

FLUORSPAR.

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Fluorspar is one of the nonmetallic minerals of moderate intrinsic value the demand for which has increased greatly since the beginning of the European war, on account of its usefulness in the metallurgic, ceramic, and chemical industries, especially in the manufacture of open-hearth steel, enameled ware, and hydrofluoric acid.

CHARACTER AND OCCURRENCE.

Fluorspar, or fluorite, chemically calcium fluoride (CaF_2), consists of calcium and fluorine in the proportions of 51.1 to 48.9. The mineral is only slightly harder than calcite and consequently crushes easily, but it may be distinguished from calcite by its failure to effervesce with dilute hydrochloric acid. It crystallizes in the isometric system and is often found in cubical crystals. In color the spar ranges, according to purity, from a clear, colorless, or slightly bluish glasslike substance through various brilliant shades, and much of it is white and opaque. The mineral is usually very pure, some of the material marketed running 98 to 99 per cent of calcium fluoride. It commonly occurs in veins cutting both sedimentary and igneous rocks.

Fluorspar, associated with other minerals, has a broad distribution geographically and a wide range geologically. The deposits thus far exploited in the United States are, however, confined to Arizona, Colorado, Illinois, Kentucky, New Hampshire, New Mexico, and Tennessee.

The Arizona output has come mainly from the Castle Dome district, Yuma County, but during recent years there has been little production. Fluorspar has been reported also in Cochise, Maricopa, Mohave, Pima, Pinal, and Yavapai counties.

In Colorado fluorspar has been mined in Boulder, Jefferson, and Custer counties, along the Front Range, and in Mineral County at Wagon Wheel Gap, and it occurs in many other counties.

The chief deposits in Illinois and Kentucky occur in adjoining portions of the two States, Hardin and Pope counties in Illinois being

separated from the Kentucky counties, Crittenden, Livingston, and Caldwell, by Ohio River. The great size and the purity of the fluorspar deposits of the Illinois-Kentucky district indicate that for many years they will continue the main source of domestic production. Prospecting with favorable results has been reported from Mercer County, in central Kentucky. Other Kentucky counties in which fluorspar is reported are Fayette, Jessamine, Trigg, and Woodford.

The deposit thus far developed in New Hampshire is near Westmoreland, Cheshire County.

In New Mexico fluorspar has been mined from several veins 10 miles northeast of Deming, Luna County, and in the Burro Mountain district, Grant County, and is reported also in Bernalillo, Sandoval, and Socorro counties.

The Tennessee production has come from Smith, Trousdale, and Wilson counties, and fluorspar is reported to occur in Carter County.

A possible addition to the list of producing States is California, as fluorspar has been reported in Inyo, Los Angeles, Mono, San Bernardino, and San Diego counties.

Fluorspar is reported to have been separated in the concentration of lead and zinc ores in Albemarle County, Va.; of gold tellurides at Cripple Creek, Colo., and at a number of localities in other States in quantities too small for use at present. Practically, wherever it has been mined, fluorspar occurs as a vein material, although under widely different conditions. In the Kentucky-Illinois district it is the chief mineral of value in the veins, lead and zinc being of secondary importance and, in many places, not valuable even as by-products, but in the Castle Dome district of Arizona jig concentrates of fluorspar have been made incidentally to concentrating the lead-silver ores. Some lump spar has also been saved in this district. In 1916 a small tonnage of spar was reported to have been mined, but not shipped, in Ferry County, Wash.

In England fluorspar occurs abundantly in the Carboniferous limestone and associated shale, limestone, and sandstone of the Yoredale group, where it is found as the gangue of metalliferous veins. It is usually but not invariably associated with calcite, quartz, and barytes. The principal producing localities are in Durham and Derbyshire. A large proportion of the fluorspar produced in England has been obtained by screening from waste dumps of old lead mines, but it is reported that these sources of supply are approaching exhaustion.¹

In Canada there are deposits of fluorspar, but little has been published concerning them. A small production has been reported from time to time.

¹ Strahan, A., Great Britain Geol. Survey Mem., vol. 4, p. ii, 1916.

PREPARATION AND USES.

