



2016 Minerals Yearbook

BORON [ADVANCE RELEASE]

BORON

By Robert D. Crangle, Jr.

Domestic survey data and tables were prepared by Sheema Merchant, statistical assistant.

In 2016, most of the boron products consumed in the United States were manufactured domestically. Two companies produced borates in the United States—U.S. Borax, Inc. in Boron, CA, and Searles Valley Minerals, Inc. (SVM) in Trona, CA. U.S. consumption of minerals and compounds reported in boric oxide (B_2O_3) content decreased in 2015; however, quantity data were withheld to avoid disclosing company proprietary data (table 1). Turkey and the United States were the world's leading producers of boron minerals (table 5). The United States exported 241,000 metric tons (t) of boric acid in 2016, a 24% increase from 195,000 t in 2015.

Elemental boron is a metalloid with limited commercial applications. The main applications were as a doping agent in the manufacture of semiconductors and as an ignition source in automobile safety airbags. Global consumption of elemental boron was estimated to be about 15 metric tons per year. Boron compounds, chiefly borates, are commercially important; boron products are priced and sold based on B_2O_3 content, which varies by ore and compound and on the absence or presence of sodium and calcium (table 2). Borax, one of the most important boron compounds for industrial use, is a white crystalline substance chemically known as sodium tetraborate decahydrate and is found in nature as the mineral tincal. Boric acid, also known as orthoboric acid or boracic acid, is a white or colorless crystalline solid sold in technical, national formulary, and special quality grades as granules or powder.

Production

Although more than 200 boron minerals occur naturally, only 4 account for 90% of the borates used by industry worldwide: the sodium borates tincal and kernite, the calcium borate colemanite, and the sodium-calcium borate ulexite. Borate deposits are associated with volcanic activity and arid climates, and the largest borate deposits are located in the Mojave Desert of the United States, the Alpidic belt in southern Asia, and the Andean belt of South America. As a result, most borates were extracted primarily in California and Turkey and to a lesser extent in Argentina, Bolivia, Chile, China, and Peru. Boron compounds and minerals were produced by surface and underground mining and from brine.

Domestic data for boron were derived by the U.S. Geological Survey from a voluntary survey and from publicly available U.S. Securities and Exchange Commission (SEC) information for two U.S. producers—SVM and Rio Tinto Group's U.S. Borax. Data from both companies were withheld to avoid disclosing company proprietary data (table 1).

SVM (a subsidiary of Nirma Ltd., India) produced borax and boric acid from brines containing potassium and sodium borates that were extracted from three salt layers, up to 100 meters (m) deep, in Searles Lake, located near Trona in San Bernardino County, CA. SVM's Trona and Westend

plants refined the brines, producing anhydrous, decahydrate, and pentahydrated borax. These brines also supplied other commercial salts in addition to sodium borates and boric acid.

U.S. Borax (a wholly owned subsidiary of United Kingdom-based Rio Tinto plc) mined mainly tincal and kernite at Boron, CA, by open pit methods. The tincal had an average grade of 25.3% B_2O_3 , and the kernite had an average grade of 31.9% B_2O_3 . Boric acid and refined sodium borates were produced at an onsite processing plant. Refined borate products were shipped by railcar or truck to customers in North America or to the company's Wilmington, CA, facility and exported from the Port of Los Angeles, CA. U.S. Borax supplied more than 30% of the world's refined borates (Rio Tinto plc, 2017a, p. 38). According to a report filed by Rio Tinto, the company produced 503,000 t of borates in 2016, an increase of 6% from the 476,000 t reported in 2015; the production increase was a result of higher market demand (Rio Tinto plc, 2017b, p. 10).

Consumption

The first reported use of borax was as a flux or bonding agent by Arabian goldsmiths and silversmiths in the eighth century, but current research suggests that the Babylonians may have used it 4,000 years ago. In 2016, borates were used in more than 300 end uses, but the 5 leading uses were, in decreasing order of quantity, glass, ceramics, agriculture, detergents, and bleaches (Hamilton, 2006).

Agriculture.—Boron was the most widely used fertilizer micronutrient, applied primarily to promote fruit and seed production. Boron fertilizers were mostly sourced from borax, boric acid, and calcium borate owing to their high water solubility; thus, boron fertilizers can be delivered through sprays or water for irrigation.

