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BORON

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Boron

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U.S. consumption of minerals and compounds reported in boron oxide continued to increase in 2009 but has been withheld to avoid disclosing company proprietary data (table 1). Turkey and the United States were the world's leading producers of boron minerals (table 6). World production of boron minerals decreased in 2009 to an estimated 3.51 million metric tons (Mt) compared with 3.85 Mt in 2008 (excluding U.S. production). The amount of boron compounds exported in 2009 was 171,000 metric tons (t) of boric acid and 417,000 t of sodium borate (tables 1, 4). Boron imports consisted primarily of borax, boric acid, colemanite, and ulexite (tables 1, 5).

Elemental boron is a metalloid which has limited commercial applications. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on boric oxide content (B_2O_3), 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 minerals for industrial use, is a white crystalline substance chemically known as sodium tetraborate decahydrate and found in nature as the mineral tincal. Boric acid, also known as orthoboric acid or boracic acid, is a white, colorless crystalline solid sold in technical, national formulary, and special quality grades as granules or powder. Colemanite (hydrated calcium borate), kernite (hydrated sodium borate), tincal, and ulexite (hydrated sodium calcium borate) were the minerals of most commercial importance in the United States (table 2).

Production

Four minerals make up 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, with the largest borate deposits located in the Mojave Desert of the United States, the Alpide 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 of two U.S. producers—Rio Tinto Group's U.S. Borax Inc. and Searles Valley Minerals, Inc. (SVM). Both companies responded; however, data were withheld to avoid disclosing company proprietary data (table 1).

The calcium borate mine in Newberry Springs, CA, owned and operated by Fort Cady Minerals Corp., has been idle since February 2003. The Billie Mine, the last active mining operation in Death Valley National Park, CA (owned by American Borate Co.), closed in 2008 (National Park Service, 2010). American Borate continued to import Turkish ulexite and colemanite, which was processed in plants in Chesapeake, VA, and Blacksburg, SC, through Industrial Minerals Inc. (American Borate Co., 2005; Industrial Minerals Inc., 2007).

SVM produced borax and boric acid from brines containing potassium and sodium borates which 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 pentahydrous borax. These brines also supplied other commercial salts in addition to sodium borates and boric acid.

Rio Tinto Borax (a wholly owned subsidiary of United Kingdom-based Rio Tinto Minerals) mined mainly tincal and kernite at Boron, CA, by open pit methods, and the ore was transported by truck to a storage area. Boric acid and refined sodium borates were produced at an onsite processing plant. Refined borate products were shipped by railcar or truck to North American customers or to the company's Wilmington facility at the Port of Los Angeles for international distribution. Specialty borate products were made at the Wilmington plant. According to a Securities and Exchange Commission report filed by Rio Tinto Borax, the company produced 411,000 t of borates in 2009, a 30% decrease from the 591,000 t reported in 2008 (Rio Tinto plc, 2010, p. 26). As part of a divestment program in September 2007, Rio Tinto Minerals put Rio Tinto Borax on sale. In July 2009, the company canceled the sale because bidders had not matched the valuation of the asset (Industrial Minerals, 2009d).

Consumption

The first reported use of borax was as a flux or bonding agent by Arabian gold and silversmiths in the eighth century, but current research suggests Babylonians may have used it 4,000 years ago. Today, there are more than 300 end uses for borates, but more than three-quarters of the world's supply is sold and distributed to five end uses. The distribution of borates by end use in 2009 was glass, 57%; ceramics, 12%; fertilizer, 12%; detergent, 5%; and other, 14% (Garrett, 1998; Hamilton, 2006; Eti Maden AS, 2009, p. 19). Global demand for borates fell from 1.88 Mt of B_2O_3 in 2008 to 1.50 Mt of B_2O_3 in 2009, a 20% decrease, spurred by decreased Asian and European demand (Katsiouleris, 2010, p. 4).

In 2009, U.S. imports for consumption of borax, boric acid, colemanite, and ulexite were 96,000 t, which was 38% less than the 156,000 t imported in 2008. In 2009, total U.S. apparent consumption of all boron products increased by 15% compared with that of 2008.

