



2016 Minerals Yearbook

STRONTIUM [ADVANCE RELEASE]

STRONTIUM

By Sheryl A. Singerling and Joyce A. Ober

Domestic survey data and tables were prepared by Susan M. Weaver, statistical assistant.

Domestic apparent consumption of strontium decreased by 66% in 2016 to 10,800 metric tons (t) mostly as the result of the decrease in imports of strontium minerals, specifically celestite, by 82% (table 1). Imports of strontium compounds also decreased, in this case by 9%. Apparent consumption of strontium peaked in 1997 and then trended downward until 2011, when consumption began to increase again. The increased imports of celestite since that time likely were the result of its increased use in petroleum industry drilling muds, although this is unconfirmed because drilling mud compositions are proprietary. Alternatively, the imported celestite could have been used for other unidentified end uses. In either case, it is unlikely that the imported celestite was being used as raw material for strontium compound production because the last domestic strontium carbonate plant, which used celestite as a raw material, ceased production in 2006. Yearly celestite imports, in gross weight, were less than 2,000 t from 2005 to 2007 but increased to 55,800 t in 2015 before decreasing to 10,100 t in 2016 (table 3). The recent decrease in celestite imports is likely a result of the low price of crude oil and decreased drilling activities (fig. 1). Strontium minerals were not mined in the United States in 2016, although deposits have been identified and were mined in the past. World production of celestite, in gross weight, decreased by 24% to 202,000 t in 2016 from 264,000 t in 2015 (tables 1, 4).

Strontium constitutes about 0.04% of the Earth's crust, ranking 15th in abundance among the elements (MacMillan and others, 2005). Owing to its high reactivity to air and water, strontium is not found in nature in metallic form. 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 mining attractive.

Legislation and Government Programs

On October 20, 2014, the U.S. Environmental Protection Agency (EPA) announced a preliminary determination to regulate strontium in drinking water. The EPA made an initial determination that ingestion of strontium has adverse health effects, especially on infants, children, and adolescents, because it can replace calcium in bones and affect bone strength. Strontium occurs naturally and has been detected in 99% of public water systems in the United States, 7% of which are at levels of concern (U.S. Environmental Protection Agency, 2014). After evaluating public feedback, the EPA announced on January 4, 2016, that it would delay its determination until additional data were considered as to whether treatment systems would inadvertently remove beneficial calcium along with the strontium in drinking water (U.S. Environmental Protection Agency, 2016).

Production

Celestite has not been actively mined in the United States since 1959, although deposits in Arizona, California, Ohio, Texas, and Washington were mined in the past. Additionally, deposits have been identified in Colorado, Kansas, Michigan, New York, Pennsylvania, Tennessee, Virginia, and West Virginia (Culin, 1916; Mitchell and Pharr, 1960). In the past, domestic production of celestite correlated with the difficulty in obtaining the mineral commodity from former import sources, especially the United Kingdom, during World War I and World War II (Schreck and Foley, 1959).

Although strontium carbonate was not produced in the United States in 2016, it was the principal strontium compound produced globally. Additionally, 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 continue to produce small quantities of downstream strontium chemicals elsewhere in the United States.

Consumption

Consumption patterns for strontium materials have shifted substantially during the past few years, with more strontium in minerals being consumed than strontium in chemicals from 2012 to 2015, which had not happened since 1992, although at that time, the strontium minerals were used to produce strontium chemicals. However, in 2016, this trend reversed with more strontium in chemicals being consumed than in minerals. In 2016, consumption of strontium contained in various chemicals was 6,430 t, whereas consumption of strontium contained in celestite was 4,420 t, in the United States (table 1). Because no strontium carbonate was produced domestically from imported celestite in 2016, imported celestite likely was used directly as an additive in drilling muds and underwent no chemical processing. Before 2006, nearly all imported celestite underwent chemical processes to be converted into strontium carbonate.