Boron is essential for plant uptake of primary and secondary nutrients, such as calcium, magnesium, manganese, phosphorus, and zinc. It improves the transport of nutrients through plant membranes, which directly correlates to improved fruit development, germination, plant reproduction, and pollen production. Normal plant leaves typically contain 25 to 100 parts per million boron, with 1 kilogram of boron per hectare (1 pound per acre) in soil being adequate to maintain these levels. In the United States, crops with boron deficiencies are often found in the Atlantic Coastal Plain, Great Lakes region, and the coastal Pacific Northwest, where soils tend to be acidic, coarse sandy, leached, or organic in nature (Albrecht, 1967; U.S. Department of Agriculture, 1998).

Ceramics.—Ceramics were the second-ranked application for borates after glass, accounting for 10% of world consumption. Borates play an important role in ceramic glazes and enamels, increasing chemical, thermal, and wear resistance. Borax and colemanite are used in ceramics primarily as fluxing agents, with borax being used in higher temperature firings and

colemanite in lower temperature firings. Borates also are used in technical ceramics, products with applications in aerospace, ballistics, electronics, and medicine, all of which experienced strong growth during the past decade. The amount of B_2O_3 used in glazes varies between 8% and 24%, and the amount used in enamels varies between 17% and 32% by weight.

Boron carbide is a key ingredient in lightweight ceramic armor, the use of which increased consumption of boron carbide in the United States and Europe since 2002. Small arms protective inserts, used by the U.S. military, are boron carbide ceramic plates inserted into Kevlar® flak jackets to protect against high-velocity projectiles (Industrial Minerals, 2008b).

Detergents and Soaps.—The use of borates in detergents and soaps represented the fourth-ranked market, accounting for an estimated 5% of world consumption. Borates were incorporated into laundry detergents, soaps, and other cleaning products because they can be used as alkaline buffers, enzyme stabilizers, oxygen-based bleaching agents, and water softeners. Sodium perborate and perborate tetrahydrate were used as oxidizing bleaching agents. Hydrogen peroxide, a very effective bleaching agent, is produced when sodium perborate undergoes hydrolysis while in contact with water. Because hydrogen peroxide cannot be effectively incorporated into detergents, sodium perborate acts as its carrier (U.S. Borax, Inc., undated). Sodium perborate, however, requires hot water to undergo hydrolysis, and concerns have emerged over excessive boron levels in waterways owing to sodium perborate in detergents. Sodium percarbonate has been used as a substitute primarily in Europe because it produces hydrogen peroxide at lower temperatures and does not increase boron content in waterways. This substitution has reduced boron consumption for detergent applications.

Glass.—The principal market for borates in 2016 was glass, representing approximately 50% of global borate consumption. Boron is used as an additive in glass to reduce thermal expansion; to improve strength, chemical resistance, and durability; and to provide resistance against vibration, high temperature, and thermal shock. Boron also is used as a fluxing agent, reducing the viscosity of glass during formation to improve manufacturing. Depending on the application and quality of the glass, borax, boric acid, colemantite, sodium borates, and (or) ulexite can be used.

Insulation and textile fiberglass represented the largest single use of borates worldwide, accounting for an estimated 43% of world borate consumption. End uses for fiberglass are corrosion-resistant, heat-resistant, and high-strength fabrics; thermal insulation; reinforcement; and sound absorption. The incorporation of borates into fiberglass greatly improves quality by increasing the absorbance of infrared radiation (U.S. Borax, Inc., undated).

Borosilicate refers to glass with boric oxide content between 5% and 30%. The boron in borosilicate imparts many valuable properties to the glass, such as increased mechanical strength, lower coefficient of thermal expansion, and greater resistance to chemical attack and thermal shock. Applications of borosilicate range from Pyrex® kitchenware to the thermal protection tiles for spacecraft.

Other.—Various boron compounds are used in nuclear powerplants to control neutrons produced during nuclear fission.

The isotope boron-10, in particular, possesses a high propensity for absorbing free neutrons, resulting in the production of lithium and alpha particles. Control rods composed of boron carbide are lowered into a nuclear reactor to control the fission reaction by capturing neutrons. Boric acid is used in the cooling water surrounding nuclear reactors to absorb escaping neutrons (Ceradyne, Inc., 2011).

Boron nitride is used in many cosmetics owing to its low coefficient of friction and lack of toxicity. Boric acid has applications in cosmetics, pharmaceuticals, and toiletries. Borates are also added to brake fluids, fuel additives, lubricants, metalworking fluids, and water-treatment chemicals. Boric oxide inhibits corrosion.