Agriculture.—Boron was the most widely used micronutrient, applied primarily to promote seed production. Boron fertilizers were mostly sourced from borax and colemanite owing to their high water solubility; thus, boron fertilizers can be delivered through sprays or irrigation water. Total global demand for micronutrients was nearly 750,000 t in 2009 (Russell, 2010). Domestic consumption of boron fertilizers was estimated to be approximately 2% of total U.S. fertilizer consumption.

Boron is essential for plant uptake of primary and secondary nutrients, such as calcium, manganese, magnesium, phosphorus, and zinc. It influences the transport of nutrients through plant membranes, which directly correlates into improved fruit development, germination, plant reproduction, and pollen production. Normal plant leaves typically contain 25 to 100 parts per million of boron, with 1 kilogram per hectare of boron (1 pound per acre) in soil being adequate to maintain these levels. U.S. boron deficiencies in crops are found primarily in the Atlantic coastal plains, Great Lakes region, and the coastal Pacific Northwest, where soils tend to be acidic, leached, coarse sandy, or organic in nature. Excessive boron fertilization, on the other hand, can cause crop toxicity, which studies suggested was more often caused by higher boron levels in irrigation water than those in soil (Troeh and Thompson, 2005, p. 489).

Ceramics.—Ceramics comprise the second largest application of borates after glass. 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, and colemanite in lower temperature firings. Borates are also used in technical ceramics, an industry with applications in aerospace, ballistics, electronics, and medicine, which observed strong growth during the past decade.

Boron carbide is a key ingredient in lightweight ceramic armor, the use of which created increased United States and European consumption of boron carbide during the past few years. 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).

A new calcined borate, known as E4972, was developed to replace conventional frits used in ceramic glazes. Frits were incorporated into glazes to obtain the appropriate technical and aesthetic properties under short firing of ceramics. E4972 possesses a low solubility, which enables its use in glaze formation (Industrial Minerals, 2009a).

Detergents and Soaps.—Borates were used as oxygen-based bleaching agents, enzyme stabilizers, alkaline buffers, and water softeners in detergents and soaps. Two borates, sodium perborate and perborate tetrahydrate, were used as oxidizing bleaching agents since they contain true peroxygen bonds. Hydrogen peroxide, a very effective bleaching agent, is produced when sodium perborate undergoes hydrolysis when in contact with water. Because hydrogen peroxide cannot be effectively incorporated into detergents, sodium perborate acts as its carrier (Rio Tinto Borax, 2005). 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. This substitution has affected boron consumption considerably.

Ferroboron.—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. On average, the steel industry consumes more than 50% of the ferroboron produced annually (Eti Holding Inc., 2003). Boron steel, containing nearly 0.008% ferroboron, possesses a higher strength and lighter weight than that of average high-strength steel, and is a useful material in the manufacturing of safe and fuel efficient automobiles.

Ferroboron was also utilized in aluminum castings to refine grain; in copper-base alloys and high-conductance copper as a degasifier; and in the nonferrous metals industry, generally as a deoxidizer. Applications also include the manufacturing of neodymium-iron-boron (Nd-Fe-B) magnets, consuming nearly 10% of the ferroboron produced annually (Eti Holding Inc., 2003). Nd-Fe-B magnets possess the highest strength of all magnets and were used in computer hard drives, guidance systems, and wind turbines (Moores, 2010).

Fire Retardants.—Boric acid was incorporated into wood flame-retardants 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. Zinc borate is mainly used in flexible and rigid polyvinyl chloride formulations partly substituting for antimony trioxide. It is increasingly used as a component of halogenated and halogen-free formulations in epoxies, nylons, polyolefins, rubber, and thermoplastic polyesters.

Glass.—Boron is used as an additive in glass to reduce thermal expansion, improve strength, chemical resistance and durability, and provide resistance against vibration, high temperature, and thermal shock. Boron is also 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, colemanite, ulexite, and sodium borates are typically used.

As in previous years, the glass industry remained the leading domestic market for boron. Insulation and textile fiberglass represents the largest single use of borates worldwide. Demand for fiberglass was dominated by the construction industry, which saw decreased U.S. activity in 2009 owing to the economic downturn. End uses for fiberglass are corrosion-resistant, heat-resistant, and high-strength fabrics, insulation, reinforcement, and sound absorption. The incorporation of borates into fiberglass greatly improves quality, establishing a product that is strong, lightweight, and thermal and chemical resistant (Garrett, 1998).

