91	1933	6,778	21.83
1928	6,499	30.14	1934	7,343	22.77
1929	5,742	31.98	1935	10,256	22.22
			1936	11,014	24.27

Utilization.—Material for the glass and enamel trades commonly brings a much higher price than that for the metallurgical industry because rigid specifications require not only a purer product but much more care in preparing fluorspar for these trades. From 50 to 500 pounds of pulverized or ground fluorspar are used for each 1,000 pounds of sand in the glass batch. Pot glasses making extremely rich dense opals may use as much as 500 pounds of spar, but this does not represent the bulk of glass made. When as little as 50 pounds of spar is used the fluorine content of the batch is built up further with cryolite. This market for fluorspar depends upon the popularity of opal glass, which normally is strong. Substitutes are not a serious threat to fluorspar, although experiments with other materials are carried on from time to time.

Fluorspar is not ordinarily bought on general specifications because of the rather limited number of companies from which it is purchased. The following notes, however, indicate the approximate requirements for spar used in the glass trade.

Chemical specifications.—Usual specifications as to content are that the fluorspar shall contain not less than 95 per cent CaF_2 and not more than 3 per cent SiO_2, 1 per cent $CaCO_3$, and 0.12 per cent Fe_2O_3. However, manufacturers of certain glass use a fluorspar containing a much lower content of CaF_2 and higher contents of SiO_2 and $CaCO_3$. The material must be practically free of lead, zinc, and sulfur. The following specifications of a large

consumer of fluorspar in the glass industry are probably representative, with some variations.

> Our specifications call for a limit of 0.12 per cent iron oxide content. Really we would object strongly if we obtained much fluorspar with that much iron in it as it colors the glass, and we have been receiving fluorspar from responsible sources around 0.06 per cent.
>
> Calcium fluoride content has been placed at a minimum of 90 per cent. However, we receive most of it well above 95 per cent, and our price is based on that. If the diluting material is something such as silica which is used in the glass, it would not interfere with the process but would with the price.
>
> Calcium carbonate content must not vary too much as it affects the formula used in the glass batch. We do not want lead, zinc, or sulfur, so this specification is not a usual one in the glass trade. We do this because we neutralize these materials rather accurately, and too much of them will give us an off shade in color.
>
> All our material is bought in bulk and is finely ground, generally nearly 100 mesh. We can stand considerable variation in this.

The following table gives representative analyses of fluorspar used in the glass industry.

TABLE 28.—ANALYSES OF FLUORSPAR USED IN THE MANUFACTURE OF GLASS, PER CENT.

CaF_2	SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$	$MgCO_3$	S
97.02	1.43	0.04	0.15	1.26	0.12	Trace
97.86	.72	.06	.08	1.01	.26	Trace
97.40	1.55	.14	.26	.54	.....	0.027
97.54	.98	0.50		.98	.....	.....
97.38	1.13	.28		1.21	.....	.....
98.53	.76	.34		.37	.....	.....
97.49	1.35	.31		.85	.....	.....
98.38	.55	.22		.85	.....	.....
98.67	.52	.05	.....	.71	.....	Trace
96.92	1.24	.88	.....	1.28	.....	.....

Physical specifications—The glass industry requires ground fluorspar. It is generally pulverized so that approximately 55 per cent will pass a 100-mesh screen and 15 or more per cent a 200-mesh screen.

Fine-ground fluorspar is screened so that about 70 per cent will pass 100 mesh and about 43 per cent 200 mesh. Extra fine-ground fluorspar is also prepared. Table 29 gives a detailed screen analysis of a coarse-ground fluorspar used in the glass industry.

The color of ground fluorspar is very important and must be watched closely by producers. For glass manufacture the color must be virtually snow white; even very light shades of brown or yellow or specks of black, such as may be produced by the presence of small quantities of galena or other impurities, are to be carefully avoided. Iron is highly objectionable, as even minute quantities impart a green or yellow tint to the glass.

Silica is objectionable only because it is a diluent of the fluorspar. It is reported that one company has used fluorspar containing as much as 13 per cent SiO_2, but such instances are singular and doubtless involved substantial price concessions.

Calcium carbonate is objectionable and generally should be less than 1.25 per cent. An excess of lime in the batch tends to make the glass brittle and easy to break. Variations in lime content naturally tend to interfere with the formula control of the glass batch.

Impurities such as lead, zinc, barium, or sulfur are objectionable because their removal or neutralization by costly oxidizing agents is an added expense.

Market districts.—Fluorspar was used in the manufacture of glass at 56 plants in ten States in 1936. Five plants, however, one each at Washington and Jeannette, Pennsylvania, Winchester and Muncie, Indiana, and Lancaster, Ohio used 71 per cent of the total consumed in the glass industry in 1936. The other plants used fluorspar in quantities ranging from less than a carload to 400 tons in 1936.

Sources of supply.—In 1936 the glass industry consumed 11,600 short tons of fluorspar. Mills at Rosiclare, Illinois, Marion, Kentucky, and Deming, New Mexico, were the only domestic sources of ground spar in 1936. There are also mills with grinding units at Derry, Hot Springs, and Mesilla Park, New Mexico, but they have been inactive for several years. Imports of spar for the glass trade in 1936 amounted to only 394 short tons. However, Germany, Spain, and Italy have been important sources, and during the 5 years 1931-1935 supplied an average of 2,100 tons a year.

Total consumption and stocks.—According to table 30, in which the annual consumption of fluorspar is compared with stocks at glass plants for the 10-year period 1927 to 1936, glass manufacturers carry only about a 2-month supply of ground spar on hand. It will also be noted that consumption declined somewhat from 1927 to 1930 but increased substantially from 1931 to 1936.

TABLE 29.—SCREEN ANALYSIS OF 500-GRAM SAMPLE OF COARSE-GROUND FLUORSPAR THROUGH 24-MESH SCREEN.

	Screen			Quantity Remaining on Screen		Cumulative Weight	
	Mesh	Opening	Quantity passing (per cent)	Grams	Per cent	Grams	Per cent
On	35	0.0164	89.48	51.5	10.30	51.5	10.30
	40	.0150	83.70	28.9	5.78	80.4	16.08
	60	.0087	67.24	82.3	16.46	162.7	32.54
	80	.0069	62.80	22.2	4.44	184.9	36.98
	100	.0058	53.92	44.4	8.88	229.3	45.86
	120	.0046	44.68	46.2	9.24	275.5	55.10
	140	.0042	40.20	22.4	4.48	297.9	59.58
	160	.0038	28.20	60.0	12.00	357.9	71.58
	180	.0033	20.58	38.1	7.62	396.0	79.20
	200	.0029	14.02	32.8	6.56	428.8	85.76
Through	200	.....	.....	70.1	14.02	498.8	99.78

TABLE 30.—CONSUMPTION OF FLUORSPAR IN MANUFACTURE OF GLASS AND STOCKS, 1927-1936, SHORT TONS.

Year	Consumption	Stocks	Year	Consumption	Stocks
1927	6,800	900	1932	6,700	700
1928	6,200	1,200	1933	7,000	1,300
1929	6,600	1,000	1934	7,700	1,600
1930	4,300	1,000	1935	11,000	1,700
1931	7,100	1,000	1936	11,600	2,300

ENAMEL

Purpose.—Fluorspar is an important ingredient in enamels used for coating steel and cast iron to make hospital and kitchen ware, plumbing fixtures such as bathtubs and kitchen sinks, barber and beauty-parlor chairs, linings for refrigerators, table and counter tops, reflectors, signs, stove parts, facing for brick and tile, art pottery, structural materials, earthen cooking ware, and other similar products. Such enamels are dense, opaque, white, or colored.

Extent of market.—As the enamel business is fairly stable there is a rather steady demand for fluorspar during normal times. Cryolite competes with and may be substituted for fluorspar. In certain cases, although not all, there are advantages in using cryolite in spite of the cost differential. Synthetic cryolite, which is becoming a competitor of natural cryolite, is being made indirectly from fluorspar.

The domestic fluorspar entering the enamel trade from 1924 to 1936 is shown in table 31.

TABLE 31.—FLUORSPAR SHIPPED FROM MINES FOR USE IN THE MANUFACTURE OF ENAMEL, 1924-1936.

Year	Short tons	Average value	Year	Short tons	Average value
1924	3,471	$34.85	1930	2,188	$33.61
1925	3,237	31.22	1931	1,996	32.79
1926	3,410	33.27	1932	1,261	28.80
1927	3,813	31.44	1933	3,100	24.82
1928	4.713	30.23	1934	2.590	26.20
1929	3,879	32.39	1935	4,087	24.64
			1936	5,249	24.62

Utilization.—Fluorspar is used in enamel batches in a similar manner as in glass manufacture. Of the enamel batches 0 to 15 per cent is fluorspar or cryolite.

One company reports that its enamels contain 0 to 6 per cent fluorspar. The function of the spar is as a flux and as an auxiliary opacifier. Spar is not a strong enough opacifier to give a white enamel, but a cloudy effect is attained which decreases the amounts required of other and more costly opacifiers. Clear or dark enamels require little or no fluorspar.

Specifications.—Chemical requirements for fluorspar in enamels are usually the same as for glass. Enamelers require a high-grade fluorspar, usually contain-

ing 95 to 98 per cent calcium fluoride and less than 2.5 per cent silica. A small content of silica is not injurious, but as calcium carbonate tends to increase the brittleness of the enamel it must be kept as low as possible. Iron, lead, zinc, and sulfur are objectionable impurities, as these elements in any appreciable quantity would stain or color the enamel. Some representative analyses of fluorspar used in enamels are given in table 32.

TABLE 32.—ANALYSIS OF FLUORSPAR USED IN MAKING ENAMELS, PER CENT.

CaF_2	SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$	$MgCO_3$	S
98.00	1.00	.....	.....	0.15	.....	.....
95.00	2.50	.....	.....	.40	.....	.....
97.86	.72	0.06	0.08	1.01	0.26	Trace
97.15	1.60	.08	.....	.90	.....	.....
97.02	1.43	.04	.15	1.26	.12	Trace

Ground fluorspar, usually about 60 or more per cent passing through a 100-mesh screen, is required in enamels. Such material is finer than that specified by the glass trade. Table 33 gives a detailed screen analysis of a ground fluorspar used in enamels.

TABLE 33.—SCREEN ANALYSIS OF NO. 1 FINE-GROUND FLUORSPAR[a].

	Opening inches	Mesh	On or between sieves, per cent	TOTAL PERCENTAGE	
				On	Passing
On	0.0116	48	9.60	9.60	90.40
	.0082	65	15.54	25.14	74.86
	.0058	100	13.71	38.85	61.15
	.0041	150	8.18	47.03	52.97
	.0029	200	25.79	72.82	27.18
Through	.0029	200	27.10	99.92	[b].08

[a] Analysis of a car shipment to the enamel trade. Courtesy Oglebay Norton & Co.
[b] Loss in sample.

Market districts.—The markets for fluorspar used in making enamels are more widely distributed but smaller than in the glass industry. In 1936, for example, fluorspar was used at 70 plants in 14 States. The largest markets are at Chicago, Illinois; Frankfort, Indiana; Baltimore, Maryland; Kohler, Wisconsin; Cleveland, Ohio; Chattanooga, Tennessee; Pittsburgh, Pennsylvania; and Parkersburg, West Virginia.

Sources of supply—Most of the fluorspar entering the enamel industry in 1936 was produced at Rosiclare, Illinois, Marion, Kentucky, and Deming, New Mexico. A little was produced at Beatty, Nevada. Imports of this grade were not so formidable in 1936, being only 544 tons. During the 5 years 1931-1935, however, imports averaged nearly 900 tons a year.

Total consumption and stocks—The consumption of fluorspar in enamel declined sharply from 5,800 tons in 1927 to 2,400 tons in 1932. Since 1933, however, consumption has increased progressively and reached 5,400 tons in 1936. Stocks held at manufacturing plants are nominal only, as table 34 indicates.

TABLE 34.—CONSUMPTION AND STOCKS OF FLUORSPAR AT ENAMEL PLANTS, 1927-1936, SHORT TONS.

