



# 2011 Minerals Yearbook

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## STRONTIUM

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Domestic apparent strontium consumption increased in 2011 as the result of increased imports of celestite and strontium compounds. Although a 58% increase compared with that of 2010, the 17,300 metric tons (t) of strontium content consumed in 2011 was substantially less than the nearly 38,000 t consumed at its peak in 1997. Strontium minerals were not mined in the United States in 2011, although deposits have been identified and were mined in the past. World production of celestite decreased to 375,000 t in 2011 from 404,000 t in 2010, mainly because of a decline in production in China.

Strontium composes about 0.04% of the Earth's crust, ranking 15th among elements in abundance (MacMillan and others, 2005). Owing to its high reactivity to air and water, strontium metal is not found in nature in metallic form. The two strontium-bearing minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), contain strontium in sufficient quantities to make recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make development of mining facilities attractive.

## Production

Although strontium carbonate was not produced in the United States in 2011, it was the principal strontium compound produced globally, and most other strontium compounds were derived from strontium carbonate. Domestic production of strontium carbonate ceased in 2006 with the closure of the Chemical Products Corp.'s strontium carbonate and strontium nitrate operations in Cartersville, GA. A few companies produced small quantities of downstream strontium chemicals elsewhere in the United States.

## Consumption

Strontium compounds were mostly consumed by the ceramic, glass, and pyrotechnics industries, with smaller amounts consumed by a multitude of other industries. Strontium carbonate is used directly in some applications and is also converted into appropriate downstream chemicals such as strontium chloride, strontium hydroxide, or strontium nitrate. Celestite is typically used as the raw material in strontium carbonate production and is consumed directly in small quantities as an alternative to barium sulfate as white filler in industrial products.

Permanent ceramic ferrite magnets are used extensively in small direct current motors for automobile windshield wipers, loudspeakers, magnetically attached decorative items, toys, and other electronic equipment. Strontium ferrite magnets possess the chemical and physical properties ideal for use in these applications, such as resistance to corrosion

and demagnetization, low densities, and effectiveness at high temperatures (Haberberger, 1971). Strontium oxide and strontium carbonate are used as frits in ceramic glazes as a nontoxic alternative to barium and lead (Yunpeng, 2009). Strontium oxide is used as a glass modifier to increase hardness and strength, enhance optical glass properties, and increase light refraction. Strontium glass is colorless and absorbs ultraviolet and x-ray radiation, an ideal glass for cathode-ray tube (CRT) faceplates. The fiberglass, lab glass, and pharmaceutical glass industries consume strontium in smaller amounts.

Strontium nitrate is used most often as a coloring agent in pyrotechnic applications, but strontium carbonate, strontium chloride, strontium oxalate, and strontium sulfate can also be used. Strontium pyrotechnic applications include civilian and military flares, fireworks, and tracer ammunition (Conkling, 1981).

Strontium is used in a few metallurgical applications. Strontium metal is added to aluminum alloys to improve castings used in aerospace and automotive applications (Metallurg Aluminum, 2006). Strontium can be used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate dissolved in sulfuric acid reduces the lead content of the electrolyte and of the zinc deposited on the cathode.

Strontium chromate was incorporated into paints as a corrosion inhibitor, effectively coating aluminum used in the construction of aircraft fuselages and ships (Roskill Information Services Ltd., 1992, p. 76). Strontium chromate, however, was classified as a carcinogen in humans because of its hexavalent chromium content, leading many in the paint industry to seek safer alternatives and the European Chemical Agency to propose strict regulations for its use. Although achieving comparable corrosion resistance proved difficult using more environmentally friendly materials, initial work resulted in the development of a calcium-strontium-phosphate complex on a silicate core that showed promise (Hodges and others, 2010; European Chemical Agency, 2012). Other strontium compounds were used as catalysts to accelerate the drying of oils, paints, and printing inks (Brezinski and others, 2011).

The drug strontium ranelate, a strontium salt of ranelic acid, has been used to reduce the incidence of fractures in osteoporotic patients by promoting the uptake of calcium into bones (Nielsen, 2004). Medical trials demonstrated strontium ranelate drugs increased bone formation and decreased bone resorption, reducing both vertebral and nonvertebral fractures in patients with postmenopausal osteoporosis (Deeks and Dhillon, 2010). The isotope strontium-89 has been used successfully in medical trials for the treatment of pain associated with advanced metastatic cancer (Porter, 1994). Strontium chloride is used in some toothpastes to treat tooth-sensitivity caused by temperature and pressure.