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, low coefficient of thermal expansion, and resistance to chemical attack and thermal shock. Past application of borosilicate ranged from Pyrex® kitchenware to the thermal protection tiles on the National Aeronautics and Space Administration Space Shuttle Orbiter.

Other.—Borate treated wood is used in the construction of homes to protect against wood destroying organisms. Borates prevent fungal decay and are deadly to carpenter ants, roaches, and termites. Borate treated wood has been used successfully for more than 50 years in New Zealand and for a decade in Hawaii—specifically to combat highly destructive termites.

Boron fiber is a monofilament nearly 125 to 140 nanometers in diameter comprising elemental boron, typically produced under chemical vapor deposition of boron trichloride with tungsten wire acting as the catalyst. Owing to its high strength and hardness, boron fiber was used in the construction of the horizontal and vertical stabilizers and rudders of the F–14 and F–15 fighter and B–1 bomber aircrafts. The lower production cost and the higher availability associated with carbon fiber has limited boron fiber's use in modern aviation structural components. However, boron fiber has proven to be more advantageous than carbon fibers when used as a repair material for structural defects (Baker and others, 2004, p. 249).

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, producing molecules of lithium and alpha particles after absorbing neutrons. 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).

Borazine and polyborazylene can be used as precursor chemicals to boron nitride coatings and composites. Boron nitride can also be found in large quantities in cosmetics owing to its low coefficient of friction and lack of toxicity. It has been shown to be an useful alternative to talcum powder, which studies show may be linked to ovarian cancer (Emsley, 2004, p. 15–17). 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. Boron oxide inhibits corrosion.

Transportation and Distribution

Almost all U.S. borates were shipped in North America by rail. Both U.S. producers had rail fleets dedicated to the exclusive transportation of their products. Small shipments of borates were shipped by rail or truck in specialty bags, usually of 2,100-pound 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) shortline 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.

The Boron Mine (owned by Rio Tinto Borax) at Boron, CA, 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. Trucks of product from Boron were driven to Cantil, about 64 km (40 miles) northwest of Boron and loaded into dedicated railcars to be shipped to customers.

Rio Tinto Borax utilized a privately owned berth located in the Port of Wilmington, CA, for ocean transportation of borate products. Products destined for Europe were shipped from the bulk terminal in Wilmington to a company-owned facility in the Port of Rotterdam, Netherlands, company facilities in Spain, or contracted warehouses. The most centrally located Rio Tinto Borax port location 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 for destinations in Central Europe, including Austria, the Czech Republic, and Slovenia. A decision to import borates was based on the geographic location, the range of borate products needed, and prices.

Rio Tinto Borax used barges to ship borates from Rotterdam to customers in Belgium, Eastern Europe, France, and Germany. Barges were the most efficient and reliable mode of transportation throughout Europe because waterways provide an ideal, low-cost linkage between large industrial areas and the Baltic, Black, Mediterranean, and North Seas and the Atlantic Ocean.

Imports from South America and Turkey entered the United States principally through the ports of Norfolk, VA, and Philadelphia, PA.

Prices

Yearend prices of boron minerals and compounds produced in the United States are listed in table 3. Prices for borates have decreased from 2008 to 2009, reflective of an imbalance between supply and demand created by the economic downturn observed in the fourth quarter of 2008. Table 4 lists the free alongside ship values for U.S exports of boric acid and quantities of boric acid and refined sodium borate compounds exported to various countries. In 2009, China received the largest amount of sodium borates from the United States owing to increased consumption of borates used in the Chinese glass and ceramic industries.

World Review

Argentina.—Argentina remained the leading producer of boron minerals in South America in 2009 (table 6). 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 edge of Chile. Recent increased demand in Asia and North America for borate use in ceramics and glass led to increased production of Argentine borates, boric acid in particular.