The uses of fluorspar depend on its chemical composition, fluxing properties, and phosphorescence when heated and on its optical and gemlike properties. Its preparation involves separation from other minerals with which it is associated, the treatment including such processes as hand-sorting, crushing, washing, screening, jigging, and flotation, depending on the nature of the ore and the extent to which concentration is practicable.¹ Part of the high-grade ore is ground and shipped in barrels and sacks; the rest is sold in lump form. Where fluorspar is associated with sphalerite, or zinc blende, complete separation of the two minerals has been difficult on account of their nearness in specific gravity. Although fluorspar is useful in smelting iron ores it is harmful to zinc, and the sulphur in the sphalerite can not be permitted in the iron and steel furnaces, therefore zinc-fluorspar concentrates are of little value unless the fluorite and sphalerite can be cleanly separated. A process for separating these minerals by means of flotation in a dilute solution of aluminum sulphate has been developed, it is reported, at Marion, Ky., the flotation being performed in shallow pans, in which mechanical stirrers are operated.

The three principal industries in which fluorspar is utilized are, in order of importance, (1) metallurgic work, (2) the manufacture of opalescent glass and sanitary and enameled ware, and (3) chemical manufacture. The highest grade, "American lump No. 1," which runs less than 1 per cent silica and is white or clear pale blue or green, is sold either ground or in lumps for use in the glass, enameling, and chemical industries, including the manufacture of hydrofluoric acid. Grinding of the pure, clear spar is unnecessary for some purposes, as the lumps readily decrepitate to a powder when heated. The second grade, "American lump No. 2," is used in blast furnaces in the production of ferrosilicon and ferromanganese and in basic open-hearth steel furnaces to give fluidity to the slag without increasing its temperature and to reduce the contents of phosphorus and sulphur. This grade includes colored spar and may run as high as 4 per cent silica, though most of it is sold with a 3 per cent guaranty. The lowest grade, "gravel spar," including all that contains more than 4 per cent silica as well as spar mixed with calcite, is also largely used in basic open-hearth steel furnaces, where it is added to fluxing limestone, and in iron and brass foundries, where it is of value in making the metal more fluid, in permitting the use of greater quantities of lower grades and scrap, and because it tends to carry phosphorus, sulphur, and other impurities into the slag. It is estimated that about 80 per cent of the domestic output of fluorspar, mainly in the form of gravel spar,

¹ Burchard, E. F., Fluorspar mining and milling at Rosiclare, Ill.: Eng. and Min. Jour., Dec. 2, 1911, pp. 1088-1090; Iron Trade Rev., Dec. 16, 1911, pp. 1046-1051.

and practically all the imported spar is now consumed as a flux in the basic open-hearth steel furnaces. In the Bessemer process it has been used in the form of artificial fluorides of iron and manganese.

Fluorspar possesses a considerably higher quantitative efficiency as a flux than limestone, especially in smelting refractory ores; but in all metallurgic operations the proportions of the spar that can be used are limited, as its favorable effects do not increase indefinitely as the quantity is increased. In England and on the Continent the metallurgic use of fluorspar has heretofore been more common than in America, probably because its value has been better understood by European metallurgists. Other minor metallurgic uses of fluorspar are in the extraction of aluminum from bauxite, in smelting gold, silver, and copper ores, in refining copper, in the electrolytic refining of antimony and lead, and in refining lead bullion. In the last-named process the spar is first converted into hydrofluoric acid. In the extraction of aluminum fluorspar is reported to be fused with bauxite and soda ash into a product resembling an artificial cryolite (sodium-aluminum fluoride), to which more bauxite is added, and from this mixture aluminum is extracted in the electric furnace. Miscellaneous uses that have been reported are as a bond for constituents of emery wheels, for carbon electrodes to increase their lighting efficiency while also decreasing the amount of current required, in the extraction of potash from feldspar, and in the manufacture of Portland cement.

Fluorspar for iron and steel making should carry at least 85 per cent calcium fluoride and preferably more, and it should be free from sulphides and sulphates. For most other chemical uses it should contain 95 to 98 per cent or more of calcium fluoride.

The following analyses of gravel fluorspar, most of them made in laboratories of steel works, show the character of commercial shipments of spar. The spar from Colorado and New Mexico has not been washed; that from Illinois and Kentucky has been subjected to mechanical treatment, including washing.

Analyses of gravel fluorspar from Colorado, New Mexico, Illinois, and Kentucky.