Year	Consumption	Stocks	Year	Consumption	Stocks
1927	5,800	800	1932	2,400	600
1928	5,700	900	1933	3,200	1,100
1929	5,200	700	1934	3,500	700
1930	4,000	600	1935	4,900	900
1931	3,000	700	1936	5,400	1,200

HYDROFLUORIC ACID AND DERIVATIVES

Purpose.—Fluorspar is the basic material in the manufacture of hydrofluoric acid which is used to a considerable extent in the electrolytic refining of metals, the pickling of metals, chromium plating, the etching of glassware, and in the removal of silica and iron oxide from graphite. It is also used in chemical analysis, in the textile and bleaching industry, the manufacture of inorganic and organic fluorides, the removal of efflorescence from stone and brick, the processing of filter and special papers, and the preparation of fungicides, antiseptics, etc. The use of fluorspar as a chemical raw material is discussed in a paper by Reed and Finger.[19]

Extent of market.—The chemical industry provides the second largest outlet for fluorspar; it consumed 11 per cent of the United States total in 1936. The market for acid-grade fluorspar during the 10 years 1927-1936 has been almost equally divided between domestic and imported fluorspar, as shown in table 35.

TABLE 35.—FLUORSPAR SOLD FOR USE IN THE MANUFACTURE OF HYDROFLUORIC ACID IN THE UNITED STATES AND RATIO OF SALES OF IMPORTED FLUORSPAR TO TOTAL, 1927-1936.

Year	Total (Short tons)	Imported		Year	Total (Short tons)	Imported	
		Short tons	Per cent of total sold			Short tons	Per cent of total sold
1927	11,248	7,500	66.7	1932	4,356	3,618	73.5
1928	19,246	3,300	17.1	1933	4,921	3,971	80.7
1929	19,540	6,634	34.0	1934	10,648	8,982	84.4
1930	13,477	3,643	27.0	1935	11,048	7,715	69.8
1931	10,942	6,556	59.9	1936	21,510	8,883	41.3
				Average	12,694	6,080	47.9

Table 36 shows shipments of fluorspar from domestic mines for use in the manufacture of hydrofluoric acid from 1922 to 1936.

[19] Reed, F. H., and Finger, G. C., Fluorspar as a chemical raw material: Chem. Industries, vol. 39, pp. 577-581, 1936.

TABLE 36.—FLUORSPAR SHIPPED FROM DOMESTIC MINES FOR USE IN THE MANUFACTURE OF HYDROFLUORIC ACID AND DERIVATIVES, 1922-1936.

Year	Short tons	Average value	Year	Short tons	Average value
1922	4,782	$24.81	1929	12,906	$27.45
1923	6,976	30.19	1930	9,834	26.45
1924	3,150	28.39	1931	4,386	24.65
1925	4,455	25.60	1932	738	19.79
1926	3,410	23.20	1933	950	19.58
1927	3,748	26.24	1934	1,666	21.43
1928	15,946	36.69	1935	3,333	22.42
			1936	12,627	25.82

Utilization.—Hydrofluoric acid is made by treating acid spar with sulfuric acid in suitable iron kilns, calcium sulfate being produced as a by-product. The reaction is expressed by the equation

$$CaF_2 + H_2SO_4 \rightarrow 2HF + CaSO_4.$$

Two types of acid are now commercially available, aqueous and anhydrous grades. The hydrofluoric acid passes off as a vapor, and is either collected in water in suitable lead cooling and absorbing towers for equeous acid, or condensed by a refrigerating system to the anhydrous grade. The anhydrous acid is made under very rigidly controlled conditions.

The aqueous acid is usually made up into 30, 40, 48, and 52 per cent and "fuming" grades; the strongest acid contains about 65 per cent hydrofluoric acid. It is generally shipped in lead carboys or more recently in special rubber barrels. The anhydrous acid is shipped in iron containers although magnesium, copper, and brass can also be used.

Considerable acid fluorspar enters the aluminum industry. The fluorspar is used first to make hydrofluoric acid. With this acid a synthetic or "artificial" cryolite can be, and is, manufactured in a limited amount, which with natural cryolite is used in a molten bath from which aluminum is recovered by electrolytic methods. The manufacture of synthetic cryolite will become of increasing importance because of the nationalism sweeping over the world and the desire of each nation to become independent of a monopoly supply of the natural mineral. Synthetic cryolite is not only being used in the metallurgy of aluminum but is also becoming of increasing importance in the enamel and insecticide industries.

A new use is rapidly being developed for acid fluorspar in the manufacture of new refrigerating mediums known as the "Freons" of which there are six different kinds. They are all synthetic organic compounds containing chlorine and fluorine. The most common and the one used to the largest extent is "Freon-12," or "Kinetic-12" or in short "F-12"; in the trade, the name Freon usually refers to this compound which is chemically known as dichlorodifluoromethane (CCl_2F_2). Other "Freons" are "Freon-11" or "F-11" and also known to the trade as "Carrene" (trichloromonofluoromethane—CCl_3F), "Freon-21" or "F-21" (dichloromonofluoromethane—$CHCl_2F$), "Freon-22" or "F-22" (monochlorodifluoromethane—$CHClF_2$), "Freon-113" or "F-113" (trichlorotrifluoroethane—$C_2Cl_3F_3$), and "Freon-114" or "F-114" (dichlorotetrafluoroethane—$C_2Cl_2F_4$).

These compounds are nonexplosive, noninflammable, noncorrosive, and practically nontoxic. A study of the physiological properties of Freon is the subject of United States Bureau of Mines Report of Investigations 3013, "Toxicity of dichlorodifluoromethane: a new refrigerant", May 1930. Results of experiments as to the stability, noninflammability, behavior when exposed to flame and hot metal surfaces, and corrosive action on common metals of these compounds are embodied in National Board of Fire Underwriters, Miscellaneous Hazard No. 2375, "Report on the comparative life, fire, and explosive hazards of common refrigerants," November 1933.

Freon is used not only in household and larger mechanical refrigerating units in cold storage for perishable products but also in the air-conditioning field of buildings, mines, railroad passenger cars, etc. Approximately 1,700 tons of acid spar were used in the manufacture of the new refrigerants in the first ten months of 1935, since which time there has been a noteworthy increase.

The Kinetic Chemicals, Inc., a du Pont subsidiary, Wilmington, Delaware, controls and manufactures the "Freons" and many of the refrigerator manufacturers are offering equipment containing these gases, particularly Freon.

Other organic fluorine compounds are being used as dyes, and patents have been issued covering their use as solvents, fire extinguishing agents, drugs, color photographic materials, insulating and cooling dielectrics for electrical apparatus such as transformers, capacitors, switches, etc. In general, these compounds possess unique properties not found in other compounds and are unusually stable. All in all, the field of organic fluorine chemistry promises to have considerable ultimate importance to fluorspar producers.

There are many other derivatives of hydrofluoric acid that are of industrial importance, namely, its salts: hydrofluosilicic acid (H_2SiF_6), sodium fluoride (NaF), sodium bifluoride ($NaHF_2$), sodium silicofluoride or sodium fluosilicate (Na_2SiF_6), potassium fluoride (KF), and potassium bifluoride (KHF_2), ammonium fluoride (NH_4F), ammonium bifluoride (NH_4HF_2), and ammonium silicofluoride [$(NH_4)_2\ SiF_6$], magnesium fluoride (MgF_2), and magnesium silicofluoride ($MgSiF_6$), zinc fluoride (ZnF_2), and zinc silicofluoride ($ZnSiF_6$), barium fluoride (BaF_2), and barium silicofluoride ($BaSiF_6$), calcium silicofluoride ($CaSiF_6$), chromium fluoride (CrF_3), aluminum fluoride (AlF_3), and antimony fluoride (SbF_3). Among the miscellaneous compounds are the cerium, iron, copper, silver, lead, lithium, strontium, boron, bismuth, beryllium, manganese, uranium, tantalum, and titanium fluorides which have been referred to in the literature as being useful in various places.

The uses of these compounds have been discussed in some detail in the paper by Reed and Finger to which reference has been made in the early part of this discussion. Therefore, a brief resumé at this point will suffice to point out the manifold applications of these compounds. Hydrofluoric acid is used chiefly in the preparation of fluosilicates, lead refining and plating, textile bleaching, and as an antiseptic. The sodium, potassium, and ammonium salts are used as preservatives, antifermentatives, and insecticides (several common roach and lice powders contain essentially sodium fluoride). The aluminum industry uses the sodium and aluminum salts. Glass and enamel opacifiers include the fluorides of zinc, barium, magnesium, sodium, and aluminum as well as the silicofluorides of the latter two. Zinc fluoride is used in insecticides and for preserving wood. The textile printing and dying industries use the chromium

salt. Barium fluoride is used in embalming fluids and as an antiseptic. In the manufacture of the new organic fluorine compounds such as the "Freons", etc., antimony fluoride is an essential constituent. Along this line boron fluoride is becoming of increasing importance not only in the synthesis of some of the organic fluorine compounds but also as an excellent polymerizing agent.

The ammonium, potassium, and sodium bifluorides or acid fluorides find extensive use as antiseptics, as laundry sours, in the etching of glass, and in chemical analysis.

The silicofluorides of zinc, magnesium, and aluminum are used as concrete and wall hardeners, and in antiseptics. Cryolite (sodium aluminum fluoride) and aluminum fluoride are being used in aerial insecticide campaigns against the Mexican bean beetle and the cotton boll weevil. Calcium silicofluoride is used chiefly in ceramics. Cerium fluoride in arc lamp pencils produces a light with certain fog penetrating powers.

The chemical industry requires exceptionally high-grade fluorspar and generally insists upon close adherence to certain rigid specifications.

Specifications.—The manufacture of hydrofluoric acid requires fluorspar of a high degree of purity, manufacturers generally specifying a minimum of 98 per cent calcium fluoride. Both silica and calcium carbonate should be less than 1 per cent. Calcium carbonate neutralizes sulfuric acid, and 1 per cent or more of it causes considerable foaming upon mixing. Silica forms hydrofluosilicic acid in such proportions that for every part of silica nearly four parts of fluorspar and more than five parts of sulfuric acid of 66° B. are wasted. Metallic minerals such as lead, zinc, or iron are highly objectionable; barite also is undesirable.

A representative analysis of acid-grade fluorspar from the Illinois-Kentucky field follows:

	Per cent		Per cent
CaF_2	98.50	Fe_2O_3	.06
SiO_2	.45	Al_2O_3	.14
$CaCO_3$	.81	Pb	Trace
		S	.018

A product containing as low as 97 per cent CaF_2 and 1.5 per cent SiO_2 occasionally is sweetened with an extremely pure fluorspar and used as acid spar. Moreover, some of the fluorspar produced by the Aluminum Ore Co. for use in the aluminum industry may grade as low as 96 per cent CaF_2 and 1 per cent SiO_2. The base scale is 98 and 1, however, and price adjustments are made for any lower-grade material.

The manufacture of hydrofluoric acid requires a finely ground fluorspar, generally ranging from 80- to 100-mesh; however, most manufacturers of hydrofluoric acid prefer to buy the fluorspar either in the lump or gravel form and to grind the material in their own plants.

Market districts.—The markets for acid fluorspar are confined to only 8 plants. By far the largest market is at East St. Louis, Illinois. Important although somewhat smaller markets are at Carney's Point, Delaware; Easton, Marcus Hook, and Newell, Pennsylvania; and Cleveland, Ohio. These six plants use about 99 per cent of the total fluorspar consumed in the United States in the chemical industry.

Sources of supply.—The Illinois-Kentucky district supplies virtually all the domestic acid fluorspar. Imports come from South Africa, Germany, Newfoundland, and Spain.

Total consumption and stocks.—Stocks of acid spar at consumers' plants average considerably more than those of other grades of fluorspar. Table 37 shows that slightly more than a year's supply was kept on hand at the plants from 1930 to 1933 but during 1934, 1935, and 1936 only 4 to 8 months supply.

TABLE 37.—CONSUMPTION AND STOCKS OF ACID FLUORSPAR AT CHEMICAL PLANTS, 1927-1936, SHORT TONS.

Year	Consumption	Stocks	Year	Consumption	Stocks
1927	15,500	13,000	1932	7,000	11,000
1928	20,500	11,000	1933	7,800	8,000
1929	15,600	14,000	1934	11,000	7,700
1930	12,600	15,000	1935	12,900	5,600
1931	12,000	14,000	1936	20,100	6,900

CEMENT MANUFACTURE AND MISCELLANEOUS

There is a small demand for fluorspar in the manufacture of cement in the United States. About 1,000 tons of fluorspar were used by cement plants in both 1929 and 1930, since when the consumption has declined to a few hundred tons annually. During the past few years several plants in the United States, chiefly those making rapid-hardening cement, have been using fluorspar in their process. Fluorspar is used to some extent in the manufacture of Portland cement abroad.

It is reported[20] that the addition of fluorspar to the raw materials permits lowering of the fusing point, thereby resulting in considerable fuel economy. It is further reported that the addition of only 0.25 to 1 per cent fluorspar was the practice for some time, but experiments have shown that the addition of 3 to 5 per cent fluorspar gives the best results. The clinker obtained in this way is very fragile; therefore grinding is greatly facilitated, with an appreciable economy in power. The addition of fluorspar is said to eliminate the formation of rings in the rotary kilns, thus reducing to a minimum the periods of stoppage and increasing the life of the refractory lining.