Borax Argentina S.A. (a subsidiary of Rio Tinto Minerals), the country's leading producer of borates, operated open pit mines at Porvenir in Jujuy Province and at Sijes and Tincalayu in Salta Province. These operations produced colemanite, hydroborocite, kernite, tincal, and ulexite at a rate of 100,000 metric tons per year (t/yr) (Industrial Minerals, 2009c). Located at 4,100 m (13,400 feet) above sea level, the Tincalayu Mine was Argentina's largest open pit operation. The deposit consisted primarily of borax, with rare occurrences of ulexite and 15 other borates. Rio Tinto also produced refined borate ores and boric acid at refineries in Campo Quijano, Sijes, and Tincalayu in Salta Province and Porvenir in Jujuy Province. Lithium

Americas Corp. entered into an agreement with Borax Argentina to extract subsurface lithium and borate brines from the salt lake at Jujuy Province. The company contends that the brine has the correct composition to be economically viable (Industrial Minerals, 2009f).

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 the natural boron minerals. MSR refined more than 50,000 t/yr of borates and was expected to refine 75,000 t/yr after the investment in a flow bed system, a device that more efficiently dries boric acid. MSR has also announced a permanent supply agreement with Sulphaar S.R.L. to furnish sulphuric acid for the Campo Quijano plant (Santa Rita Mining Co., 2010).

Bolivia.—The most important Bolivian borate deposits, mined primarily by small cooperatives, are located in the Altiplano of the Andes and contain ulexite with associated tincal. The Bolivian mining agency, Corporación Minera de Bolivia (COMIBOL), was seeking to develop the Salar de Uyuni salt flats for future borate production. COMIBOL planned to establish a $5 million borate pilot plant on the deposit to determine full-scale feasibility. A full-scale boric acid plant was expected to produce 20,000 t/yr (Industrial Minerals, 2006, 2009c; Moores, 2009).

Chile.—In 2009, Chile was the second leading producer of boron minerals in South America (table 6). The Chilean borate producers were all located in the northeastern edge of Chile, which contains one the world's largest deposits of ulexite. The largest producer, Quimica e Industrial del Borax Limitada (Quiborax), mined 450,000 t/yr of crude ulexite and produced up to 80,000 t/yr of boric acid and 40,000 t/yr of granular ulexite (Tran, 2008).

China.—China possessed more than 100 borate deposits in 14 Provinces. 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. Chinese boron resources are of low quality, averaging nearly 8.4% B_2O_3, in comparison to the Turkish and United States reserves, which average nearly 26% to 31% and 25.3% to 31.9% B_2O_3, respectively. Apparent consumption of borate in China increased by 7% per year between 2000 and 2009 fueled by the glass and ceramic industries, but domestic production remained relatively consistent during this period. To maintain this high level of consumption and moderate level of production, China became more import reliant on borate products originating from Russia, South America, the United States, and Turkey (Industrial Minerals, 2008a; Baylis, 2010, p. 5).

India.—India relied entirely on American, Chinese, and Turkish imports of borates to fulfill domestic needs. Borate products produced in India include boric acid, boron carbide, ferroboron, and sodium perborate. The leading producer of refined borates was Indo Borax & Chemical Ltd., which operated borax and boric acid plants in Pithampur, Madhya Pradesh, northeast of Mumbai.

Italy.—The Italian ceramic industry, which constitutes nearly 20% of global ceramics exports by volume, experienced its worst year owing to the global economic downturn. The industry observed a decline of 30% in output, 19.4% in sales volumes, and 19.6% in exports. Exports to the United States and Russia decreased by 39% and 46%, respectively. These declines created a drop in demand for many key ceramic minerals, including borates. Italian ceramic production was expected to remain at 2009 levels until 2011 (Industrial Minerals, 2009b).

Serbia.—Erin Ventures Inc. entered into a binding agreement with the Serbian state-owned coal mining company, JP PEU, for joint development of the Piskanja borate deposit in southern Serbia. Additionally, Erin Ventures was seeking monetary compensation totaling $15 million from Elektroprevreda, the Serbian national power corporation, over an alleged 1997 breach of contract in the development of the Piskanja deposit (O'Driscoll, 2010).

Rio Tinto Minerals held a license to the Jadar borate lithium deposit 150 km north of the Piskanja deposit and was planning further exploration drilling in 2010. The company expected to produce borate by 2015 (Industrial Minerals, 2009e; O'Driscoll, 2010).