Ferroboron (FeB) is a binary alloy of iron with a boron content between 17.5% and 24% and is the lowest cost boron additive for steel and other ferrous-metals alloys. On average, the steel industry consumes more than 50% of the ferroboron produced annually (Eti Holding Inc., 2003, p. 8). Boron steel, a product manufactured through the addition of ferroboron, is stronger and lighter in weight than average high-strength steel, which makes it useful in the manufacture of safe and fuel-efficient automobiles (Ray and others, 1966). Ferroboron is also used in the manufacture of neodymium magnets, rare-earth permanent magnets frequently used in actuators, bearings and couplings, computer drives, and servomotors.

Borates were incorporated into various materials, such as cellulosic insulation, textiles, and timber, to impart flame-retardant properties. Boric acid was incorporated into flame retardants for wood to inhibit the transfer of combustible vapors and reduce the effective heat of combustion, resulting in reduced flame spread. Zinc borate was used in plastics as a multifunctional boron-based fire retardant, with applications in a variety of plastics and rubber compounds.

Transportation

Almost all U.S. borates were shipped by rail in North America. Both U.S. producers had rail fleets dedicated to the exclusive transportation of their products. Small quantities of borates were shipped by rail or truck in specialty bags, usually of 950-kilogram capacity. Prices for rail haulage depended on the ability of customers to load and unload efficiently, the ability to use unit trains and to supply one's own railcars, and fuel prices.

SVM owned the Trona Railway, a 50-kilometer (km) (31-mile) short-line railroad that connects to the Southern Pacific Railroad between Trona and Searles stations in California. The Trona Railway provided a dedicated line with access to the national rail system for the borate, soda ash, and sodium sulfate markets. Nearly 80% of output was transported by rail to domestic consumers and to the Ports of Long Beach, CA, and San Diego, CA, for export.

U.S. Borax's Boron Mine was served solely by the Burlington Northern Santa Fe Railroad. In order to connect to another rail line, a transload or transfer point was set up in Cantil, CA, served by the Union Pacific Railroad. Truckloads of product from Boron were driven to Cantil, about 64 km (40 miles) northwest of Boron, and loaded onto dedicated railcars for shipment to customers.

U.S. Borax used a privately owned berth located in the Port of Los Angeles, CA, for ocean transportation of borate products. Products destined for Europe were shipped from the bulk terminal in Wilmington, CA, to a company-owned facility in the Port of Rotterdam, Netherlands; company facilities in Spain; or contracted warehouses. The most centrally located port used by Rio Tinto for borax shipments in Europe was Antwerp, Belgium. The industrial minerals market in Europe was characterized by high volumes of imported materials, mostly forwarded through the industrialized areas of Belgium, France, Germany, and the Netherlands to other destinations in Europe, including Austria, Czechia, and Slovenia. A decision to import borates was based on the geographic location, the range of borate products needed, and prices.

Prices

Average unit values for borates, based on publicly available information obtained through SEC filing information, were unchanged compared with those reported for 2015 (Rio Tinto plc, 2017a, p. 38). Other 2016 borate values, as published by Industrial Minerals, ranged in average unit price from \$620 per metric ton (boric acid) to \$1,050 per metric ton (borax).

Foreign Trade

Boric acid exports for 2016 were 241,000 t, a 24% increase from the 195,000 t reported in 2015. Exports of sodium borates increased by 10% in 2016 to 552,000 t from 504,000 t in 2015 (tables 1, 3). Boron imports consisted primarily of borax, boric acid, colemanite, and ulexite (tables 1, 4). U.S. imports for consumption of boric acid were 46,300 t in 2016, a 17% increase from the 39,700 t reported in 2015. In 2016, 67% of total boric acid imports originated from Turkey, followed by Chile with 16%, Italy with 7%, and 14 additional countries accounting for the remaining 10% (table 4).

World Review

Argentina.—Argentina was the second-ranked producer of boron minerals in South America in 2016 (table 5). Borate deposits are located primarily in the Puna region, which includes the northwestern tip of Argentina, the southeastern corner of Peru, the southwestern corner of Bolivia, and the northeastern border of Chile. The principal markets for borates produced in Argentina were in Brazil and, to a lesser degree, domestic consumers (Orocobre Ltd., 2016).

Borax Argentina S.A. (a subsidiary of Orocobre Ltd.), the country's leading producer of borates, operated the Tincalayu Mine, the largest open pit operation in the country, which is 4,100 m (13,500 feet) above sea level. The deposit consisted primarily of borax, with rare occurrences of ulexite and 15 other borates. Borate production in 2016 was estimated to be 39,000 t (Orocobre Ltd., 2016).