The use of fluorspar in cement manufacture has been discussed in considerable detail by Becker,[21] who concludes as follows:

> An admixture of fluorspar can not be expected to produce successful results in every mix, of which fineness, temperature of sintering, and duration of the sintering remain.
>
> The fineness of the raw mix, and particularly the conditions of sintering, should be selected with special consideration of a new mix. In a given case one may also vary the components of the raw mix accordingly, the variation being most easily produced by a change of the lime content.
>
> Only in relatively rare cases does a plant require but one change—the aiding of the sintering process—and accomplishes it by the selection of a proper quantity of admixture. In most cases some of the other plant processes must be altered to suit the lower sintering temperatures or lighter sintering.

[20] Chermette, A., and Sire, L., Le spath fluor dans le massif central, ses applications: Rev. de l'Ind. Min., Mem., vol. 6, pp. 515-528, Paris, 1926.

[21] Becker, Hans, Use of fluorspar in cement manufacture: Rock Products, vol. 30, pp. 83-84, Sept. 3, 1927.

> It remains an established fact, however, that fluorspar greatly benefits the sintering process. Proofs of any detrimental effect on cement properties produced by CaF_2 have not been furnished.
>
> All of my personal experience and all test results reported by others bring one conclusion: Sintering is aided and the sintering temperature is lowered.
>
> The phenomena of quick or slow-setting properties, of good or poor hardening, observations of soundness, ease of grinding, etc., are the results of low sintering in its effect on the raw mixes used and the handling during sintering.

Lea and Desch[22] also discuss briefly the use of fluorspar in cement in their book which appeared in 1935.

Small quantities of fluorspar have been used in the recovery of potassium compounds from flue dust of cement works in the United States, but this saving of potash has been discontinued.

TABLE 38.—FLUORSPAR SHIPPED FROM DOMESTIC MINES FOR MISCELLANEOUS PURPOSES, 1922-1936.

Year	Short tons	Average value	Year	Short tons	Average value
1922	213	$18.02	1929	1,004	$14.96
1923	1,839	20.85	1930	1,342	16.32
1924	160	21.13	1931	557	14.13
1925	120	39.00	1932	226	11.91
1926	372	21.47	1933	713	15.44
1927	903	17.59	1934	1,504	17.55
1928	1,176	16.23	1935	2,248	13.76
			1936	3,157	16.19

OPTICAL FLUORSPAR

There is limited market for flawless transparent crystals of fluorspar which, used as lenses, are necessary in the better microscopes and small telescopes. The quantity consumed annually probably is not more than a few hundred pounds. The market, although definite, can absorb only a certain amount, therefore the demand is easily satisfied. Hughes[23] states:

> The unit value of optical fluorite varies considerably depending directly upon the size of the flawless pieces. The price during the past few years has fluctauated from $1 to $10 a pound for material of average quality, but especially fine specimens may be sold for $10 or more each. Only about 5 per cent of the fluorspar sold as optical material actually is consumed in lenses and other equipment. For this reason one manufacturer has adopted a policy of paying only for the finished parts. On this basis one crystal may be used satisfactorily for two or three lenses and be paid for at a rate comparable to $50 or $75 a pound, while 25 or 30 pounds of fluorspar ordinarily sold as optical fluorite may bring only $4 or $5. This system of payment encourages more careful selection of crystals and eliminates such material which obviously is too imperfect for optical use. The actual price for each transaction usually is established by negotiation with the prospective consumer or dealer.

[22] Lea, F. M., and Desch, C. H., The chemistry of cement and concrete, pp. 123, 127, Edward Arnold & Co., London, 1935.

[23] Hughes, H. H., Iceland spar and optical fluorite: U. S. Bur. Mines, Inf. Circ. 6468, pp. 1-17, 1931.

Fluorspar of optical grade has certain very desirable light-transmitting qualities. It bends light only slightly, disperses light faintly, and normally displays no double refraction. Pogue states:[24]

> Due to its low refractive power and very weak color dispersion, this mineral is especially suitable for correcting the spherical and chromatic errors of lens systems. * * *
>
> For optical use a specimen of fluorite must contain a portion at least one-fourth of an inch in diameter, free from flaws, and colorless or nearly so. Crystals, or pieces bounded more or less completely by plane surfaces, are more likely to qualify than irregular masses. As the surfaces of most crystals are dull, a corner of such a specimen should be broken off with a sharp blow so as to expose the interior. In doing this it is desirable to rest the specimen on a wooden base and break off the corner along an incipient cleavage plane by means of a knife blade or chisel; such planes are usually present and may be located by moistening the specimens with kerosene. If the specimen looks promising, it is better to proceed no further, as fluorite is fragile and a misdirected blow will fill a clear piece with a network of fractures. A peculiarity of fluorite of optical quality is its conchoidal (irregularly curved) fracture and the absence of a strong tendency to break into pieces bounded by smooth planes in the fashion of the ordinary mineral.
>
> * * * As to color, material that is absolutely water clear is of course the most desirable and, in fact, is essential for highly specialized uses; but faint tints of green, yellow, and purple do not in themselves render material altogether unsuited for optical use. Flaws must be lacking from the portion to be used, but flaws are present in the bulk of fluorite due both to cracks (incipient cleavages) and to inclusions of bubbles or of visible impurities; accordingly, the most detailed search is necessary to find pieces free from these objections. Moreover, careless handling, even jolts resulting from shipping, may develop flaws in clear material; hence, the utmost care must be exercised in separating material of optical promise from its crude associations and in suitably packing such material.

NOTES ON FOREIGN DEPOSITS

Discussion of utilization is the final step in describing the past and present fluorspar industry. The future can be appraised only in so far as it can be shown whether or not prevailing conditions will be perpetuated. The foregoing sections have described the industry from a domestic viewpoint. Fluorspar is also an important commodity in other countries. Foreign deposits are mentioned briefly to round out the world picture and to allow the factors relevant to the future to be summarized.

Fluorspar occurs in many countries of the world besides the United States. Deposits in Canada, England, France, Germany, Italy, Newfoundland, Russia, South Africa, and Spain have yielded important tonnages of commercial spar, and smaller quantities have been produced in several other countries. Certain occurrences in other countries are potential sources of supply when economic conditions justify exploitation. Many other places where fluorspar is found are of mineralogical interest only.

The following discussion is designed to cover briefly some of the more important points of the foreign deposits. More detailed information can be obtained by consulting past Minerals Yearbook and Mineral Resources chapters of the United States Bureau of Mines on fluorspar or references listed in the bibliography. Production data for 1931 to 1935, so far as available, are shown in table 3 of world production on pages 38-39.

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24 Pogue, J. E., Optical fluorite in southern Illinois: Illinois State Geol. Survey, Bull. 38, pp. 419-425, 1918.

ARGENTINA

Fluorspar occurs at San Roque, Province of Córdoba, associated with pyrite, quartz, chalcedony, and mica, in fissure veins traversing biotite gneiss east of the gneiss-granite contact of the Andes. Pegmatite dikes are common. The fluorspar veins strike northwest and have been traced for several hundred yards. Their widths range from 1 foot or less to as much as several yards. Fluorspar occurs in colorless, light green, yellow, blue, violet, or almost black bands. These deposits have not been developed actively, owing to their remoteness from markets.

AUSTRALIA

Deposits of fluorspar occur in the Yass and Tumbarumba divisions, New South Wales; the Emmaville division, Queensland; and Beechworth and Woolshed, Victoria.

Most of the production from New South Wales has come from the old Woolgarlo silver-lead mine in the Yass division and from Carboona in the Tumbarumba division. In the Emmaville division, Queensland, fluorspar occurs with wolfram and copper ores in the vicinity of "The Gulf." A large tonnage of spar is said to occur in small, irregular deposits. Other deposits in Queensland occur in the Herbertson district.

CANADA

The principal Canadian deposits occur in British Columbia and in Ontario. The British Columbia deposit, consisting of fluorspar associated with iron and copper minerals, is on Kennedy Creek near Lynch Creek station on the Kettle River Railway north of Grand Forks. Silica is associated so intimately with the spar that production of a high-grade concentrate is difficult. This handicap, together with high freight rates to markets in the United States and Canada, has restricted operations in this area. Decrepitation was at on time a unique feature of the mill process.

The Ontario deposits occur near Madoc in the central part of southeastern Ontario. The ore occurs mainly as lenses in fault fissure veins in a complex series of pre-Cambrian sedimentaries. The deposits apparently are unable to produce large tonnages of market-grade fluorspar.

CHINA

According to the China Year Book for 1928 (ch. 2, pp. 66-106) important fluorspar deposits occur (1) in Kaipinghsien and Pulantiet of southern Fengtien, (2) at Kaiohsien of Shantung, and (3) between Sinchang and Chenghsien in Chekiang. The deposits of Chekiang and Fengtien appear to be the most important, these provinces having produced 4,498 metric tons during 1925. The bulk of it was exported to Japan and the United States. Chekiang Province appears to have been the most active. The production of fluorspar in China in 1934, the latest year for which data are available, was 5,050 metric tons.

In 1924 the total mining area conceded for fluorspar was 16,408 square li, or about 26,250 square miles, as compared with 23,389 square miles in 1921.

FRANCE

France, like Germany, has displayed amazing enterprise in the development of her fluorspar deposits since the World War.

Fluorspar occurring in France is characterized by its exceptional purity. Much of the ore, especially from the Puy-de-Dôme district, is used in chemical works. The most important deposits are found in the Department of Var on the northern Mediterranean coast, which produced 26,000 metric tons in 1929, or about half of the total production in France. Modern mining and milling equipment has been installed since the war. The product, which may contain 93 per cent or more calcium fluoride, is attractive to American buyers because of its high grade. The deposits are situated favorably to the ports of St. Raphael, Toulon, and La Napoule. Toulon is frequently visited by tramp steamers which load cargoes of cork and cork waste for the United States. These steamers can afford to take fluorspar as ballast at low rates.

Other fluorspar districts of France include Sâone-et-Loire, Aveyron-Lozère, Haute-Loire, Indre, Rhône, and Nièvre.

GERMANY

Important fluorspar deposits occur in Anhalt, Baden, Bavaria, Prussia, Saxony, and Thuringia. In general, the spar occurs in fissure veins associated with barite and with lead, copper, iron, and zinc minerals. Deposits in the Harz Mountains, Prussia, are closely related to the silver veins which have been worked for centuries.

According to available information, reserves are more than ample to enable Germany to continue as an important source of supply. One mine in Bavaria is reported to contain about 1,700,000 tons of unmined spar.

Although fluorspar operations have been numerous since the war there has been a marked tendency toward consolidations into strong operating units. Moreover, mining and milling technique has shown great progress. Development of the industry as a whole has been intensive and thorough. It is reliably reported that the German spar mines will be able to produce 100,000 tons annually for many years to come.

GREAT BRITAIN

In England important deposits of fluorspar occur in Derbyshire and Durham. Less important occurrences are found in Cornwall and Devon and in Flintshire.

Most of the mines were first opened for lead, and much lead mining was done before fluorspar had appreciable commercial value. Both the Derbyshire and Durham districts are characterized by old extensive underground workings which contain more or less unmined spar (originally considered waste gangue material) and by old dumps or hillocks on the surface which have been a fruitful source of spar. Many old underground workings are very extensive.

In Derbyshire and Durham the topography is semimountainous, with ridges rising as much as 800 feet above the valleys. Mine water is removed by drainage adits into the hillsides and by pumps from workings that extend below the drained areas.

Spar in Derbyshire occurs only in the upper part of the Mountain limestone formation of Carboniferous age and is found in veins and pipes associated

with galena, calcite, silica, and barite. In this district the rocks have been folded considerably. With depth the fluorite is displaced by barite and calcite. Spar from this district is quite low in silica, and some of the material is of acid grade.

In Durham the fluorspar occurs only in veins in flat-lying beds of limestone, ganister, calcareous shales, and sandy shales. The wall rocks contain appreciable silica, and the spar itself it somewhat siliceous. Acid grades are difficult to obtain, and it is even hard to make "85 and 5" grades. Barite is virtually absent.

The fluorspar industry in Durham and Derbyshire has not been developed as intensively as in the United States. A large proportion of the English output was obtained formerly by simply screening and hand-sorting the waste dumps of old lead mines. This material was obtainable at quite low cost, but these high-grade dumps were more or less depleted of material easy to obtain by the end of the World War. The log washer, known and used by operators in this country for two generations or longer, was patented in England about 15 years ago. Jigs and tables, however, together with accessory crushing and screening equipment, have been installed in a number of mills. At some operations lead constitutes a valuable by-product.