Locality.	Calcium fluoride (CaF ₂).	Silica (SiO ₂).	Oxides, mostly iron (Fe ₂ O ₃) and alumina (Al ₂ O ₃).	Calcium carbonate (CaCO ₃).	Barium sulphate (BaSO ₄).
Colorado:					
Jamestown.....	82.16	10.64	4.27	2.26	.....
Jefferson.....	68.34	28.33	1.69	1.34	.....
Morrison.....	72.21	21.93	3.08	2.78	.....
Rosita.....	86.75	9.3	4.2	.....	.....
Wagon Wheel Gap.....	90.08	2.21	2.14	1.17	3.22-6.00
New Mexico:					
Near Deming.....	92.31	5.28	1.07	1.19	.....
Do.....	88.94	8.35	1.20	1.34	.....
Illinois:					
Rosiclare.....	87.64	4.15	1.58	6.41	.....
Do.....	90.41	3.35	1.03	4.33	.....
Fairview.....	88.85	3.4	1.45	.....	.....
Do.....	87.07	3.12	.....	8.96	.....
Kentucky:					
Marion.....	87.8	3.10	2.06	.....	.....
Do.....	90.02	4.72	1.5	.....	.....

The following notes¹ on the use and requirements of fluorspar for optical purposes have been published by the Kentucky Geological Survey:

An apochromatic lens is one that shows objects viewed or magnified through it more nearly free from color rings than is obtainable with any other kind of lens. For this purpose certain transparent minerals crystallizing in the isometric system (cubes, octahedrons, etc.) come nearest fulfilling the required conditions, because they do not show objects viewed through them double (double refractions). The diamond is suitable when found completely transparent, but owing to its high refractive power and reflection from two faces rarely occurs in this condition, not to mention its prohibitive high cost and difficulty of grinding.

Fluorspar has low refractive and dispersive powers and hence is especially adapted to the production of such lenses, as was pointed out by Abbe. It is much sought after by European optical makers where perfect lenses are necessary for the highest class of such instruments as spectrosopes, etc. Such lenses show very low differences because of refraction. For the three hydrogen lines H_{α} , H_{β} , and H_{γ} the differences in refractive indices are $n_{\beta}-n_{\alpha}=0.00455$ and $n_{\gamma}-n_{\beta}=0.00255$. (Dana, *New system of mineralogy*, 1901, p. 1034.) It is of special value for certain work in ultraviolet light.

Fluorite pellucid (water-clear) enough for this purpose is, however, extremely rare. It is to be found in simple crystals of fluorspar groups which are either colorless or very light yellow, green, blue, etc. As the crystal faces are usually dull or have a satin luster, it is necessary to cut off (truncate) the corners of the cubes along cleavage planes, to determine whether it contains any sufficiently clear and flawless. The clearest portion usually occurs in the center of the triangular face exposed by truncation. A peculiar property of fluorite of this quality is its conchoidal (irregularly curved) fractures and less facile cleavage. Twinned crystals usually show flaws due to striae along twinning planes, hence do not contain optical fluorite. Pieces as small as one-quarter inch across may serve for lenses, though, of course, larger ones are more valuable. Prices range according to size and quality of pieces.

As indicated above, fluorspar suitable for optical purposes is very rare and difficult to obtain. At present there is no reported domestic production of it. Some absolutely clear fluorspar has been imported from Japan and has been valued at about \$30 an ounce. Such fluorspar has been used as part of the lens in a telescope in order to correct certain color effects, and pieces only a few millimeters thick will suffice.

There is an abundance of crystalline fluorspar in southern Illinois, western Kentucky, southwestern New Hampshire, and at many places in Colorado, New Mexico, and Arizona, but most of the material is colored faint to deep shades of purple or green. In the hope of finding a domestic supply of fluorspar suitable for optical purposes the United States Geological Survey has already communicated with the fluorspar producers of the country, earnestly requesting them to watch carefully for any crystals that may appear exceptionally clear and free from flaws or fractures, and to notify the Survey if anything is discovered that may be thought to be of value for the purposes mentioned in order that arrangements may be made for testing the material. In response to the letters of the Survey several promising samples had been received from domestic sources up to July 15, 1917.

¹ Fohs, F. J., *Fluorspar deposits of Kentucky*: Kentucky Geol. Survey Bull. 9, pp. 178-179, 1907.

INDUSTRY PRECEDING AND DURING THE WAR.