Strontium carbonate is used directly in some applications and also is converted into appropriate downstream chemicals such as strontium chloride, strontium hydroxide, or strontium nitrate. Celestite typically has been used as the raw material in strontium carbonate production and was consumed directly in small quantities as an alternative to barium sulfate as white filler in industrial products. However, increased imports of celestite since 2010 most likely were the result of celestite being used in some drilling muds used in natural gas and crude oil wells. Celestite may be used as a substitute for barite in these muds owing to the similar specific gravities of the two minerals (4.1 to 4.2 for the American Petroleum Institute specification for barite in drilling muds and an average of 3.95 for celestite). The

possible use of celestite as a substitute for barite as an additive in drilling muds is likely because of the recent increase in the price of barite (McRae, 2016) (fig. 1).

Strontium chemicals were mostly consumed by the ceramics, glass, and pyrotechnics industries, with smaller quantities consumed by a multitude of other industries. Strontium carbonate is used to produce permanent ceramic ferrite magnets, which are used extensively in small direct current motors for automobile windshield wipers, loudspeakers, magnetically attached decorative items, toys, and other electronic equipment. These magnets are produced by several U.S. companies and possess the chemical and physical properties that are ideal for use in these applications, such as effectiveness at high temperatures, low densities, and resistance to corrosion and demagnetization.

Strontium oxide and strontium carbonate are used as frits in ceramic glazes as a nontoxic alternative to barium and lead. Strontium oxide is used as a glass modifier to enhance optical glass properties, increase hardness and strength, and intensify light refraction. Strontium glass is colorless and absorbs ultraviolet and x-ray radiation, an ideal glass for cathode-ray tube (CRT) faceplates, although flat panel displays have almost completely replaced CRTs. The fiberglass, lab glass, and pharmaceutical glass industries consume strontium in smaller quantities. Additionally, with future development in holography, strontium barium niobate could be a significant storage medium for three-dimensional color holograms (Ketchel and others, 1999).

Strontium nitrate is used most commonly as a coloring agent in pyrotechnic applications to produce a bright red and, in combination with a copper compound, purple. 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.

In metallurgical applications, strontium metal is added to aluminum alloys to improve the strength and ductility of castings used in aerospace and automotive applications. Addition of even a few hundred parts per million of strontium causes the microscopic structure of the alloys to transform from a coarse, plate-like texture to a fine, fibrous network (Timpel and others, 2012). 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.

Prior to being labeled as a carcinogen in humans owing to its hexavalent chromium content, strontium chromate was incorporated into paints as a corrosion inhibitor, effectively coating aluminum used in the construction of aircraft fuselages and ships. Many in the paint industry have moved to safer alternatives. The European Chemicals Agency proposed strict regulations for its use, although achieving comparable corrosion resistance proved difficult using more environmentally friendly materials. A mixed metal calcium-strontium-phosphate complex on a silicate core provides excellent corrosion resistance (Hodges and others, 2010; European Chemicals Agency, 2012; Koleske and others, 2014, p. 50). Other strontium chemicals are used as catalysts to accelerate the drying of oils, paints, and printing inks (Koleske and others, 2014, p. 55).

Strontium is absorbed and processed in the human body in the same manner as calcium owing to the chemical similarities of the two elements. As a result, strontium has a number of medical applications including the use of the isotope strontium-89 for the treatment of bone cancer (Porter, 1994), the use of strontium chloride in toothpastes to treat temperature- and pressure-related sensitivity, and the recent development of the prescription drug strontium ranelate used to reduce the incidence of fractures in osteoporotic patients by promoting the uptake of calcium into bones. No rigorous clinical studies have been completed that prove whether strontium dietary supplements, such as strontium carbonate and strontium citrate, are effective treatments for osteoporosis (Johannes, 2013). Further studies, however, have shown that strontium ranelate may present cardiovascular risks that outweigh its benefits (Price, 2014a). Although the European Medicines Agency considered withdrawing the drug from the market, strontium ranelate remained on the market in Europe but only for patients that were unable to take other osteoporosis medication (Price, 2014b).