INDIA

Unimportant occurrences of fluorspar have been reported at Barla in the Kishangarh State, Rajputana, and at Sleemanabad, Jubbulpore district, but these have yielded no commercial production. According to the records of the Geological Survey of India[25] the Tata Iron and Steel Co. investigated the Rajputana occurrence but found very little fluorspar present, and reported that European fluorspar would be less costly. Apparently, the spar is associated with calcite and quartz in a vein only about 1 foot thick traversing gneiss.

Occurrences of fluorspar, which at present are of mineralogic interest only, have been reported from at least seven other localities in India.

ITALY

Important deposits of fluorspar in veins 6 to 12 feet wide occur at (1) Monte Fronte near Vetriolo (Val Sugano, Province of Trento); (2) Valle della Sarn in the Province of Bolzano (Trento); (3) Collio (Val Trompia); (4) the vicinity of Varese; (5) Val Brembana; and (6) Sarrabus.

Certain veins have been developed quite extensively. In the Bolzano district alone, proved, probable, and possible ore reserves of more than 1,000,000 tons have been estimated.

NEWFOUNDLAND

Fluorspar occurs in the vicinity of Cape Chapeau Rouge, Districts of Burin East and Burin West, near East St. Lawrence, Newfoundland, and 9½ square miles comprising 48 locations have been recorded according to the Minister of Agriculture and Mines for Newfoundland.

The fluorspar occurs in fissure veins in granite.[26]

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[25] Pascoe, E. H., Quinquennial review of the mineral production of India, 1924-1928: India Geol. Survey Records, vol. 64, p. 384, Calcutta, 1930.

[26] Kaufmann II, Rudolph, Reconnaissance of the regional and economic geology of the St. Lawrence area, Newfoundland, with notes on fluorite (Senior Thesis): Dept. of Geology, Princeton University, 1936.

Mining of fluorspar was begun in March 1933, since which time through 1936 about 18,300 short tons have been shipped. The deposit is virtually on tidewater at Little St. Lawrence Bay; it is reported to be extensive. The distance from the deposit to the dock from which shipments are made is approximately one mile, and the fluorspar is shipped chiefly by water. The geographical location is favorable for water shipments both to Atlantic ports and by St. Lawrence River and Great Lakes waterways to Great Lakes ports. The methods of mining employed are trenching or openpit and shafts.

Shipments in 1936 totaled 9,368 short tons, of which 1,822 tons of acid-grade and 2,358 tons of fluxing-grade went to consumers in the United States, 2,007 tons of special-grade lump (93 to 95 per cent CaF_2) to Ontario, and 3,181 tons of fluxing-grade to Nova Scotia.

NORWAY

Deposits of fluorspar of potential economic importance occur near Dalen, Telemark County, and near Kingsberg, Buskerud County. Some development work has been done, indicating workable widths of ore of marketable grade, but no extensive mining operations have been begun. The deposits are reported to be capable of producing eventually 20,000 to 25,000 tons annually if market conditions warrant the necessary capital expenditures to bring the mines to full production capacity.

U. S. S. R. (RUSSIA)

The most important fluorspar deposits in the Union of Soviet Socialist Republics until comparatively recent years were those in the Transbaikalia region beyond Lake Baikal in the Far East province.[27] Deposits were also known at Aurakhmat in Central Asia and occurrences of fluorspar have been reported in the district of Svetensk. Only the Abagatuevsk mine was worked in 1926-1927. The price of the fluorspar at the mine in 1926 was 60 rubles ($30) a metric ton but declined to 50 rubles ($25) in 1927. The Ural province reported a small production in 1922, 1923, and 1924.

The fact that most if not all the fluorspar deposits exploited in the Soviet Union have been far removed from the industrial centers in the Urals, Donets Basin, and Karelia makes of much importance the discovery in comparatively recent years of a new deposit on the shore of Kara Sea, covering a large area including the mainland and Novaya Zemlia. The purest fluorspar so far found in U. S. S. R., which resembles that of Illinois and Kentucky but averages higher in grade, was disclosed in 1933 by prespecting along the Amderma River, which runs north into the Kara Sea. The construction of a 15½ mile railroad has been proposed from these deposits to Kara Sea in order that fluorspar may be shipped to Archangel by boat.[28]

UNION OF SOUTH AFRICA

The occurrence of fluorspar has been reported in South Africa near Zeerust in the Marico district of Western Transvaal; near Hlabisa, Zululand; in

27 Mineral resources U.S.S.R.: Geol. Commission, Second Ann. Rept., 1926-1927, pp. 751-756, Leningrad, 1928.

28 Discovery of fluorspar deposits: Bur. Foreign and Domestic Commerce, Russian Econ. Notes, No. 278, p. 9, Washington, July 30, 1934.

the Warmbad area, Transvaal; and on Gamib near Kalkfontein, South-West Africa.

According to Abbey[29] fluorspar from the Marico district is shipped to the coast by rail via Mafeking. The more important deposits are on the farms of Malmani Oog, Buffelshoek, and Witkop. The ore occurs in gash veins and in pipes or chimneys in limestone, dolomite, and chert formations.

According to the Department of Mines of the Union of South Africa:[30]

> A flotation plant has recently been erected [in the Marico district] with a view to producing fluorspar of about 200 mesh and of the following specifications: Calcium fluoride, 98 per cent minimum; silica, 1 per cent maximum; and calcium carbonate, 1 per cent maximum. The lump spar at present being exported is of the same specifications.
>
> Another producer has erected a small plant and in addition to lump spar can supply ground spar containing calcium fluoride not below 90 per cent, maximum $CaCO_3$ 1 per cent, silica 4 per cent, water under 0.25 per cent. The ground spar is supplied in the following mesh per linear inch—100 mesh, 85 per cent; 150 mesh, 80 per cent; 200 mesh, 70 per cent.

A considerable deposit of very pure fluorspar (99 per cent calcium fluoride) is reported to have been opened about 50 miles from the railway in Kalkfontein district, South-West Africa, according to consular report by M. K. Moorhead, Johannesburg, South Africa, October 23, 1931.

No work is now being done in the Hlabisa or Kalkfontein areas, but production near Warmbad continues mainly for local consumption.[31] The Hlabisa deposits have been described as fissure veins occurring in country rock devoid of limestone.[32]

All shipments to the United States have been acid-grade material, generally averaging 98 per cent or more calcium fluoride and less than 1 per cent silica. Increased mining costs due to depletion of the easily accessible surface ore and comparatively high transportation and other handling costs, together with stiff competition from Europe, have adversely affected the South African producers. Operators state, however, that with improved market conditions and firmer prices, production could be increased greatly.

SPAIN

The more important fluorspar occurrences of Spain are in Barcelona, Oviedo, Gerona, Córdoba, and Guipúzcoa provinces.

In Barcelona near Papiol fluorspar occurs in fissure veins associated with lead. It is reported that the mines were opened originally for lead but were unsuccessful as lead mines owing to the leanness of the ore. The lead, however, forms a valuable by-product of the fluorspar. The vein is said to have been traced a length of about 3 miles and to show widths to 15 feet. Some spar is available from old dumps of former lead operations.

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29 Abbey, G. A., American Vice Consul, Johannesburg, South Africa, Production of fluorspar in South Africa, Ms. Rept., Oct. 30, 1930.

30 Industrial minerals: Dept. Mines, Union of South Africa, Pretoria, Quart. Inf. Circ., p. 23, August 1936.

31 Industrial minerals: Dept. Mines, Union of South Africa, Pretoria, Quart. Inf. Circ., p. 26, February 1936.

32 Kupferburger, W., Fluorspar veins near Hlabisa, Zululand: Trans. Geol. Soc. South Africa, vol. 37, pp. 87-96, Johannesburg, 1935.

SWITZERLAND

Some optical spar was at one time mined from the high mountain chalks of Bern; and fluorspar associated with barite, galena, and quartz occurs near Lembrancher in the Dranse Valley. In the Trappist mine the vein is about one meter wide but may widen locally to three meters. In 1922 a deposit of fluorspar was discovered on the side of Mont Chemin between Martigny and Lembrancher. Production from these sources so far has had little economic importance.

OTHER COUNTRIES

Fluorspar is known to occur in many other countries, including Brazil, Bolivia, Chosen, Cuba, Guatemala, Mexico, and Persia. As data covering some of these deposits may be obtained by consulting past Mineral Resources chapters of the United States Bureau of Mines or references listed in the bibliography it is unnecessary to repeat such information in this paper.

SUMMARY

PAST AND PRESENT CONSUMPTION AND SOURCES OF SUPPLY

Up to the end of the nineteenth century only about 165,000 short tons of fluorspar had been consumed in the United States, virtually all of which came from mines in the Illinois-Kentucky district.

In the decade 1900-1909, due to the progress in basic open-hearth steel production, consumption of fluorspar rapidly increased and amounted to about 552,000 tons (about 55,200 tons annually), of which mines in the Illinois-Kentucky district contributed 71.3 per cent, the United Kingdom 27.2 per cent, and Arizona, Colorado, New Mexico, and Tennessee the remainder.

During the 15 years following (1910-1924), chiefly because of greatly expanded operations at basic open-hearth steel plants, consumption of fluorspar in the United States totaled about 2,270,000 tons (about 151,300 tons annually). Sales of fluorspar to consumers in the United States during this period, however, amounted to about 2,351,000 tons (about 156,700 tons annually), of which mines in the Illinois-Kentucky district supplied 78.1 per cent; Arizona, Nevada, New Hampshire, and Washington together 7.3 per cent; the United Kingdom 11.8 per cent; and other foreign countries 2.8 per cent.

In the so-called normal years 1925-1929 a total of about 910,000 tons (about 182,000 tons annually) of fluorspar were consumed in the United States. Of this quantity the metallurgical industry used about 85 per cent, ceramic plants 7 per cent, and chemical industry 8 per cent.

During the 5-year period 1925-1929 total sales of fluorspar to consumers in the United States amounted to 934,739 short tons (about 186,900 tons annually), of which the Illinois-Kentucky district furnished 62.9 per cent; Colorado 3.8 per cent; Nevada and New Mexico 1.5 per cent; Germany 10.5 per cent; the United Kingdom 8.9 per cent; France 6.1 per cent; Africa 3.5 per cent; and other foreign countries 2.8 per cent.

Prices of domestic fluorspar sold during the 5 years 1925-1929 averaged $16 to $17 per short ton for fluxing-gravel, $31 to $32 for ceramic-ground, and $25 to $26 for acid-lump.

In the subnormal years 1930-1934 the total consumption of fluorspar in the United States declined to 483,000 tons (about 96,700 tons annually); total sales were only 458,051 tons (about 91,600 tons annually), due to low activity in the

industries using fluorspar and to liquidation of the large stocks accumulated by consumers. During this period the proportions consumed by the ceramic and chemical trades increased to 10.6 and 10.4 per cent, respectively, while the metallurgical industry decreased to 79 per cent. There also was a noteworthy shift in the source of supply of fluorspar after 1930. For example, of the total sales in the United States during the 4 years 1931-1934 domestic mines supplied 79.4 per cent and foreign countries 20.6 per cent, whereas during 1925-1929 domestic mines contributed 68.2 per cent and foreign sources 31.8 per cent. The decline in imports into the United States was mainly due to low activity in the steel industry, an advance in the rate of duty, and unfavorable rates of exchange in certain countries, chiefly Italy, France, and the United Kingdom.

Prices of domestic fluorspar sold during the 5 years 1930-1934 averaged $12 to $16 per short ton for fluxing-gravel, $23 to $33 for ceramic-ground, and $20 to $26 for acid-lump.

Accelerated activity in the steel industry, coupled with improvement in the ceramic and chemical trades, resulted in a consumption of 137,400 tons of fluorspar in the United States in 1935. Both domestic producers and importers shared in the increase. Total sales to consumers in the United States in 1935 were 139,554 tons, of which domestic producers supplied 88.3 per cent and importers only 11.7 per cent. The Illinois-Kentucky district furnished 80.6 per cent, Colorado 5.0 per cent, Germany 5.9 per cent, and Spain 3.5 per cent. Despite the improved demand for fluorspar in 1935, the average selling price of fluxing gravel decreased from $15.28 a ton f. o. b. Illinois-Kentucky mines in 1934 to $13.76 a ton in 1935.

Increased demand for fluorspar chiefly by manufacturers of basic open-hearth steel and hydrofluoric acid was reflected in consumption of 182,400 short tons of fluorspar in 1936. As a consequence, domestic sales and imports were substantially higher in 1936, total sales to consumers in the United States amounting to 200,908 tons, of which domestic producers supplied 87.6 per cent and importers 12.4 per cent. The Illinois-Kentucky district furnished 80.7 per cent, Colorado 4.7 per cent, Germany 6.3 per cent, Spain 2.8 per cent, and Newfoundland 2.1 per cent.