Minera Santa Rita S.R.L. (MSR) operated mines in Catamarca, Jujuy, and Salta Provinces and operated a processing plant in Campo Quijano, which produced granular deca- and pentahydrate borax, technical-grade boric acid powder, and various grades and sizes of natural boron minerals. MSR exported the majority of its mined borates to 28 countries

through the Port of Buenos Aires and by land to Brazil (Minera Santa Rita S.R.L., undated).

Chile.—The largest ulexite deposit in the world, Salar de Suirire, was operated by Quiborax SA, a Government entity with reserves estimated to be 1.5 million metric tons (Mt). Almost all of the material mined at this location was exported in 2016 (Quiborax SA, 2017a). Chile was the leading borate producer in South America with production of 36,000 t of boric acid in addition to 100,000 t of borate-derived agrochemical products (Quiborax SA, 2017b).

China.—Because China has low-grade boron resources and demand for boron was expected to increase in China, imports from Chile, Russia, Turkey, and the United States also were expected to increase during the next several years. More than 100 borate deposits occur in 14 Provinces in China. The northeastern Province of Liaoning and the western Province of Qinghai accounted for more than 80% of the resources, mostly in the form of sassolite and tincal. China's boron resources average about 8% B₂O₃; in comparison, reserves from Turkey and the United States average from 26% to 31% and 25% to 32% B₂O₃, respectively (Industrial Minerals, 2008a; Baylis, 2010, p. 5; National Boron Research Institute, 2012).

Serbia.—A Canadian mining and exploration company, Erin Ventures Inc., initiated proceedings to begin borate mining in Piskanja, a mining region in Serbia approximately 250 km (155 miles) south of Belgrade. The deposit is primarily composed of colemanite and ulexite with estimated reserves of 11.8 Mt. Exploration began in early 2016 with two drill holes that indicated B₂O₃ content between 22% and 35% (Erin Ventures Inc., 2016).

Turkey.—The first known instances of borate mining in Turkey date to Roman times, with borate mining continuing to this day. Approximately 73% of the world's boron reserves are in Turkey, with the Kirka deposit at Eskisehir reported to be the largest tincal deposit in the world (Engineering and Mining Journal, 2012; National Boron Research Institute, 2012; Özdemir and others, 2013). The main borate producing areas of Turkey, all controlled by the state-owned mining company Eti Maden AS, are Bigadic (colemanite and ulexite), Emet (colemanite), Kestelek (colemanite, probertite, and ulexite), and Kirka (tincal). Production of refined borates has increased since 2008 owing to continued investment in new refineries and technologies. A recent examination of plant species in boron-rich areas of Turkey revealed a number of indicator plants, which may be used for boron prospecting in Turkey or in similar biome areas elsewhere in the world (Özdemir and others, 2013). Eti Maden projected a borate production capacity of 5.5 Mt with an anticipated sales income of \$2.5 billion by 2023 (Helvacı, 2015, p. 209)

Outlook

Consumption of borates is expected to increase, spurred by strong demand in agriculture, ceramic, and glass markets in Asia and South America. Continued investment in new refineries and technologies and the continued increase in demand were expected to fuel growth in world production for the foreseeable future. In 2013, the European Union (EU) added borates to the Registration, Evaluation, Authorization, and Restrictions of

Chemicals (REACH) Restricted Substances List, following an EU study that determined continuous exposure to humans may be harmful. The ruling required detergent makers to decrease their use of boron (Lismore, 2012). Consumption of boron-based fertilizers is expected to increase as the demand for food and biofuel crops also increases. Higher crop prices have enabled farmers to invest in advanced farming techniques and higher grade fertilizers. Consumption of borates by the ceramics industry is expected to shift away from Europe to Asia, which accounted for the majority of world demand for ceramics in 2016.

Consumption of boron nitride is expected to increase owing to the development of high-volume production techniques coupled with the creation of new technologies requiring boron nitride. The properties intrinsic to cubic boron nitride, such as hardness (second only to diamond), high thermal conductivity, and oxidation resistance, make it an ideal material for use in a variety of emerging applications. Hexagonal boron nitride is used in ceramics, intermetallic composites, imparting thermal shock resistance, improved machinability, and reduction of friction.