Strontium exhibits a high dielectric constant, making it an attractive material for use in wireless devices and memory chips (McCoy, 2009; McIntosh, 2009). Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications (Singh and others, 2011). Research has also been conducted on the use of strontium in superconductors and radiation detectors (Physorg, 2010; Walter, 2010). Promising developments in the use of lead halogen perovskite solar cells may also pertain to strontium because its substitution for lead represents a more environmentally friendly alternative to the toxic, water-soluble lead currently used (Jacobsson and others, 2015). As the technology improves and costs decrease, high-tech industries may use more strontium.

Strontium oxide aluminate is used as a phosphorescent (glow-in-the-dark) pigment in applications, such as emergency exit signs, which 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 \$77 per metric ton, the highest average unit value since 1991 (table 3). Imports from Madagascar and Morocco were reported in 2016, but the high unit values (\$6,220 per metric ton and \$300 per metric ton, respectively) and low tonnages indicated that those imports likely were as mineral specimens not industrial additives or raw materials. The average unit customs value of imported strontium carbonate was \$0.81 per kilogram, slightly lower than that in 2015. In 2016, the unit value of imported strontium metal decreased by 19% to \$6.21 per kilogram from \$7.68 per kilogram, and the unit value for strontium nitrate decreased to \$1.24 per kilogram from \$1.30 per kilogram.

Foreign Trade

Strontium exports from and imports into the United States have become unpredictable from year to year. Adequate information to explain the variations was unavailable. Imports of strontium minerals, all of which were celestite, were 10,100 t by gross weight (4,400 t by contained weight) in 2016, a decrease of 82% compared with that of 2015. Total strontium chemical and metal imports were 11,500 t by gross weight (6,430 t by strontium content) in 2016, 9% less than those of 2015 (table 3). Strontium chemical and metal imports into the United States were sourced predominantly from Mexico, 55%; Germany, 37%; and China, 7%.

Strontium carbonate exports were 154 t by gross weight (91 t by strontium content) in 2016, a 6% increase compared with 2015 (table 2). Export and import data in table 1 represent only the strontium content of the celestite and strontium compounds.

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 accounted for 98% of total celestite production in 2016. Some celestite was also produced in Argentina and Tajikistan. Many large deposits are not economic to mine owing to high levels of barium and calcium, which are impurities that require energy-intensive and cost-prohibitive methods for separation. Most strontium producers require a minimum of 90% strontium sulfate content to achieve profitability. In terms of processing ore, 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. Major global producers of strontium chemicals in 2016 were in China, Germany, and Mexico.

Outlook

Improved economic conditions worldwide could spur increased demand for strontium carbonate in more traditional applications. Use of strontium by the ceramics, glass, and pyrotechnics industries is expected to continue, with continued demand for strontium used in ferrite magnets. In addition, if barite prices remain high, strontium could continue to be used as a partial substitute in drilling muds. However, if gas and oil prices remain low, drilling activity likely will continue to decline, leading to lower imports of celestite for use in drilling muds. Forthcoming EPA determinations to regulate strontium in drinking water are unlikely to affect the domestic use of strontium because strontium in drinking water is naturally occurring, not from industrial facilities (Roberts, 2016). With developments in advanced applications, consumption of strontium in new end uses may increase.