The improved demand for fluorspar in 1936 was accompanied by a substantial increase in the average selling price of fluxing-gravel, from $13.76 a ton f. o. b. Illinois-Kentucky mines in 1935 to $16.53 a ton in 1936.

FUTURE TRENDS IN CONSUMPTION

UNITED STATES

The quantity and grade of fluorspar that will be consumed in the future can be evaluated partly by consideration of past trends. Steel has influenced profoundly the prosperity of the domestic fluorspar industry, as is strikingly revealed in figure 3, page 10. Two facts are apparent: (1) That fluorspar consumption until 1921 followed the curve of steel regularly and precisely, and (2) that since 1921 fluorspar consumption has not kept pace with increased production of basic open-hearth steel. The latter is due almost entirely to the fact that since 1921, chiefly as a result of refinements in furnace practice, less spar per ton of steel has been consumed.

Steel, however, will continue to dominate the fluorspar market. It is true that the price of fluxing spar is much below that of acid and ceramic grades and

that in proportion more profit is returned from sales of high-grade fluorspar; nevertheless, the normal output from mines and mills can be maintained only by maintaining the volume of fluxing grades without which the higher grades of spar could not be produced, except at much higher prices than they now command. The future requirements of ceramic grades may continue at the 1935-1936 level or may advance somewhat, and demand for acid grades very probably will increase greatly in importance; but in the near future, at least, steel will "call the tune."

No doubt can be entertained as to the future of the steel industry. The long-time trend is definitely upward. So long as our present industrial order endures, steel will continue to play a vital and increasingly important part. Although the manufacture of steel may require less spar in the future, there is no evidence that fluorspar will cease to be a valuable and highly useful agent in basic open-hearth practice, both at home and abroad.

FOREIGN

The world production of steel was about 124 million gross tons in 1936, thus exceeding all previous records. The United States produced about 48 million tons, whereas Europe, including the United Kingdom, Germany, Saar, Luxemburg, France, Belgium, Russia, Poland, Sweden, Spain, Austria, Hungary, Czechoslovakia, and Italy, produced about 66 million tons. In the United States, however, 43 million tons were produced by the basic open-hearth process. Of the 66 million tons produced in Europe, possibly two-thirds were made in basic open-hearth furnaces.

Precise data are lacking as to the trend in European furnace practice, but Russia appears to offer the greatest possibilities for the future. Much European iron ore is high in phosphorus and is used for making steel by the Bessemer process, particularly in Saar, Luxemburg, France, and Belgium. On the other hand, basic open-hearth practice predominates in the United Kingdom, Germany, Poland, and Russia and is strong in Sweden. Basic open-hearth practice also predominates in Japan and Canada as well as in the United States.

Evidently, European markets can absorb enough fluorspar to maintain European fluorspar production at a fairly large volume, a strong factor in keeping costs at a minimum. Large deposits, low labor costs, and favorable mining conditions will make the fluorspar available as fast as is required abroad with a large surplus available for export to the United States.

The foreign situation depends also upon world politics. Social and economic revolutions and possible wars could change the picture almost overnight. Probably no other event has such far-reaching economic effects as warfare.

FUTURE SOURCES OF SUPPLY AND RESERVES

UNITED STATES

Present reserves of fluorspar constitute the future sources of supply. The Illinois-Kentucky district is the most important producing region in the United States. According to available statistics 3,849,000 tons of fluorspar have been produced in the United States since the beginning of operations through 1936. Of this total the Illinois-Kentucky district has contributed 92.6 per cent, Colorado 5.2 per cent, and New Mexico 1.7 per cent. Only an insignificant quantity (0.5 per cent or about 20,000 tons) has been produced from other states.

The Illinois-Kentucky field doubtless will continue to be the chief source of domestic fluorspar for many years. Various estimates have been made of the reserves of the district. The United States Tariff Commission report covering investigations in 1926 included an estimate of reserves of 2,660,000 tons of finished product in the Illinois-Kentucky district. If production since then is deducted this estimate indicates a reserve of slightly more than 1,550,000 tons at the end of 1936, with no credit for ore discovered since 1926.

In the spring of 1927 operators in Illinois and Kentucky estimated reserves in the district as approximately 5,000,000 tons of salable fluorspar, representing the total tonnages of proved, probable, and possible ore, the possible ore being calculated so conservatively as to class it virtually as probable ore. After subsequent production is deducted a reserve of about 4,000,000 tons of merchantable fluorspar is indicated at the end of 1936, making no allowance for ore discovered since 1927.

The figures given above included an estimated reserve of 80,000 tons for the bedding deposits of the Cave in Rock district. A recent detailed study of the district by L. W. Currier[33] of the United States Geological Survey, reveals a possibility of a much greater tonnage. On the basis of structural studies of the deposits and geologic mapping, he makes an estimate of 500,000 to 700,000 tons of fluorspar for this district. This estimate is based entirely on geologic factors, since relatively little "ore" has been blocked out or proved in advance of mining.

An estimate of probable reserves of fluorspar in the Western States was made by E. F. Burchard[34] of the United States Geological Survey in 1928 from field work during 1926 and 1927 and from certain data gathered by other investigators. The estimated probable reserves of all grades of spar, mostly fluxing, amounted to 1,035,000 short tons.

TABLE 39.—ESTIMATED FLUORSPAR RESERVES IN THE WESTERN STATES.

	Short tons
Arizona	90,000
California	75,000
Colorado	400,000
New Mexico	400,000
Nevada, Utah, Washington	70,000
Total	1,035,000

Figures of ore reserves must be regarded cautiously. More precise estimates would comprise not only the exact tonnages in the different classes of proved, probable, and possible ore but would indicate also the production cost of each class. Doubtless, much fluorspar is included in the foregoing estimates that can be won only at a considerably higher cost than would be economical under present operating conditions; obviously it would be impossible to predict how much of it may be mined profitably on the basis of operating costs 5, 10, or 20 years hence. On the other hand, it is possible that additional reserves will have been discovered by the end of 15, 20, or 30 years which will automatically prolong the life of the domestic deposits.

[33] Currier, L. W., Geologic factors in the interpretation of fluorspar reserves in the Illinois-Kentucky field: U. S. Geol. Survey, Bull. 886-B, 10 pp., 1937.

[34] Burchard, Ernest F., Fluorspar deposits in Western United States: Am. Inst. Min. and Met. Engrs., Tech. Pub. No. 500, 26 pp., February 1933.

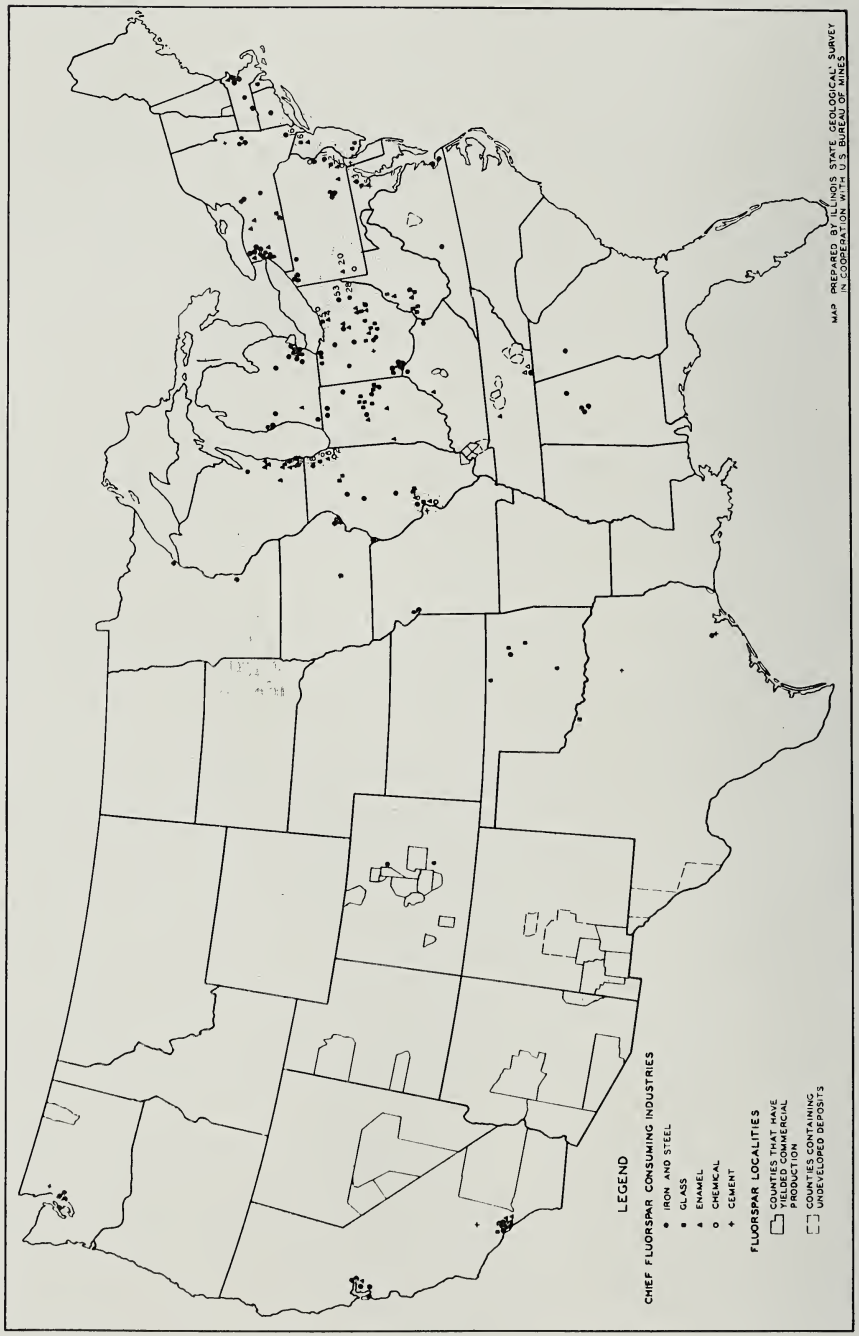

FIGURE 14.—CONSUMING DISTRICTS OF FLUORSPAR IN THE UNITED STATES, IN RELATION TO PRODUCING AREAS.

Even a brief consideration of domestic reserves invites attention to the fact that a certain amount of fluorspar necessarily must be lost if production ever falls to the point where mines are closed before the deposits are exhausted. Enforced shutdowns, which sometimes lead eventually to abandonment of the workings, involve huge losses to the operators. Some mines so shut down perhaps never regain an efficient working basis due to cave-ins and other catastrophes during the period of neglect.

Even discounting unfavorable operating conditions, however, reserves of merchantable spar in the United States appear to be 3 to 5½ million tons. It may be asserted with some confidence that sufficient domestic fluorspar is now in sight to satisfy at least 15 or 20 years of normal demand. Abnormal conditions such as wars, with the withdrawal of foreign supplies, would of course tend to deplete domestic reserves more quickly.

FOREIGN

Future production of fluorspar abroad will depend upon the virility of foreign enterprise, availability and cost of ore, development of foreign markets, and world political conditions.

Foreign enterprise, notably in Germany and France, has shown amazing vigor during the past 6 or 7 years. Ore reserves abroad, according to available information, appear to be almost of the same order as those in the United States and may prove greater. Many European deposits are being developed intensively with a thoroughness that promises continuance in the future. This development does not depend upon United States markets alone. Shipments to the United States are a relatively small part of the European production. In 1929, for example, approximately 254,000 short tons of fluorspar were produced in Europe and only about 46,600 tons were exported to the United States. Thus, about 82 per cent of European spar was consumed at home and about 18 per cent in United States markets.

Foreign production, now so well established, doubtless will continue on a firm basis. Periods of industrial inactivity can not be considered as representing long-time trends in the industry, either abroad or in the United States. Fluorspar has and will continue to have marked importance to the industries of the world.

In conclusion, this report lists domestic producers and consumers. The bibliography at the end will be helpful to those seeking more detailed discussions of individual phases of the fluorspar industry.

LIST OF DOMESTIC FLUORSPAR MINES OR DEPOSITS

The following list gives the names and addresses of owners or lessees of fluorspar mines and deposits in the United States together with the location of the property. It includes mines that are worked more or less regularly, those worked sporadically, and many (but not all) deposits that have been prospected sufficiently to indicate the possible existence of fluorspar in commercial quantities. Profitable operation under present economic conditions is hindered or prohibited at many of the properties listed because of the nature of the deposit, high mining cost, lack of adequate or proper milling equipment, and distance from markets or transportation, or both.