Strontium exhibits a high dielectric constant, making it an attractive material for use in wireless devices and memory chips. Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications. Research also was conducted into the use of strontium in superconductors and radiation detectors. As the technology improves and costs decrease, high-tech industries may consume more strontium (McCoy, 2009; McIntosh, 2009; Physorg, 2010; Walter, 2010; Singh and others, 2011).

Strontium oxide aluminate is used as a phosphorescent (glow-in-the-dark) pigment in applications such as emergency exit signs that glow brighter and longer than those using more common photoluminescent pigments (Merit Lighting, LLC, 2008). Strontium phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals is used in analytical chemistry laboratories.

### Prices

Based on data published by the U.S. Census Bureau, the average customs unit value for celestite imported from Mexico was \$46.08 per metric ton, a slight increase compared with that of 2010. The average unit customs value of imported strontium carbonate was \$1.01 per kilogram, a 42% increase from \$0.71 per kilogram in 2010. In 2011, the unit value of imported strontium metal increased by 23% to \$7.14 per kilogram from \$5.80 per kilogram. In 2011, the corresponding value for strontium nitrate was \$1.13 per kilogram, which was 15% lower than that of 2010. Turkish f.o.b. prices for celestite (96% strontium sulfate) ranged from \$90 per ton to \$100 per ton throughout 2011, averaging slightly less than those in 2010 (Industrial Minerals, 2012).

### Foreign Trade

With the changes in the domestic strontium market—strontium carbonate consumption for CRT production shifting to Asia and the continued consumption of strontium compounds for ceramics, glass, and pyrotechnics—strontium exports from and imports into the United States have become erratic from year to year. Adequate information to explain the variations is unavailable. Total strontium imports by gross weight were 34,400 t in 2011, a 64% increase from those of 2010 and a 36% increase from those of 2009 (table 3).

Total strontium exports by gross weight were 30 t in 2011—75% less than revised exports in 2010, and 81% less than those in 2009. Exports to Canada and Germany accounted for 87% of total strontium exports by gross weight (table 2).

Imports of celestite from Mexico were 16,700 t in 2011, more than three times the quantity imported in 2010 and 14% more than those of 2009 (table 3). Imports of strontium carbonate and strontium metal increased compared with those of 2010 by 22% and 48%, respectively, spurred by increases in imports from China, Mexico, and Spain. Strontium compounds imported from China, Germany, and Mexico represented nearly 99% of total strontium imports into the United States by gross weight, with Mexico representing 76%, Germany 13%, and China 9% of total imports.

### World Review

Large deposits of high-grade celestite have been discovered throughout the world, but active mines were primarily in China, Mexico, and Spain. These countries represented 96% of total celestite produced in 2011. Turkey once was a leading celestite producer but experienced significant declines in production in recent years, with no celestite production in 2009 and 2010, but production resumed in 2011. Smaller operations are located in Argentina, Iran, Morocco, and Pakistan. Many large deposits are not economically feasible to mine owing to high levels of barium and calcium, impurities requiring energy-intensive and cost-prohibitive methods for separation. Most strontium producers require a minimum of 90% strontium sulfate content to achieve profitability. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use froth flotation, gravity separation, or other methods to beneficiate ore. Production facilities for strontium compounds and metal have operated in Canada, China, Germany, Japan, the Republic of Korea, Mexico, and the United States, but the status of some of these operations was unclear in 2011, and some were thought to be idle.

### Outlook

Improved economic conditions worldwide could spur increased demand for strontium carbonate in more traditional applications. Use of strontium by the ceramics, glass, and pyrotechnic industries is expected to continue, with solid demand for strontium used in ferrite magnets. With improvements in advanced applications, consumption of strontium in new end uses may increase.

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## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States, Data Series 140.  
Strontium. Ch. in Mineral Commodity Summaries, annual.

TABLE 1  
SALIENT STRONTIUM STATISTICS<sup>1</sup>

(Metric tons of contained strontium and dollars per metric ton unless otherwise noted)<sup>2</sup>

	2007	2008	2009	2010	2011
<b>United States:</b>					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: <sup>3</sup>					
Strontium compounds	8,550	9,420	5,860	8,640	10,000
Strontium minerals	541	2,030	6,420	2,370	7,320
Exports, carbonate <sup>3</sup>	69 <sup>r</sup>	70 <sup>r</sup>	94 <sup>r</sup>	72 <sup>r</sup>	18
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption <sup>4</sup>	9,020 <sup>r</sup>	11,400 <sup>r</sup>	12,200 <sup>r</sup>	10,900 <sup>r</sup>	17,300
Price, average value of mineral imports at port of exportation	67	64	47	45	46
World, production of celestite, gross weight	518,000	655,000 <sup>r</sup>	398,000 <sup>r</sup>	404,000 <sup>r</sup>	375,000 <sup>e</sup>

<sup>e</sup>Estimated. <sup>r</sup>Revised. -- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits.