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TABLE 1
SALIENT U.S. STATISTICS OF BORON MINERALS AND COMPOUNDS¹

(Thousand metric tons and thousand dollars)

	2012	2013	2014	2015	2016
Sold or used by producers:					
Quantity:					
Gross weight	W	W	W	W	W
B ₂ O ₃ content	W	W	W	W	W
Value	W	W	W	W	W
Exports:					
Boric acid: ²					
Quantity	190	232	395 ^r	195 ^r	241
Value	155,000	211,000	178,000	149,000	150,000
Sodium borates:					
Quantity	456 ^r	489	584	504 ^r	552
Value	259,000	287,000	304,000	264,000	284,000
Imports for consumption:					
Refined borax: ³					
Quantity	86	127	152	136	173
Value	33,300	45,300	52,400	49,200	60,400
Boric acid: ²					
Quantity	55	53	57	40	46
Value	43,000 ^r	36,400 ^r	37,600	25,700 ^r	27,800
Colemanite: ⁴					
Quantity	24	38	45	35	35
Value ^e	8,410	12,400	14,500	11,900	11,400
Ulexite: ⁴					
Quantity	1	--	34	70	43
Value ^e	77	--	2,840	4,620	4,790
Consumption, B ₂ O ₃ content	W	W	W	W	W

^eEstimated. ^rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

¹Table includes data available through May 11, 2017. Data are rounded to no more than three significant digits.

²Source: U.S. Census Bureau, Harmonized Tariff Schedule of the United States code for boric acid, 2810.00.0000.

³Source: U.S. Census Bureau, Harmonized Tariff Schedule of the United States codes for refined borax, 2840.11.0000 and 2840.19.0000.

⁴Source: U.S. Census Bureau, Harmonized Tariff Schedule of the United States code for calcium borates, 2528.00.0010.

TABLE 2
BORON MINERALS OF COMMERCIAL IMPORTANCE

Mineral ¹	Chemical composition	B ₂ O ₃ , ² weight percent
Boracite (stassfurtite)	Mg ₃ B ₇ O ₁₃ Cl	62.2
Colemanite	Ca ₂ B ₆ O ₁₁ ·5H ₂ O	50.8
Datolite	CaBSiO ₄ OH	24.9
Hydroboracite	CaMgB ₆ O ₁₁ ·6H ₂ O	50.5
Kernite (rasorite)	Na ₂ B ₄ O ₇ ·4H ₂ O	51.0
Priceite (pandermite)	CaB ₁₀ O ₁₉ ·7H ₂ O	49.8
Probertite (kramerite)	NaCaB ₃ O ₉ ·5H ₂ O	49.6
Sassolite (natural boric acid)	H ₃ BO ₃	56.3
Szaibelyite (ascharite)	MgBO ₂ OH	41.4
Tincal (natural borax)	Na ₂ B ₄ O ₇ ·10H ₂ O	36.5
Tincalconite (mohavite)	Na ₂ B ₄ O ₇ ·5H ₂ O	47.8
Ulexite (boronatrocaltite)	NaCaB ₅ O ₉ ·8H ₂ O	43.0

¹Parentheses indicate common names.

²Boric oxide.

TABLE 3
U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY OR LOCALITY¹

Country or locality	2015			2016		
	Boric acid ²		Sodium borates ⁴ (metric tons)	Boric acid ²		Sodium borates ⁴ (metric tons)
	Quantity (metric tons)	Value ³ (thousands)		Quantity (metric tons)	Value ³ (thousands)	
Argentina	8 ^r	\$19 ^r	74	--	--	206
Australia	1,340	1,030	6,390	1,710	\$1,370	8,690
Bangladesh	835	613	1,330	695	526	1,160
Brazil	1,520	1,190	1,110 ^r	2,680	2,000	834
Burma	149	97	326	168	97	731
Canada	3,640 ^r	3,620 ^r	32,700 ^r	5,520	5,040	33,800
Chile	1 ^r	6 ^r	1,870	--	--	1,670
China	37,700	27,800	226,000	47,800	29,600	304,000
Colombia	422	398	5,510 ^r	404	394	4,120
Costa Rica	--	--	595	489	48	752
Ecuador	5	10	868 ^r	41	32	976
El Salvador	--	--	--	13	4	39
France	262	167	62	200	227	178
Germany	269	129	43 ^r	618	604	40
Guatemala	11	10	4,070	73	56	2,400
Honduras	80	79	622 ^r	--	--	746
India	4,910	3,780	21,700 ^r	7,760	5,010	26,600
Indonesia	498	364	1,130	1,160	830	685
Japan	23,500	19,300 ^r	22,000 ^r	23,000	17,200	21,700
Korea, Republic of	35,300 ^r	27,700 ^r	12,800 ^r	40,900	29,600	11,700
Kuwait	--	--	1,950	20	16	900
Lithuania	40	28	--	--	--	2
Malaysia	745	544	62,800	6,090	3,810	25,000
Mexico	7,420 ^r	7,210 ^r	13,800 ^r	29,300	8,370	19,000
Montenegro	--	--	--	39	33	--
Netherlands	37,300	25,500	53,200	20,600	9,440	33,300
New Zealand	379	347	1,050	418	379	1,640
Nicaragua	17	15	763	--	--	863
Pakistan	20	17	1,640 ^r	275	216	893
Peru	160	143	1,360	78	54	1,190
Philippines	20	17	1,580	104	82	1,710
Saudi Arabia	1,360	989	154	2,550	1,730	187
Singapore	617 ^r	496 ^r	699 ^r	974	668	492
South Africa	298	267	2,420	238	192	1,960
Spain	--	--	2,920 ^r	3,170	2,320	18,300
Switzerland	1	4	--	26	22	--
Taiwan	31,900	23,900	2,750	39,500	26,800	3,200
Thailand	2,290	1,850	9,630	2,090	1,500	10,100
United Arab Emirates	19	14	--	40	28	68
United Kingdom	112	93	609 ^r	101	98	1,340
Venezuela	11	15	142	17	14	119
Vietnam	1,740	1,280	7,480	2,080	1,430	9,620
Other	22 ^r	46 ^r	405 ^r	5	22	922
Total	195,000 ^r	149,000 ^r	504,000 ^r	241,000	150,000	552,000