SOURCES OF SUPPLY OF DOMESTIC FLUORSPAR.

Owner or lessee	Address	Location of mine or deposit
ARIZONA		
		GREENLEE COUNTY
Cook, Amos	Safford	Duncan
Luckie, E. M.	Lordsburg, N. Mex.	Do.
		PIMA COUNTY
Purcell, S. W. and Martin, A. P.	Tucson	Tucson
		YUMA COUNTY
DeLuce, Mrs. Eliza	Yuma	Dome
Modesti, Althee	Los Angeles, Calif.	Do.
CALIFORNIA		
		SAN BERNARDINO COUNTY
Whitlock, Claude J.	San Bernardino	Afton
COLORADO		
		BOULDER COUNTY
Atkinson, C. W.	Boulder	Jamestown
Boulder Fluorspar & Radium Co.	Denver	Do.
Crystal Fluorspar Co.	Boulder	Do.
Evans, John	Jamestown	Do.
Evans, L. R.	Do.	Do.
Fluorite Mining Co.	Denver	Do.
Harlow Estate, W. P.	Boulder	Do.
Lehman Fluorspar Co.	Jamestown	Do.
Terry, E. R.	Do.	Do.
Walker, George	Do.	Do.
		CHAFFEE COUNTY
American Fluorspar Corp.	Colorado Springs	Salida
Chaffee County Fluorspar Corp.	Salida	Do.
Colorado Fluorspar Corp.	Do.	Do.
Fahnestock, J. L.	Omaha, Nebr.	Poncha Springs
Lionelli, Joe	Salida	Salida
Salida Fluorspar Co.	Do.	Do.
		JACKSON COUNTY
Colorado Fluorspar Corp.	Cowdrey	Cowdrey
		MINERAL COUNTY
Colorado Fuel & Iron Corp.	Pueblo	Wagon Wheel Gap
ILLINOIS		
		HARDIN COUNTY
Aluminum Ore Co.	Pittsburgh, Pa.	Karbers Ridge, Rosiclare
Benzon Fluorspar Co.	Cave in Rock	Cave in Rock
Crystal Fluorspar Co.	Rosiclare	Do.
Cullum & Sons, Fred	Elizabethtown	Elizabethtown
Dimick, W. E.	Rosiclare	Rosiclare
Fluorspar Products Corp.	Elizabethtown	Cave in Rock, Rosiclare
Hillside Fluor Spar Mines	Chicago	Karbers Ridge, Rosiclare

SOURCES OF SUPPLY OF DOMESTIC FLUORSPAR—*Continued.*

Owner or lessee	Address	Location of mine or deposit
ILLINOIS—Continued		
		HARDIN COUNTY *(cont'd)*
Jackson, J. M.	Rosiclare	Rosiclare
Jefferson Mineral Corp.	Indianapolis, Ind.	Do.
Rorer & Lanham	Rosiclare	Hicks
Rosiclare Lead & Fluorspar Mining Co.	St. Louis, Mo.	Rosiclare
Sunbeam Fluorspar Co.	Louisville, Ky.	Cave in Rock
Victory Fluorspar Mining Co.	Elizabethtown	Elizabethtown
		POPE COUNTY
Crabb, Oscar	Rosiclare	Herod
Knight, Knight & Clark	Do.	Rosiclare
Taylor, R. F.	Elizabethtown	Eichorn
KENTUCKY		
		CALDWELL COUNTY
Arrow Fluorspar Co.	Princeton	Crider
Crook Corporation, S. L.	Crider	Do.
Glass Fluorspar Co.	Princeton	Do.
Hughett, John	Princeton	Princeton
Lester, C. F.	Do.	Do.
Princeton Spar Co.	Cincinnati, Ohio	Crider
Senator Fluorspar Co.	Princeton	Princeton
		CRITTENDEN COUNTY
Aluminum Ore Co.	Pittsburgh, Pa.	Crayne, Marion, Mexico, Salem
Bellamy, J. G.	Marion	Mexico
Clark, Joe	Do.	Marion
Conyer, J. O.	Do.	Do.
Corley, Robert B.	Do.	Do.
Cox, F. G.	Do.	Sheridan
Crider, W. H.	Mexico	Marion, Mexico
Damron, George	Salem	Salem
Davidson, R. P.	Marion	Marion
Delhi Foundry Sand Co.	Do.	Do.
Denny, O. S.	Do.	Do.
Eagle Fluor-Spar Co.	Salem	Salem
Forester, R. J.	Du Quoin, Ill.	Do.
Gugenheim Mining Co.	Marion	Do.
Haynes Fluorspar Co.	Do.	Do.
Hillside Fluor Spar Mines	Chicago, Ill.	Do.
Hodge Mining Co.	Marion	Do.
Holly Fluorspar Co.	Do.	Sheridan
Kentucky Fluor Spar Co.	Do.	Marion
Lafeyette Fluorspar Co.	Duluth, Minn.	Marion, Mexico
McClain, R. A.	Youngstown, Ohio	Marion
McMaster, Hunter & Tabor	Mexico	Mexico
Marion Mineral Co.	Fredonia	Mexico
National Fluorspar Co.	Marion	Salem
Perry & Loyd	Do.	Mexico
Pigmy Corporation	St. Louis, Mo.	Mexico

SOURCES OF SUPPLY OF DOMESTIC FLUORSPAR—*Continued.*

Owner or lessee	Address	Location of mine or deposit
KENTUCKY—Continued		
		CRITTENDEN COUNTY *(cont'd)*
Reed, A. H.	Marion	Marion
Reiter, W. A.	Mexia, Texas	Frances
Shewmaker & Shewmaker	Marion	Marion
Williamson, T. W.	Do.	Mexico
Zaiser & Zaiser	Indianapolis, Ind.	Marion
		LIVINGSTON COUNTY
Aluminum Ore Co.	Pittsburgh, Pa.	Salem
Brasher, J. A.	Salem	Salem
Collins, Arthur	Do.	Lola
Curtis Fluorspar Co.	Chicago, Ill.	Do.
Davis Mining Co.	Lola	Do.
Delhi Foundry Sand Co.	Marion	Lola, Salem
Eagle Fluor-Spar Co.	Salem	Salem
Flanery, C. A.	Marion	Do.
Grassham & Pace	Paducah	Do.
Haynes, W. V.	Marion	Salem
Johnson, B. A.	Lola	Lola
Klondike Fluorspar Corp.	Smithland	Smithland
Knight, Knight & Clark	Rosiclare, Ill.	Carrsville
Loveless, Dewey	Salem	Salem
May, Ernest	Lola	Lola
Myers, Vaughn	Marion	Do.
Roberts & Frazer	Do.	Salem, Carrsville
United Mining Co.	Lola	Lola
Wallace Fluorspar Co.	Sturgis	Salem
		WOODFORD COUNTY
Jones, Ralph E.	Wilmore	Wilmore
NEVADA		
		MINERAL COUNTY
Baxter, V. S.	Broken Hills	Broken Hills
		NYE COUNTY
Crowell, J. Irving, Jr.	Beatty	Beatty
NEW HAMPSHIRE		
		CHESHIRE COUNTY
New England Fluorspar Co.	Boston, Mass.	Westmoreland
NEW MEXICO		
		DONA ANA COUNTY
Hayner & Manasee	Las Cruces	Mesilla Park
		GRANT COUNTY
Great Eagle Mining Co.	Lampasas, Tex.	Lordsburg
Osmer, Louis L.	Silver City	Silver City
		LUNA COUNTY
Duryea Estate, J. T.	New York, N. Y.	Silton
La Purisima Fluorspar Co.	Deming	Deming

SOURCES OF SUPPLY OF DOMESTIC FLUORSPAR—*Concluded.*

Owner or lessee	Address	Location of mine or deposit
NEW MEXICO—Continued		
		SIERRA COUNTY
Alamo Fluorspar Mills	Hot Springs	Derry
Cox Fluorspar Co.	Caballo	Cutter
Fluorspar Mines of America	Hot Springs	Hot Springs
Kinetic Chemicals, Inc.	Wilmington, Del.	Derry
		SOCORRO COUNTY
Fluorspar Mines of America	Hot Springs	Oscuro
TENNESSEE		
		SMITH COUNTY
Purnell, R. C.	Lebanon	Carthage
TEXAS		
		HUDSPETH COUNTY
Melton, W. B.	Allamoore	Hot Wells
		PRESIDIO COUNTY
Warner, W. G.	Marfa	Shafter
UTAH		
		BEAVER COUNTY
Mortensen, Bart W.	Parowan	Lund
		TOOELE COUNTY
Dole, Frank E.	Salt Lake City	Clive
WASHINGTON		
		FERRY COUNTY
Mitchem, P. H. & A. W.	Los Angeles, Cal.	Keller

LIST OF CONSUMERS OF FLUORSPAR IN THE UNITED STATES

Consumers of fluorspar in the United States, classified according to the industries in which the mineral is used and each industry arranged alphabetically by States and by location of consuming plant, are listed below and shown on the map, figure 14, page 96. The address given is usually that of the purchasing agent.

CONSUMERS OF FLUORSPAR IN STEEL PLANTS IN THE UNITED STATES.

Name of consumer	Address	Location of plant
ALABAMA:		
Republic Steel Corp.	Cleveland, Ohio	Alabama City
Kilby Car & Foundry Co.	Anniston	Anniston
Tennessee Coal, Iron & Railroad Co.	Birmingham	Ensley, Fairfield
CALIFORNIA:		
Pacific Coast Steel Corp.	San Francisco	Huntington Park, South San Francisco
Alloy Steel & Metals Co.	Los Angeles	Los Angeles
Warman Steel Casting Co.	Huntington Park	Do.
American Manganese Steel Co.	New York, N. Y.	Los Angeles, Oakland
Judson Steel Corp.	San Francisco	Oakland
Columbia Steel Co.	Do.	Pittsburg, Torrance
National Supply Co. of Delaware.	Torrance	Torrance
COLORADO:		
American Manganese Steel So.	New York, N. Y.	Denver
Colorado Fuel & Iron Corp.	Pueblo	Pueblo
CONNECTICUT:		
American Tube & Stamping Co. (Stanley Works)	New Britain	Bridgeport
DELAWARE:		
Worth Steel Co.	Claymont	Claymont
American Manganese Steel Co.	New York	New Castle
DISTRICT OF COLUMBIA:		
Naval Gun Factory	Washington	Washington
GEORGIA:		
Atlantic Steel Co.	Atlanta	Atlanta
ILLINOIS:		
Laclede Steel Co.	St. Louis, Mo.	Alton
Burnside Steel Foundry Co.	Chicago	Chicago
Crane Co.	Do.	Do.
Kensington Steel Co.	Do.	Do.
Pettibone Mulliken Co.	Do.	Do.
Trojan Electric Steel Co.	Do.	Do.
American Manganese Steel Co.	New York, N. Y.	Chicago Heights
Columbia Tool Steel Co.	Chicago Heights	Do.
Railway Steel-Spring Co.	New York, N. Y.	Do.
National Malleable & Steel Castings Co.	Cleveland, Ohio	Cicero, Melrose Park
American Steel Foundries	Chicago	East St. Louis, Granite City
General Steel Castings Corp. (Commonwealth Division)	Eddystone, Pa.	Granite City
Granite City Steel Co.	Granite City	Do.
Western Electric Co.	New York, N. Y.	Hawthorne Station (Chicago)
Keystone Steel & Wire Co.	Peoria	Peoria
Carnegie-Illinois Steel Corp.	Chicago	South Chicago