<sup>2</sup>The strontium content of celestite is 43.88%, which was used to convert units of celestite.

<sup>3</sup>Source: U.S. Census Bureau.

<sup>4</sup>Production plus imports minus exports.

TABLE 2  
U.S. EXPORTS OF STRONTIUM CARBONATE, BY COUNTRY<sup>1</sup>

Country	2010		2011	
	Gross weight (kilograms)	Value <sup>2</sup>	Gross weight (kilograms)	Value <sup>2</sup>
Argentina	--	--	2,600	\$3,450
Austria	2,690	\$2,550	--	--
Brazil	--	--	600	5,030
Canada	7,500	10,200	14,300	17,900
Germany	--	--	12,200	11,500
Japan	30,000	39,400	--	--
Mexico	73,100	45,800	--	--
Saudi Arabia	--	--	650	3,360
Spain	7,530	7,150	--	--
Total	121,000	105,000	30,300	41,300

-- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Free alongside ship value.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 3  
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY<sup>1</sup>

Compound and country	2010		2011	
	Gross weight (kilograms)	Value <sup>2</sup>	Gross weight (kilograms)	Value <sup>2</sup>
Celestite, Mexico	5,400,000	\$245,000	16,700,000	\$768,000
Strontium carbonate:				
China	2,380,000	2,320,000	2,740,000	6,290,000
Germany	4,290,000	2,880,000	4,480,000	3,360,000
Italy	14,000	82,300	13,400	76,200
Mexico	5,000,000	2,990,000	6,860,000	4,540,000
Spain	26,000	29,200	157,000	132,000
United Kingdom	10	4,430	--	--
Total	11,700,000	8,310,000	14,200,000	14,400,000
Strontium metal:				
Canada	--	--	552	33,400
China	118,000	682,000	165,000	1,180,000
Germany	21	3,500	--	--
Mexico	--	--	9,260	38,500
Total	118,000	686,000	175,000	1,250,000
Strontium nitrate:				
China	231,000	273,000	321,000	452,000
France	1,600	16,100	--	--
Israel	9,600	9,070	--	--
Japan	181,000	1,540,000	108,000	379,000
Mexico	3,160,000	2,920,000	2,740,000	2,750,000
Spain	--	--	81,700	70,700
Total	3,580,000	4,760,000	3,250,000	3,660,000
Strontium oxide, hydroxide, peroxide:				
China	122,000	163,000	37,600	67,500
Japan	7,000	22,700	1	2,030
Russia	--	--	10	6,500
Total	129,000	185,000	37,600	76,000

-- Zero.

<sup>1</sup>Data rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 4  
CELESTITE: WORLD PRODUCTION, BY COUNTRY<sup>1,2</sup>

(Metric tons)

Country <sup>3</sup>	2007	2008	2009	2010	2011 <sup>c</sup>
Argentina	4,904	14,910	8,169	8,512 <sup>r</sup>	8,000
China <sup>c</sup>	190,000	200,000	210,000	220,000	190,000
Iran <sup>c</sup>	2,000	2,000	2,000	2,000	2,000
Mexico	125,000 <sup>c</sup>	96,902	37,601	31,429	31,500
Morocco <sup>c</sup>	2,700	2,700	2,600	2,500	2,500
Pakistan <sup>e</sup>	1,476 <sup>4</sup>	1,000 <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	--
Spain <sup>c</sup>	188,000	336,000 <sup>4</sup>	138,000 <sup>4</sup>	140,000	140,000
Turkey <sup>c</sup>	4,200	1,600	--	--	1,100
Total	518,000	655,000 <sup>r</sup>	398,000 <sup>r</sup>	404,000 <sup>r</sup>	375,000

<sup>c</sup>Estimated. <sup>r</sup>Revised. -- Zero.

<sup>1</sup>World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Table includes data available through May 25, 2012.

<sup>3</sup>In addition to the countries listed, Tajikistan was thought to produce celestite, but information was not available to make reliable estimates.

<sup>4</sup>Reported figure.