References Cited

- Culin, F.L., Jr., 1916, Celestite and strontianite: University of Arizona Bureau of Mines Bulletin No. 35, Mineral Technology Series No. 13, 4 p. (Accessed May 9, 2016, at http://repository.azgs.az.gov/sites/default/files/dlio/files/nid1152/b-35_celestite_strontianite.pdf)
- European Chemicals Agency, 2012, 4th draft recommendation of priority substances to be included in Annex XIV of the REACH regulation: European Chemicals Agency, June 20, 2 p. (Accessed March 28, 2016, at http://echa.europa.eu/documents/10162/13640/draft_axiv_entries_summarytable_4th_en.pdf.)
- Hodges, S.A., Raurell, D.M., and Llovens, Xavier, 2010, New “eco-friendly” universal corrosion inhibitors: Paint & Coatings Industry, January 1. (Accessed March 28, 2016, at <http://www.pcimag.com/articles/90463-new-eco-friendly-universal-corrosion-inhibitors>.)
- Jacobsson, T.J., Pazoki, M., Hagfeldt, A., and Edvinsson, T., 2015, Goldschmidt’s rules and strontium replacement in lead halogen perovskite solar cells—Theory and preliminary experiments on CH₃NH₃SrI₃: Journal of Physical Chemistry, v. 119, no. 46, p. 25673–25683. (Accessed November 8, 2016, via <http://pubs.acs.org/doi/abs/10.1021/acs.jpcc.5b06436>.)
- Johannes, Laura, 2013, Can a metal help slow down the effects of osteoporosis?: The Wall Street Journal, June 10. (Accessed August 23, 2016, via <http://www.wsj.com/articles/SB10001424127887324798904578531691422239954>.)
- Ketchel, B.P., Heid, C.A., Wood, G.L., Miller, M.J., Mott, A.G., Anderson, R.J., and Salamo, G.J., 1999, Three-dimensional color holographic display: Applied Optics, v. 38, no. 29, p. 6159–6166. (Accessed May 9, 2016, via <https://www.osapublishing.org/ao/abstract.cfm?id=60250>.)
- Koleske, J.V., Springate, Robert, and Brezinzki, Darlene, 2014, Additives reference guide: Paint & Coatings Industry, v. 30, no. 6, June 16, p. 38–89.
- MacMillan, J.P., Park, J.W., Gerstenberg, Rolf, Wagner, Heinz, Köhler, Karl, and Wallbrecht, Peter, 2005, Strontium and strontium compounds, in Ullmann’s encyclopedia of industrial chemistry (7th ed.): Weinheim, Germany, VCH Verlagsgesellschaft mbH, v. A25, p. 321–327.
- McCoy, Michael, 2009, Precursor powerhouse—Air Liquide finds success in a specialized electronic materials niche: Chemical & Engineering News, v. 87, no. 31, August 3, p. 18–19. (Accessed March 28, 2016, via <http://pubs.acs.org/doi/pdf/10.1021/cen-v087n031.p018>.)
- McIntosh, Paul, 2009, Improving mobile wireless performance: Electronic Products, February 19. (Accessed March 28, 2016, at http://www.electronicproducts.com/Analog_Mixed_Signal_ICs/Standard_Linear/Improving_mobile_wireless_performance.aspx.)
- McRae, M.E., 2016, Barite [advance release], in Metals and minerals: U.S. Geological Survey Minerals Yearbook 2014, v. I, p. 9.1–9.9. (Accessed February 14, 2017, at <https://minerals.usgs.gov/minerals/pubs/commodity/barite/myb1-2014-barit.pdf>.)
- Merit Lighting, LLC, 2008, Photoluminescent exit signs: Pasadena, CA, Merit Lighting, LLC. (Accessed March 28, 2016, at <http://www.meritlighting.com/photoluminescent.html>.)
- Mitchell, R.S., and Pharr, R.F., 1960, Strontium minerals from Wise County, Virginia: Virginia Minerals, v. 6, no. 4, October, p. 1–7.
- Physorg, 2010, Roller coaster superconductivity discovered: Physorg.com, August 18. (Accessed March 28, 2016, at <http://www.physorg.com/news201355600.html>.)
- Porter, A.T., 1994, Use of strontium-89 in metastatic cancer—US and UK experience: Oncology, v. 8, no. 11, October 1, p. 25–29. (Accessed March 28, 2016, at <http://www.cancernetwork.com/oncology-journal/use-strontium-89-metastatic-cancer-us-and-uk-experience>.)
- Price, Caroline, 2014a, Regulators consider withdrawing strontium ranelate over CV safety concerns: Pulse, February 3. (Accessed March 28, 2016, at <http://www.pulsetoday.co.uk/clinical/more-clinical-/musculoskeletal/regulators-consider-withdrawing-strontium-ranelate-over-cv-safety-concerns/20005748.article>.)
- Price, Caroline, 2014b, Strontium ranelate gets reprieve from European regulator: Pulse, February 21. (Accessed March 28, 2016, at <http://www.pulsetoday.co.uk/clinical/more-clinical-areas/musculoskeletal/strontium-ranelate-gets-reprieve-from-european-regulator/20005928.fullarticle>.)
- Roberts, Jane, 2016, Wisconsin strontium levels among highest in U.S. drinking water supplies: WisconsinWatch.org, March 13. (Accessed November 8, 2016, at <http://wisconsinwatch.org/2016/03/wisconsin-strontium-levels-among-highest-in-u-s-drinking-water-supplies/>.)
- Schreck, A.E., and Foley, J.M., 1959, Strontium, in Metals and minerals (except fuels): U.S. Bureau of Mines Minerals Yearbook 1958, v. I, p. 1003–1006. (Accessed May 2, 2017, at <http://images.library.wisc.edu/EcoNatRes/EFacs2/MineralsYearBk/MinYB1958v1/reference/econatres.minyb1958v1.aschreck3.pdf>.)