CONSUMERS OF FLUORSPAR IN STEEL PLANTS IN THE UNITED STATES—*Continued.*

Name of consumer	Address	Location of plant
ILLINOIS—*Continued*		
International Harvester Co.	Chicago	South Chicago
Republic Steel Corp.	Youngstown, Ohio	Do.
INDIANA:		
Joslyn Manufacturing & Supply Co.	Fort Wayne	Fort Wayne
Carnegie-Illinois Steel Corp.	Chicago, Ill.	Gary
Inland Steel Co.	Indiana Harbor	Indiana Harbor
Youngstown Sheet & Tube Co.	Youngstown, Ohio	Do.
Continental Steel Corp.	Kokomo	Kokomo
Ingersoll Steel & Disc Co.	New Castle	New Castle
IOWA:		
Bettendorf Co.	Bettendorf	Bettendorf
Zimmerman Steel Co.	Do.	Do.
KENTUCKY:		
American Rolling Mill Co.	Middletown, Ohio	Ashland
Andrews Steel Co.	Newport	Newport
MARYLAND:		
Rustless Iron & Steel Corp.	Baltimore	Baltimore
Bethlehem Steel Co.	Bethlehem, Pa.	Sparrows Point
MASSACHUSETTS:		
General Electric Co.	Schenectady, N. Y.	Everett, Lynn
Watertown Arsenal	Watertown	Watertown
American Steel & Wire Co.	Cleveland, Ohio	Worcester
MICHIGAN:		
Clark Equipment Co.	Buchanan	Buchanan
Ford Motor Co.	Dearborn	Dearborn
Great Lakes Steel Corp.	Ecorse	Ecorse
MINNESOTA:		
American Steel & Wire Co.	Cleveland, Ohio	Duluth
MISSOURI:		
Sheffield Steel Corp.	Kansas City	Kansas City, St. Louis
Scullin Steel Co.	St. Louis	St. Louis
Southern Manganese Steel Co.	Do.	Do.
NEW JERSEY:		
Crucible Steel Co. of America	New York, N. Y.	Harrison
John A. Roebling's Sons Co.	Trenton	Roebling
NEW YORK:		
Republic Steel Corp.	Youngstown, Ohio	Buffalo
Wickwire Spencer Steel Co.	New York	Do.
Wickwire Bros.	Cortland	Cortland
Gould Coupler Corp.	Depew	Depew
Onondaga Steel Co.	Syracuse	Dewitt
Ludlum Steel Co.	Watervliet	Dunkirk, Watervliet
Bethlehem Steel Co.	Bethlehem, Pa.	Lackawanna

CONSUMERS OF FLUORSPAR IN STEEL PLANTS IN THE UNITED STATES—*Continued.*

Name of consumer	Address	Location of plant
NEW YORK—*Continued*		
Simmonds Saw & Steel Co.	Lockport	Lockport
General Electric Co.	Schenectady	Schenectady
Crucible Steel Co. of America	New York	Syracuse
OHIO:		
American Steel Foundries	Chicago, Ill.	Alliance
Republic Steel Corp.	Youngstown	Canton, Cleveland, Columbia Heights, Warren, Youngstown
Barium Stainless Steel Corp.	Canton	Canton
Timken Steel & Tube Co.	Do.	Do.
National Malleable & Steel Castings Co.	Cleveland	Cleveland
Otis Steel Co.	Do.	Do.
Ohio Steel Foundry Co.	Lima	Lima
National Tube Co.	Pittsburgh, Pa.	Lorain
Sharon Steel Corp.	Sharon, Pa.	Lowellville
Empire Sheet & Tin Plate Co.	Mansfield	Mansfield
Marion Steam Shovel Co.	Marion	Marion
American Rolling Mill Co.	Middletown	Middletown
Allis-Chalmers Manufacturing Co.	Norwood	Norwood
Wheeling Steel Corp.	Wheeling, W. Va.	Portsmouth, Steubenville
Bonney-Floyd Co.	Columbus	South Columbus
Buckeye Steel Castings Co.	Do.	Do.
Follansbee Bros. Co.	Pittsburgh, Pa.	Toronto
Carnegie-Illinois Steel Corp.	Chicago, Ill.	Youngstown
Youngstown Sheet & Tube Co.	Youngstown	Do.
OKLAHOMA:		
Sheffield Steel Corp.	Kansas City, Mo.	Sand Springs
PENNSYLVANIA:		
Jones & Laughlin Steel Corp.	Pittsburgh	Aliquippa, Pittsburgh
Vulcan Crucible Steel Co.	Aliquippa	Aliquippa
Beaver Falls Steel Co.	Beaver Falls	Beaver Falls
Bethlehem Steel Co.	Bethlehem	Bethlehem, Johnstown, Steelton
National Alloy Steel Co.	Blawnox	Blawnox
Braeburn Alloy Steel Corp.	Braeburn	Braeburn
Allegheny Steel Co.	Brackenridge	Brackenridge
Universal Steel Co.	Bridgeville	Bridgeville
American Rolling Mill Co.	Middletown, Ohio	Butler
Union Electric Steel Corp.	Pittsburgh	Carnegie
Carnegie-Illinois Steel Corp.	Chicago, Ill.	Clairton, Duquesne, Farrell, Munhall, North Braddock
Lukens Steel Co.	Coatesville	Coatesville
Colonial Steel Co.	Pittsburgh	Colona (Monaca)
American Steel & Wire Co.	Cleveland, Ohio	Donora
General Steel Castings Corp. (Eddystone Works)	Eddystone	Eddystone
Erie Forge & Steel Co.	Erie	Erie
Pittsburgh Steel Foundry Corp.	Glassport	Glassport
Central Iron & Steel Co.	Harrisburg	Harrisburg

CONSUMERS OF FLUORSPAR IN STEEL PLANTS IN THE UNITED STATES—*Concluded.*

Name of consumer	Address	Location of plant
PENNSYLVANIA—*Continued*		
Harrisburg Steel Corp.	Harrisburg	Harrisburg
National Forge & Ordnance Co.	Irvine	Irvine
Alan Wood Steel Co.	Conshohoken	Ivy Rock
Latrobe Electric Steel Co.	Latrobe	Latrobe
Vanadium Alloys Steel Co.	Do.	Do.
Firth-Sterling Steel Co.	McKeesport	McKeesport
National Tube Co.	Pittsburgh	Do.
Pittsburgh Crucible Steel Co.	New York, N. Y.	Midland
Pittsburgh Steel Co.	Pittsburgh	Monessen
Midvale Co.	Philadelphia	Nicetown
Edgewater Steel Co.	Pittsburgh	Oakmont
American Bridge Co.	Do.	Pencoyd
Henry Disston & Sons (Inc.)	Philadelphia	Philadelphia
Philadelphia Navy Yard	Do.	Do.
Phoenix Iron Co.	Do.	Phoenixville
Crucible Steel Co. of America	New York, N. Y.	Pittsburgh
Carpenter Steel Co.	Reading	Reading
National Malleable & Steel Castings Co.	Cleveland, Ohio	Sharon
American Sheet & Tin Plate Co.	Pittsburgh	Vandergrift
American Steel Foundries	Chicago, Ill.	Verona
Jessop Steel Co.	Washington	Washington
RHODE ISLAND:		
Washburn Wire Co.	Phillipsdale	Phillipsdale
TEXAS:		
Hughes Tool Co.	Houston	Houston
VIRGINIA:		
Newport News Shipbuilding & Dry Dock Co.	Newport News	Newport News
Norfolk Navy Yard	Norfolk	Portsmouth
Norfolk & Western Railway Co.	Roanoke	Roanoke
WASHINGTON:		
Puget Sound Navy Yard	Bremerton	Bremerton
Pacific Car & Foundry Co.	Renton	Renton
Washington Iron Works	Seattle	Seattle
Pacific Coast Steel Corp.	San Francisco, Calif.	Youngtown
WEST VIRGINIA:		
Follansbee Bros. Co.	Pittsburgh, Pa.	Follansbee
Weirton Steel Co.	Weirton	Weirton
WISCONSIN:		
Moloch Foundry & Machine Co.	Kaukauna	Kaukauna
Milwaukee Steel Foundry Co.	Milwaukee	Milwaukee
Racine Steel Castings Co.	Racine	Racine
Bucyrus-Erie Co.	South Milwaukee	South Milwaukee

CONSUMERS OF FLUORSPAR IN IRON FOUNDRIES IN THE UNITED STATES.

Name of consumer	Address	Location of plant
ALABAMA:		
American Radiator Co.	New York, N. Y.	Birmingham
CALIFORNIA:		
Washington Eljer Co.	Los Angeles	Los Angeles
Standard Sanitary Manufacturing Co.	Pittsburgh, Pa.	Richmond
CONNECTICUT:		
Crane Co.	Bridgeport	Bridgeport
North & Judd Manufacturing Co.	New Britain	New Britain
ILLINOIS:		
Crane Co.	Chicago	Chicago
Moore Bros. Co.	Joliet	Joliet
Walworth Co.	Kewanee	Kewanee
American Radiator Co.	New York, N. Y.	Litchfield, Springfield
INDIANA:		
New York Central Ralroad Co.	Collinwood, Ohio	Elkhart
Perfect Circle Co.	New Castle	New Castle
Studebaker Corp.	South Bend	South Bend
IOWA:		
French & Hecht (Inc.)	Davenport	Davenport
Maytag Co.	Newton	Newton
MASSACHUSETTS:		
Richards Co.	Boston	Malden
Gilbert & Barker Manufacturing Co.	Springfield	West Springfield
MICHIGAN:		
Ford Motor Co.	Dearborn	Dearborn
American Radiator Co.	New York, N. Y.	Detroit
Cadillac Motor Car Co.	Detroit	Do.
Packard Motor Car Co.	Do.	Do.
Buick Motor Co.	Flint	Flint
Campbell, Wyant & Cannon Foundry Co.	Muskegon	Muskegon
Sealed Power Corp.	Do.	Do.
Wilson Foundry & Machine Co.	Pontiac	Pontiac
Sparta Foundry Co.	Sparta	Sparta
Central Specialty Co.	Ypsilanti	Ypsilanti
MINNESOTA:		
American Radiator Co.	New York, N. Y.	St. Paul
MISSOURI:		
American Radiator Co.	New York, N. Y.	Kansas City
NEW JERSEY:		
American Radiator Co.	New York, N. Y.	Bayonne
Driver-Harris Co.	Harrison	Harrison

CONSUMERS OF FLUORSPAR IN IRON FOUNDRIES IN THE UNITED STATES—*Concluded.*

Name of consumer	Address	Location of plant
NEW YORK:		
American Radiator Co.	New York	Black Rock (Buffalo)
Standard-North Buffalo Foundry Co.	Buffalo	Buffalo
Kennedy Valve Manufacturing Co	Elmira	Elmira
General Electric Co.	Schenectady	Schenectady
OHIO:		
Hill & Griffith Co.	Cincinnati	Cincinnati
Fox Furnace Co.	Elyria	Elyria
Electric Auto-Lite Co.	Fostoria	Fostoria
Estate Stove Co.	Hamilton	Hamilton
Allis-Chalmers Manufacturing Co.	Norwood	Norwood
Quality Castings Co.	Orrville	Orrville
Toledo Machine & Tool Co.	Toledo	Toledo
PENNSYLVANIA:		
Westinghouse Electric & Manufacturing Co.	East Pittsburgh	East Pittsburgh
Hays Manufacturing Co.	Erie	Erie
Standard Stoker Co.	Do.	Do.
Westinghouse Air Brake Co.	Wilmerding	Wilmerding
TENNESSEE:		
Crane Enamelware Co.	Chattanooga	Chattanooga
WISCONSIN:		
Kohler Co.	Kohler	Kohler
Rundle Manufacturing Co.	Milwaukee	Milwaukee

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF FERRO-ALLOYS IN THE UNITED STATES.

Name of consumer	Address	Location of plant
IOWA:		
Keokuk Electro-Metals Co.	Keokuk	Keokuk
NEW YORK:		
Electro Metallurgical Co.	New York	Niagara Falls
Vanadium Corp. of America	Do.	Do.
OHIO:		
United States Vanadium Corp.	Columbiana	Columbiana
Ohio Ferro-Alloys Corp.	Canton	Philo
PENNSYLVANIA:		
Vanadium Corp. of America	New York, N. Y.	Bridgeville
Climax Molybdenum Co.	Do.	Langeloth
Molybdenum Corp. of America	Do.	Washington
WEST VIRGINIA:		
Electro Metallurgical Co.	New York, N. Y.	Alloy

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF GLASS IN THE UNITED STATES.