Prior to 1905 the production of fluorspar was less than 50,000 short tons annually; up to 1908 it fluctuated considerably, but in 1909 it began to increase rapidly, owing to the more general recognition of the value of fluorspar in the manufacture of open-hearth steel and to the expansions in facilities for mining and milling the mineral in Illinois and Kentucky. There was a steady increase in production from 1908 to 1912, but in 1913 and 1914 there were decreases coincident with depression in the steel industry. In 1915 and 1916 the production largely increased, owing to the revival of the steel and chemical industries, the output for both of these years exceeding all previous records. During the period 1910 to 1916, for which complete records are available, there has been almost steady decrease in imports, but the considerable falling off during the war years may be attributed to the interruption to commerce as well as to depression in the mining industry in England caused by the scarcity of available miners.

Fluorspar produced and imported before and during the war, in short tons.

Year.	Production.	Imports.
1911.....	87,048	32,764
1912.....	116,545	26,176
1913.....	115,580	22,682
1914.....	95,116	10,205
1915.....	136,941	7,167
1916.....	155,735	12,323

From this table it is apparent that American fluorspar deposits have proved ample to supply more than the additional fluorspar needed to make up for the decrease in imports. There are no considerable exports of fluorspar at present, so that the consumption is represented practically by the domestic production plus the imports. This is shown graphically in figure 5.

The average price of domestic fluorspar at mines or local shipping points, for all localities and all grades of spar, has ranged between \$5.50 and \$6.50 a short ton during the last four years. The price decreased from 1913 to 1915 but increased more than 50 cents a ton in 1916. Ground spar has commanded the highest price—from \$10.75 to \$13.15 in recent years; lump spar has brought from \$6.90 to \$13, and gravel spar from \$4.85 to \$10 a ton, the price depending on quality, locality, and condition of the market.

Practically all the fluorspar imported in recent years has been a medium-grade gravel spar, brought over either as ballast or at a very low ocean freight rate, and, having been recovered from old mine dumps, it can be sold at a low figure on the American market. The highest average valuation assigned to such spar in the last six years is \$4.38 a ton in 1916, and the lowest is \$2.46 in 1911. These values do not include the duty, which, together with freight charges, must be added to the declared value in order to arrive at an average approximation of cost to the consumer. A tariff of \$3 a ton was imposed on imported fluorspar by the Payne-Aldrich bill in August, 1909. Prior to that time the mineral had been imported duty free.