Turkey.—The main borate producing areas of Turkey are Bigadic, Emet, Kestelek, Kirka, and Sultancayiri, all controlled by Eti Maden AS, the Turkish state-owned mining company. Production of refined borates increased during the past few years owing to continued investment in new refineries and technologies. However, sales of Turkish borate exports to the United States and Europe plunged in 2009 owing to the economic downturn, totaling $420 million compared with $488 million in 2008 (Today's Zaman, 2009).

Eti Maden planned to expand its share in the world boron market from 36% to 39% by 2013, increasing sales to $1 billion by expanding its production facilities and product range (Today's Zaman, 2009). In 2009, Turkey exported 4 Mt of borates valued at $104 million (Uyanik, 2010).

Outlook

Because U.S. demand for boron glass greatly depends on the construction industry, this sector was significantly affected by the 2008 economic downturn. With a potential recovery forecasted, U.S. consumption was projected to expand 2.3% per year through 2011, totaling 3.7 Mt of fiberglass in 2011 (Weizer, 2007). Europe and emerging markets are requiring higher building standards, which directly correlate to higher consumption of insulation fiberglass. Global consumption of liquid-crystal display televisions, which use small amounts of borates, was expected to double by 2012. Consumption of borates used in high-tech applications was expected to increase by 13% in Europe and 10% in North America by 2012 (Tran, 2008).

Research into boron use in nanotechnology is progressing rapidly, with studies constructing more stable forms of boron nanotubes and developing more efficient fabrication techniques. In 2009, a team of material scientists created the first high-quality, uniformly crystalline boron nitride nanotubes in large qualities (EurekAlert, 2010). Boron nanotubes were expected to overtake carbon nanotubes as the ideal material in nanoengineering, because boron nanotubes can be configured as electrical conductors, a property not inherent to carbon nanotubes (Battersby, 2008; Oku, 2008, p. 335–350).

The European Chemical Agency has declared the use of boric acid in the development of photographs to pose no health risk to consumers with the proper handling of the chemicals. This ruling was considered to have wider implications for the use of borates used in other applications, such as in the ceramic and glass industries (Industrial Minerals, 2010a).

Chinese Nd-Fe-B magnet production is expected to increase 25% per year through 2014, driven by an increase in high-technical applications. With boron content in Nd-Fe-B magnets averaging 18% to 22%, the Chinese boron industry was investigating ways to expand the use of boron from its low-grade deposits through more efficient and effective processes (Industrial Minerals, 2010b).

With the increase in government involvement and funding into "greener" policies, a greater importance has been placed on the development of alternative automotive power sources. The use of fuel cells has for decades been a viable solution, but commercially did not come to true fruition until recently with the greater use of lithium-ion batteries. Sodium tetrahydroborate is a principal component in direct borohydride fuel cells (DBFC), which have been successfully produced for several small-scale uses. Although considered a hydrogen fuel cell, DBFC differs from traditional hydrogen fuel cell in that hydrogen is produced as the waste product (exhaust) with sodium tetrahydroborate and water being the input fuels. This design is advantageous since hydrogen can be stored and then reused as the input fuel for another hydrogen fuel cell (Moores, 2008).

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TABLE 1

SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS[1]

(Thousand metric tons and thousand dollars)

	2005	2006	2007	2008	2009
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[2]	1,150	W	W	W	W
B_2O_3 content	612	W	W	W	W
Value	713,000	W	W	W	W
Exports:[3]					
Boric acid:[4]					
Quantity	183	221	248	303	171
Value	96,800	126,000	124,000	165,000	109,000
Sodium borates:					
Quantity	308	393	446	519	417
Value	110,000	138,000	146,000	192,000	176,000
Imports for consumption:					
Borax:[3]					
Quantity	1	2	1	1	(5)
Value	319	701	647	566	376
Boric acid:[3]					
Quantity	52	85	67	50	36
Value	22,500	34,900	27,500	26,200	26,100
Colemanite:					
Quantity[6]	31	25	26	30	31
Value	8,900	7,260	7,640	8,880	8,630
Ulexite:					
Quantity[6]	103	131	92	75	28
Value	31,000	39,200	27,600	22,600	11,300
Consumption, B_2O_3 content	W	W	W	W	W
World, production[7]	4,950	3,760	4,200	3,850 r	3,510 e

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits.