- Singh, Ranjan, Azad, A.K., Jia, Q.X., Taylor, A.J., and Chen, H.-T., 2011, Thermal tunability in terahertz metamaterials fabricated on strontium titanate single-crystal substrates: *Optical Letters*, v. 36, no. 7, April 1, p. 1230–1232. (Accessed March 28, 2016, via <https://www.osapublishing.org/ol/abstract.cfm?uri=ol-36-7-1230>.)
- Timpel, M., Wanderka, N., Schlesiger, R., Yamamoto, T., Lazarev, N.P., Isheim, D., Schmitz, G., Matsumura, S., and Banhart, J., 2012, The role of strontium in modifying aluminium-silicon alloys: *Acta Materialia*, v. 60, no. 9, May 1, p. 3920–3928. (Accessed April 25, 2016, at https://www.researchgate.net/profile/Melanie_Timpel/publication/257540922_The_role_of_strontium_in_modifying_aluminiumsilicon_alloys/links/54f372880cf24eb8794c2cf6.pdf.)
- U.S. Environmental Protection Agency, 2014, EPA makes preliminary determination to regulate strontium in drinking water: U.S. Environmental Protection Agency news release, October 20. (Accessed March 29, 2016, at <https://yosemite.epa.gov/opa/admpress.nsf/596e17d7cac720848525781f0043629e327f339e63facb5a85257d77005f4bf9!OpenDocument>.)
- U.S. Environmental Protection Agency, 2016, Announcement of final regulatory determinations for contaminants on the third drinking water contaminant candidate list: *Federal Register*, v. 81, no. 1, January 4, p. 13–19. (Accessed June 6, 2016, at <https://www.gpo.gov/fdsys/pkg/FR-2016-01-04/pdf/2015-32760.pdf>.)
- Walter, Katie, 2010, A scintillating radiation detection material: *Science and Technology Review*, October 18. (Accessed March 28, 2016, at <https://str.llnl.gov/OctNov10/cherepy.html>.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Evaporites and Brines. Ch. in *United States Mineral Resources*, Professional Paper 820, 1973.
- Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
- Strontium. Ch. in *Mineral Commodity Summaries*, annual.