Name of consumer	Address	Location of plant
CALIFORNIA:		
Owens-Illinois Glass Co.	Toledo, Ohio	Los Angeles
ILLINOIS:		
Owens-Illinois Glass Co.	Toledo, Ohio	Alton, Chicago Heights, Streator
Inland Glass Works (Inc.)	Chicago	Chicago
Ball Bros. Co.	Muncie, Ind.	Hillsboro
Peltier Glass Co.	Ottawa	Ottawa
INDIANA:		
Owens-Illinois Glass Co.	Toledo, Ohio	Gas City
Macbeth-Evans Glass Co.	Charleroi, Pa.	Elwood
Sneath Glass Co.	Hartford City	Hartford City
Kokomo Opalescent Glass Co.	Kokomo	Kokomo
Canton Glass Co.	Marion	Marion
Ball Bros. Co.	Muncie	Muncie
General Glass Corp.	Winchester	Winchester
MARYLAND:		
Carr-Lowrey Glass Co.	Baltimore	Baltimore
NEW JERSEY:		
Owens-Illinois Glass Co.	Toledo, Ohio	Bridgeton
Kimble Glass Co.	Vineland	Vineland
NEW YORK:		
Dannenhoffer Glass Works	Brooklyn	Brooklyn
Demuth Glass Manufacturing Co.	Do.	Do.
Gleason-Tiebout Glass Co.	Do.	Brooklyn, Maspeth
Corning Glass Works	Corning	Corning
Louis C. Tiffany Furnaces	Corona	Corona
Gillinder Brothers (Inc.)	Port Jervis	Port Jervis
OHIO:		
Rodefer Glass Co.	Bellaire	Bellaire
Houston-Wells Glass Co.	Bremen	Bremen
Cambridge Glass Co.	Cambridge	Cambridge
Owens-Illinois Glass Co.	Toledo	Columbus
Hocking Glass Co.	Lancaster	Lancaster
Lancaster Glass Co.	Do.	Do.
Advance Glass Co.	Newark	Newark
Libbey-Owens-Ford Glass Co.	Toledo	Toledo
Libbey Glass Co.	Do.	Do.
Hazel-Atlas Glass Co.	Wheeling, W. Va.	Zanesville
OKLAHOMA:		
Hazel-Atlas Glass Co.	Wheeling, W. Va.	Ada, Blackwell
Ball Bros. Co.	Muncie, Ind.	Okmulgee
Kerr, Hubbard & Kelly	Sand Springs	Sand Springs
PENNSYLVANIA:		
Macbeth-Evans Glass Co.	Charleroi	Charleroi
Consolidated Lamp & Glass Co.	Corapolis	Corapolis

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF GLASS IN THE UNITED STATES—*Concluded.*

Name of consumer	Address	Location of plant
PENNSYLVANIA—*Continued*		
Pittsburgh Plate Glass Co.	Ford City	Ford City
Point Marion Glass Novelty Co.	Guyaux	Guyaux
Jeannette Glass Co.	Jeannette	Jeannette
Jeannette Shade & Novelty Co.	Do.	Do.
McKee Glass Co.	Do.	Do.
Phoenix Glass Co.	Monaca	Monaca
Gill Glass and Fixture Co.	Philadelphia	Philadelphia
L. J. House Convex Glass Co.	Point Marion	Point Marion
Gillinder & Sons (Inc.)	Philadelphia	Tacony (Philadelphia)
Duncan & Miller Glass Co.	Washington	Washington
Hazel-Atlas Glass Co.	Wheeling, W. Va.	Do.
Mississippi Glass Co.	Washington	Do.
TEXAS:		
Ball Bros. Co.	Muncie, Ind.	Wichita Falls
WEST VIRGINIA:		
Owens-Illinois Glass Co.	Toledo, Ohio	Charleston, Fairmont, Huntington
Akro Agate Co.	Clarksburg	Clarksburg
Master Marble Co.	Do.	Do.
Jefferson Glass Co.	Follansbee	Follansbee
Hazel-Atlas Glass Co.	Wheeling	Grafton
Ball Bros. Co.	Muncie, Ind.	Huntington
Sinclair Glass Co.	Huntington	Do.
Beaumont Co.	Morgantown	Morgantown
Morgantown Glass Works	Do.	Do.
New Martinsville Glass Manufacturing Co.	New Martinsville	New Martinsville
Paul Wissmach Glass Co.	Long Island City, N. Y.	Paden City
Marion Glass Co.	Shinnston	Shinnston
Lawrence Glass Novelty Co.	Sistersville	Sistersville
Westite Co.	Weston	Weston
Fenton Art Glass Co.	Williamstown	Williamstown

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF CHEMICALS IN THE UNITED STATES.

Name of consumer	Address	Location of plant
DELAWARE:		
Kinetic Chemicals (Inc.)	Wilmington	Carney's Point
ILLINOIS:		
Aluminum Ore Co.	Pittsburgh, Pa.	East St. Louis
Lindsay Light & Chemical Co.	West Chicago	West Chicago
INDIANA:		
U. S. S. Lead Refinery (Inc.)	New York, N. Y.	East Chicago
OHIO:		
Harshaw Chemical Co.	Cleveland	Cleveland
PENNSYLVANIA:		
Sterling Products Co.	Easton	Easton
General Chemical Co.	New York, N. Y.	Marcus Hook, Newell

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF ENAMEL, VITROLITE, AND GLAZES IN THE UNITED STATES.

Name of consumer	Address	Location of plant
CALIFORNIA:		
Smoot-Holman Co.	Inglewood	Inglewood
California Metal Enameling Co.	Los Angeles	Los Angeles
Washington Eljer Co.	Do.	Do.
Standard Sanitary Manufacturing Co.	Pittsburgh, Pa.	Richmond
ILLINOIS:		
Roesch Enamel Range Co.	Belleville	Belleville
Century Vitreous Enamel Co.	Chicago	Chicago
Federal Electric Co.	Do.	Do.
General Porcelain Enameling & Manufacturing Co.	Do.	Do.
Chicago Vitreous Enamel Product Co.	Cicero	Cicero
Benjamin Electric Manufacturing Co.	Des Plaines	Des Plaines
Chicago Hardware Foundry Co.	North Chicago	North Chicago
INDIANA:		
Ingram-Richardson Mfg. Co. of Indiana (Inc.)	Frankfort	Frankfort
Marietta Manufacturing Corp.	Indianapolis	Indianapolis
Columbian Enameling & Stamping Co.	Terre Haute	Terre Haute
KENTUCKY:		
Standard Sanitary Manufacturing Co.	Pittsburgh, Pa.	Louisville
MARYLAND:		
Baltimore Enamel & Novelty Co.	Baltimore	Baltimore
Jones Hollow Ware Co.	Do.	Do.
Porcelain Enamel & Manufacturing Co.	Do.	Do.
Standard Sanitary Manufacturing Co.	Pittsburgh, Pa.	Do.
A. Weiskittel & Son Co.	Baltimore	Do.
MASSACHUSETTS:		
General Electric Co.	Schenectady, N. Y.	Lynn
MICHIGAN:		
Detroit-Michigan Stove Co.	Detroit	Detroit
Michigan Enameling Works	Kalamazoo	Kalamazoo
NEW JERSEY:		
Rundle Manufacturing Co.	Milwaukee, Wis.	Camden
Central Stamping Co.	Newark	Newark
NEW YORK:		
Republic Metal Ware Co.	Buffalo	Buffalo
Lisk Manufacturing Co.	Canandaigua	Canandaigua

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF ENAMEL, VITROLITE, AND GLAZES IN THE UNITED STATES—*Continued.*

Name of consumer	Address	Location of plant
NEW YORK—*Continued*		
Vitreous Enameling & Stamping Co.	New York	New York
Titanium Alloy Manufacturing Co.	Niagara Falls	Niagara Falls
Pfaudler Co.	Rochester	Rochester
OHIO:		
Bellaire Enamel Co.	Bellaire	Bellaire
Canton Stamping & Enameling Co.	Canton	Canton
Republic Stamping & Enameling Co.	Do.	Do.
Limberg Enameling Works	Cincinnati	Cincinnati
Enamel Products Co.	Cleveland	Cleveland
Ferro Enamel Corp.	Do.	Do.
Perfection Stove Co.	Do.	Do.
Ebco Manufacturing Co.	Columbus	Columbus
Beach Enameling Co.	Coshocton	Coshocton
Pfaudler Co.	Rochester, N. Y.	Elyria
Barnes Manufacturing Co.	Mansfield	Mansfield
Humphryes Manufacturing Co.	Do.	Do.
Belmont Stamping & Enameling Co.	New Philadelphia	New Philadelphia
National Sanitary Co.	Salem	Salem
Moore Enameling & Manufacturing Co.	West Lafayette	West Lafayette
Roseville Pottery Co.	Zanesville	Zanesville
S. A. Weller Co.	Do.	Do.
PENNSYLVANIA:		
Ingram-Richardson Manufacturing Co.	Beaver Falls	Beaver Falls
Conemaugh Iron Works	Blairsville	Blairsville
John Dunlap Co.	Pittsburgh	Carnegie
O. Hommel Co.	Do.	Do.
Beaver Enameling Co.	Ellwood City	Ellwood City
Ellwood Co.	Do.	Do.
Roberts & Mander Stove Co.	Philadelphia	Hatboro
Federal Enameling & Stamping Co.	McKees Rocks	McKees Rocks
Marietta Hollow Ware & Enameling Co.	Marietta	Marietta
United States Sanitary Manufacturing Co.	Pittsburgh	Monaca
Ceramic Color and Chemical Manufacturing Co.	New Brighton	New Brighton
Standard Sanitary Manufacturing Co.	Pittsburgh	Pittsburgh
Vitro Manufacturing Co.	Do.	Do.
Richmond Radiator Co.	Uniontown	Uniontown
Iron City Sanitary Manufacturing Co.	Pittsburgh	Zelienople

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF ENAMEL, VITROLITE, AND GLAZES IN THE UNITED STATES—*Concluded.*

Name of consumer	Address	Location of plant
TENNESSEE:		
Crane Enamelware Co.	Chattanooga	Chattanooga
Samuel Stamping Enameling Co.	Do.	Do.
Tennessee Enamel Manufacturing Co.	Nashville	Nashville
WEST VIRGINIA:		
Fletcher Enamel Co.	Charleston	Dunbar
United States Stamping Co.	Moundsville	Moundsville
Libbey-Owens-Ford Glass Co.	Toledo, Ohio	Parkersburg
WISCONSIN:		
Malleable Iron Range Co.	Beaver Dam	Beaver Dam
Kohler Co.	Kohler	Kohler
Geuder, Paeschke & Frey Co.	Wilwaukee	Milwaukee
A. J. Lindemann & Hoverson Co.	Do.	Do.
Rundle Manufacturing Co.	Do.	Do.
A. O. Smith Corp	Do.	Do.
Polar Ware Co.	Sheboygan	Sheboygan
Vollrath Co.	Do.	Do.

CONSUMERS OF FLUORSPAR IN THE MANUFACTURE OF CEMENT IN THE UNITED STATES.

Name of consumer	Address	Location of plant
CALIFORNIA:		
Monolith Portland Cement Co.	Los Angeles	Monolith
MISSOURI:		
Missouri Portland Cement Co.	St. Louis	Prospect Hill
NEW YORK:		
Glens Falls Portland Cement Co.	Glens Falls	Glens Falls
OHIO:		
Southwestern Portland Cement Co.	Osborn	Osborn
PENNSYLVANIA:		
Coplay Cement Manufacturing Co.	Coplay	Coplay
TEXAS:		
Trinity Portland Cement Co.	Dallas	Eagle Ford, Houston
WASHINGTON:		
Superior Portland Cement (Inc.)	Seattle	Concrete
WYOMING:		
Monolith Portland-Midwest Co.	Los Angeles, Calif.	Laramie

CONSUMERS OF FLUORSPAR FOR MISCELLANEOUS PURPOSES IN THE UNITED STATES.

Name of consumer	Address	Location of plant
CALIFORNIA:		
Federated Metals Corp.	San Francisco	San Francisco
COLORADO:		
American Smelting & Refining Co.	New York, N. Y.	Leadville
IDAHO:		
Sullivan Mining Co.	Kellogg	Kellogg
ILLINOIS:		
Federated Metals Corp.	Chicago	Chicago
Evans-Wallower Zinc Co.	East St. Louis	East St. Louis
MICHIGAN:		
Michigan Smelting & Refining Co.	Detroit	Detroit
NEBRASKA:		
American Smelting & Refining Co.	New York, N. Y.	Omaha
NEW JERSEY:		
American Smelting & Refining Co	New York, N. Y.	Perth Amboy
Federated Metals Corp.	Do.	Newark
Rouse & Shearer	Trenton	Trenton
NEW YORK:		
Aluminum Co. of America	Pittsburgh, Pa.	Massena, Niagara Falls
American Valve Co.	Coxsackie	Coxsackie
Nassau Smelting & Refining Co.	Tottenville	Tottenville
The Carborundum Co.	Niagara Falls	Niagara Falls
National Carbon Co.	New York	Niagara Falls
NORTH CAROLINA:		
Aluminum Co. of America	Pittsburgh, Pa.	Badin
OHIO:		
Lincoln Electric Co.	Cleveland	Cleveland
Shepherd Chemical Co.	Cincinnati	Cincinnati
PENNSYLVANIA:		
American Smelting & Refining Co (Federated Metals Division)	New York, N. Y.	Pittsburgh
TENNESSEE:		
Aluminum Co. of America	Pittsburgh, Pa.	Alcoa
TEXAS:		
Texas Mining & Smelting Co.	Laredo	Laredo
WEST VIRGINIA:		
International Nickel Co.	New York, N. Y.	Huntington

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