^rRevised. -- Zero.

¹Table includes data available through May 11, 2017. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States (HTS) code 2810.00.0000.

³Free alongside ship valuation.

⁴HTS codes 2840.19.0000, 2840.20.0000, and 2840.30.0000.

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

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY OR LOCALITY¹

Country or locality	2015		2016	
	Quantity (metric tons)	Value ² (thousands)	Quantity (metric tons)	Value ² (thousands)
Argentina	458	\$366	--	--
Australia	1	4	1	\$4
Bolivia	3,270	1,910	1,980	904
Canada	514 ^r	393 ^r	423	310
Chile	8,480	5,240	7,390	4,160
China	192	220	231	326
France	--	--	165	264
Germany	14	19	122	87
Hong Kong	184	253	236	358
India	22	59	157	108
Italy	3,440	2,390	3,400	2,430
Japan	249	221	115	134
Korea, Republic of	--	--	20	11
Netherlands	146	136	--	--
Peru	1,160	833	1,050	621
Russia	300	156	179	111
Taiwan	--	--	34	35
Turkey	21,300	13,500	30,800	17,900
United Kingdom	1	4	3	8
Total	39,700 ^r	25,700 ^r	46,300	27,800

^rRevised. -- Zero.

¹Table includes data available through May 11, 2017. Data are rounded to no more than three significant digits; may not add to totals shown.

²U.S. customs declared values.

Source: U.S. Census Bureau.

TABLE 5
BORON MINERALS: WORLD PRODUCTION, BY COUNTRY OR LOCALITY¹

(Thousand metric tons)

Country or locality	2012	2013	2014	2015	2016
Argentina, boron minerals, crude	479	426	450	450	450
Bolivia, ulexite, natural	128	150	152	150 ^e	150 ^e
Chile, ulexite, natural	444	581	497	518	520 ^e
China ^{e,2}	160	160	160	160	160
Germany, compounds	149 ^r	143 ^r	139 ^r	-- ^e	-- ^e
Iran, borax ^{e,3}	1	1	1	1	1
Kazakhstan	300 ^e	348	507	500 ^e	500 ^e
Peru, borates, crude	104	224	240	660 ^e	660 ^e
Russia ⁴	250	76	81	80 ^e	80 ^e
Turkey:					
Concentrate ^e	2,130 ^r	2,130 ^r	2,400 ^r	2,200	2,200
Run of mine ⁵	4,220	4,070	7,310	7,300 ^e	7,300 ^e
United States ⁶	W	W	W	W	W

^eEstimated. ^rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

¹Includes data available through April 7, 2017. All data are reported unless otherwise noted. U.S. data and estimated data are rounded to no more than three significant digits.

²Boric oxide (B₂O₃) equivalent.

³Production is based on fiscal year starting March 21 of the year shown.

⁴Blended Russian datolite ore that reportedly grades 8.6% B₂O₃.

⁵Concentrates from ore.

⁶Minerals and compounds sold or used by producers, including both actual mine production and marketable products.