Other

- American Ceramic Society Bulletin, monthly.
- Chemical Market Reporter, weekly.
- Engineering and Mining Journal, monthly.
- Industrial Minerals, monthly.
- Mining Annual Review.
- Mining Engineering, monthly.
- Mining Journal, weekly.
- Roskill Information Services Ltd. [last reported on strontium in 1995].
- Strontium. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.
- Strontium—Supply, Demand, and Technology. U.S. Bureau of Mines Information Circular 9213, 1989.

TABLE 1
SALIENT STRONTIUM STATISTICS¹

(Metric tons of contained strontium and dollars per metric ton unless otherwise noted)

	2012	2013	2014	2015	2016
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: ²					
Strontium compounds ³	8,150	7,190	7,600	7,100	6,430
Celestite ⁴	8,660	21,900	24,200	24,500	4,420
Exports, carbonate ²	71	37	104	86	91
Apparent consumption ⁵	16,700	29,000	31,700	31,500	10,800
Price, average value of mineral imports at port of exportation	50	50	50	51	78
World, production of celestite, gross weight ^c	282,000 ^r	240,000 ^r	249,000 ^r	264,000 ^r	202,000

^cEstimated. ^rRevised. -- Zero.

¹Table includes data available through May 17, 2017. Data are rounded to no more than three significant digits.

²Source: U.S. Census Bureau.

³Strontium compounds, with their respective strontium contents, include strontium metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert units of strontium compounds to strontium content.

⁴In previous years (2015 and prior), this category was labeled "Strontium materials." As this includes only celestite, the label has been changed to reflect that. The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of gross weight celestite to strontium content.

⁵Production plus imports minus exports.

TABLE 2
U.S. EXPORTS OF STRONTIUM CARBONATE, BY COUNTRY¹

Country	2015		2016	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Canada	28,600	\$26,900	9,540	\$9,500
India	--	--	125	3,120
Japan	--	--	4,410	8,890
Korea, Republic of	62,800	59,700	36,900	35,000
Mexico	37,000	25,200	103,000	90,900
United Kingdom	16,100	35,000	--	--
Total	145,000	147,000	154,000	147,000

-- Zero.

¹Table includes data available through May 17, 2017. Data are rounded to no more than three significant digits; may not add to totals shown.

²Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS,
BY COUNTRY OR LOCALITY¹

Compound and country or locality	2015		2016	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Celestite:				
Madagascar	--	--	1,670	\$10,400
Mexico	55,800,000	\$2,850,000	10,100,000	772,000
Morocco	--	--	16,000	4,800
Total	55,800,000	2,850,000	10,100,000	787,000
Strontium carbonate:				
China	146,000	363,000	184,000	224,000
France	300	4,790	--	--
Germany	4,900,000	3,980,000	4,210,000	3,400,000
Italy	--	--	34,900	35,400
Japan	45	2,710	--	--
Mexico	4,670,000	3,680,000	4,430,000	3,500,000
Spain	--	--	11,000	9,350
United Kingdom	4	2,260	97,500	93,900
Total	9,710,000	8,030,000	8,960,000	7,260,000
Strontium metal:				
China	116,000	837,000	70,800	409,000
France	7,110	66,800	1,350	9,570
Germany	575	8,080	--	--
Japan	500	5,290	7,000	56,700
Mexico	17,100	164,000	4,760	45,700
United Kingdom	1	2,550	--	--
Total	141,000	1,080,000	83,900	521,000
Strontium nitrate:				
China	501,000	660,000	493,000	557,000
Germany	500	6,020	12,900	25,700
India	20,900	20,100	3,000	27,800
Japan	16,700	20,700	--	--
Mexico	2,160,000	2,810,000	1,840,000	2,330,000
Spain	20,000	22,000	74,000	77,600
United Kingdom	--	--	5	2,170
Total	2,720,000	3,540,000	2,430,000	3,020,000
Strontium oxide, hydroxide, peroxide:				
China	--	--	1,030	12,500
France	25,800	46,100	34,100	51,200
Germany	--	--	937	13,200
Japan	77,000	126,000	1	3,000
Peru	--	--	697	2,190
Total	103,000	172,000	36,800	82,100

-- Zero.