SHORT TONS

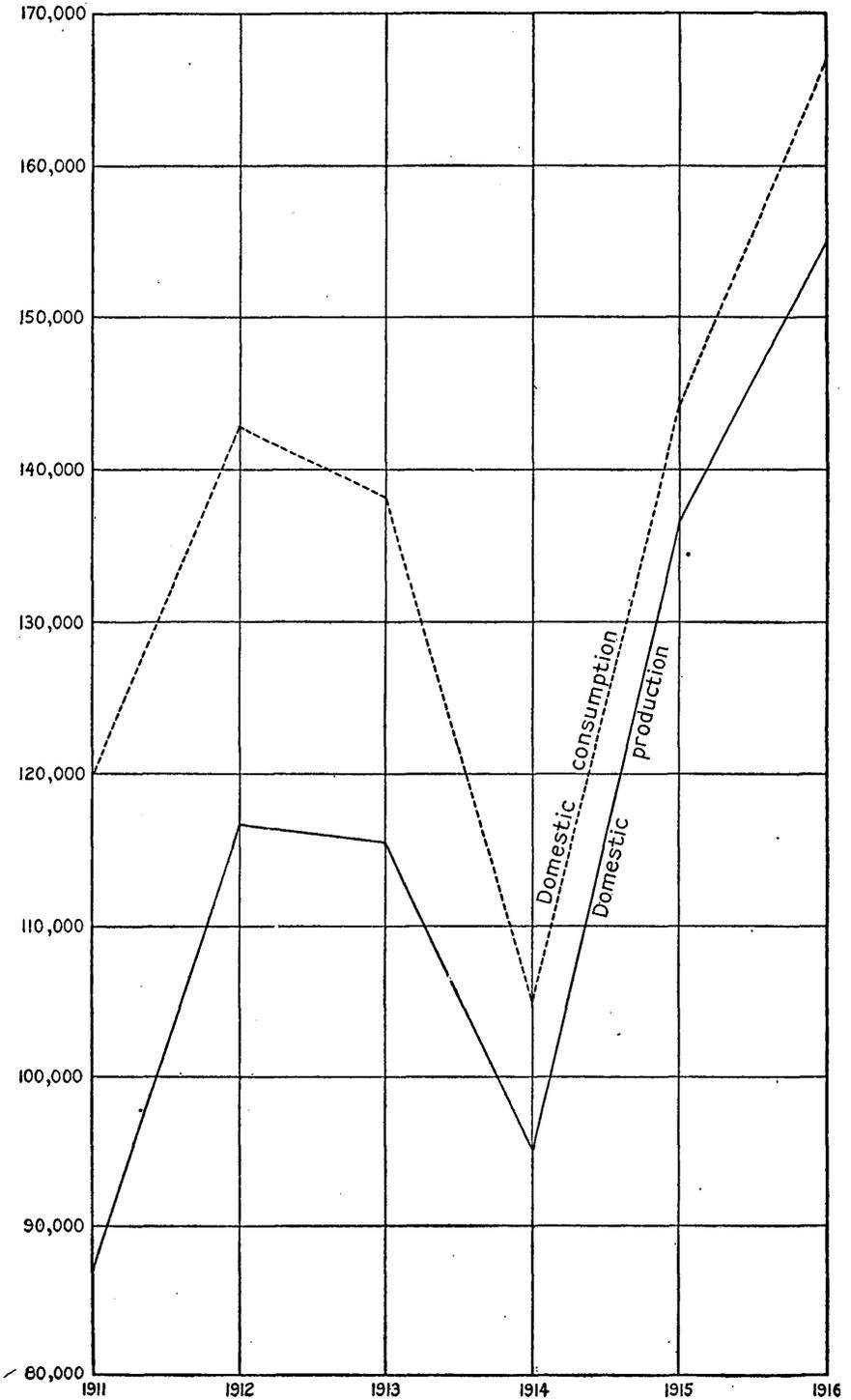


FIGURE 5.—Domestic production and consumption of fluor spar, 1911-1916.

The Underwood bill reduced the duty to \$1.50 a ton in October, 1913. Gravel spar from England has always competed¹ with the domestic product at the steel furnaces on or near the Atlantic seaboard and at times as far west as Pittsburgh and has practically fixed the price in that territory, but since imports have been curtailed the domestic product has been in greater demand and has sold at better prices in the eastern market.

SUPPLIES.

No attempt has ever been made to estimate the fluorspar reserves in the United States. Field work by the United States Geological Survey and the Kentucky Geological Survey has shown conclusively, however, that the deposits in Illinois and Kentucky are of sufficient extent to supply for many years demands much greater than at present. Reconnaissance by the Federal Survey indicates that Colorado, New Mexico, and New Hampshire possess deposits that may be drawn upon to supplement the supply from the larger deposits for a considerable period. Moreover, the deposits reported to have been discovered in numerous other States promise to yield commercial quantities of spar from time to time as transportation facilities are developed. The geologic relations of the known deposits indicate that many more of similar grade and extent should be discovered as prospecting progresses in mining regions in the Central and Western States. If the demand should ever greatly exceed the supply from the present principal domestic sources a considerable quantity might be obtained by saving the concentrates at metalliferous mines, although this would involve in most places the separation of fluorspar from other gangue minerals, and the price would have to be much higher than at present to render this procedure profitable.

It is probable that little dependence can be placed on a steady supply of fluorspar from England during war years. In normal years more than 50 per cent of the English production has been shipped to the United States. Probably this was a surplus, but it is doubtful whether in the next five years there will be any such surplus available, as the demands in Great Britain are certain to be heavier than before the war. Furthermore the foreign spar is of lower grade than the mechanically treated spar from Illinois and Kentucky and the high-grade vein material of New Hampshire, Colorado, and New Mexico, and as fluorspar is of value chiefly according to its purity, purchasers find that the American product is more efficient and consequently cheaper in the end. At any rate, there should be no necessity for the United States to experience a shortage of fluorspar except through lack of miners, labor troubles, or scarcity of boats and cars to move the product. The largest mines are partly dependent on Ohio River for transportation of fluorspar to railroad shipping points.