¹Table includes data available through May 17, 2017. Data are rounded to no more than three significant digits; may not add to totals shown.

²Customs value.

Source: U.S. Census Bureau.

TABLE 4
CELESTITE: WORLD PRODUCTION, BY COUNTRY¹

(Metric tons)

Country ²	2012	2013	2014	2015	2016
Argentina	22,750	5,246	5,000 ^e	5,000 ^e	5,000 ^e
China ^e	96,000 ^r	76,000 ^r	50,600 ^r	50,000 ^r	50,000
Iran ^e	20,000	--	--	--	--
Mexico	46,192	67,778	64,931	79,022 ^r	56,544
Spain	96,688	90,972	128,077 ^r	130,000 ^{r,e}	90,000 ^e
Total ^e	282,000 ^r	240,000 ^r	249,000 ^r	264,000 ^r	202,000

^eEstimated. ^rRevised. -- Zero.

¹Table includes data available through April 7, 2017. All data are reported unless otherwise noted. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²In addition to the countries listed, Tajikistan may have produced celestite, but available information was inadequate to make reliable estimates of output.

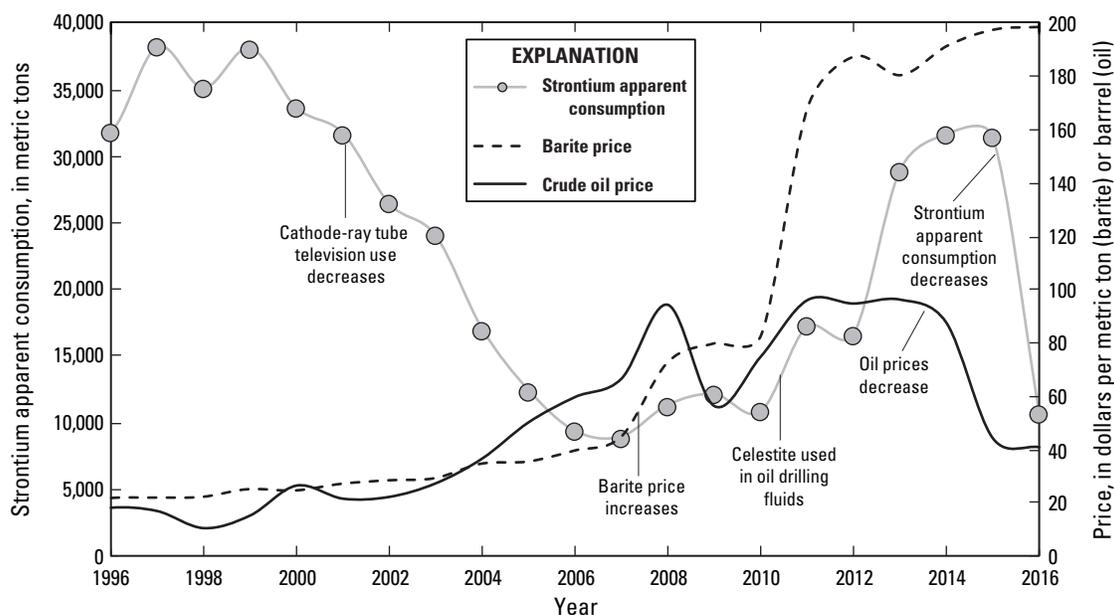


Figure 1. Relations between strontium consumption, barite prices, and crude oil prices. As barite prices increased starting in about 2007, the strontium-bearing mineral celestite may have been used to some extent in its place for petroleum industry drilling muds. Decreasing crude oil prices, starting around 2013, resulted in decreased drilling activity and, hence, decreased strontium consumption. Note that changes in crude oil prices precede changes in strontium consumption by about 1 or 2 years.