[2]Minerals and compounds sold or used by producers, including actual mine production, and marketable products.

[3]Source: U.S. Census Bureau.

[4]Includes orthoboric and anhydrous boric acid. Harmonized Tariff Schedule of the United States codes 2840.19.0000, 2840.20.0000, and 2840.30.0000.

[5]Less than ½ unit.

[6]Source: Journal of Commerce Port Import/Export Reporting Service.

[7]U.S. production withheld from world production in 2006–09 to avoid disclosing company proprietary data.

TABLE 2

BORON MINERALS OF COMMERCIAL IMPORTANCE

Mineral[1]	Chemical composition	B_2O_3, weight percentage
Boracite (stassfurite)	$Mg_3B_7O_{13}Cl$	62.2
Colemanite	$Ca_2B_6O_{11}\cdot5H_2O$	50.8
Datolite	$CaBSiO_4OH$	24.9
Hydroboracite	$CaMgB_6O_{11}\cdot6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7\cdot4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19}\cdot7H_2O$	49.8
Probertite (kramerite)	$NaCaB_3O_9\cdot5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2OH$	41.4
Tincal (natural borax)	$Na_2B_4O_7\cdot10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O_7\cdot5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9\cdot8H_2O$	43.0

[1]Parentheses indicate common names.

TABLE 3

YEAREND PRICES FOR BORON MINERALS AND COMPOUNDS[1]

(Dollars per metric ton)

Product	Price, December 31, 2008	Price, March 31, 2009	Price, December 31, 2009[2]
Borax, anhydrous, 25 kg bags	1,223–1,310	1,194–1,279	NA
Borax, decahydrate	340–380	340–380	NA
Borax, decahydrate, Buenos Aires	560	560	520
Borax, decahydrate, granular	582–655	569–640	NA
Borax, pentahydrate	400–430	400–430	NA
Borax, pentahydrate, granular	437–509	426–497	NA
Boric acid, Chile	950	950	800
Boric acid, granular	509–582	497–569	NA
Colemanite, Buenos Aires, 40% boron oxide (B_2O_3)	420–460	420–460	370–420
Colemanite, Turkish lump, 40%-42% boron oxide (B_2O_3)	270–290	270–290	NA
Ulexite, Buenos Aires, 40% B_2O_3	390–410	390–410	350–380
Ulexite, granular, Chile, 40% B_2O_3	500	500	400
Ulexite, Lima, 40% B_2O_3	490–520	490–520	250–300

NA Not available.

[1]U.S. free on board plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and (or) somewhat different price quotations. Values have been rounded to the nearest dollar.

[2]Industrial Minerals ceased publication of seven boron products on April 1, 2009.

Source: Industrial Minerals, no. 495, December 2008, p. 88; no. 498, March 2009, p. 68; no. 507, December 2009, p. 68.

TABLE 4

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY[1]

	2008			2009		
	Boric acid[2]		Sodium	Boric acid[2]		Sodium
	Quantity	Value[3]	borates[4]	Quantity	Value[3]	borates[4]
Country	(metric tons)	(thousands)	(metric tons)	(metric tons)	(thousands)	(metric tons)
Australia	3,100	$1,690	7,750	3,990	$2,550	9,310
Belgium	64	129	265	132	172	259
Brazil	1,840	1,970	4,060	448	613	3,300
Canada	4,210	3,090	38,100	2,970	2,440	27,500
China	73,400	37,900	109,000	26,500	14,500	146,000
Colombia	347	383	6,240	190	250	3,990
France	12,700	7,860	514	4,280	5,270	312
Germany	357	851	12	316	532	1
Hong Kong	2,060	1,050	125	--	--	4
India	1,890	941	26,200	1,530	1,200	17,400
Indonesia	1,690	966	3,140	833	532	4,770
Italy	1	3	240	--	--	2,400
Japan	33,900	21,400	26,600	22,800	16,700	19,500
Korea, Republic of	35,500	19,500	17,600	38,800	21,700	12,700
Malaysia	2,140	1,110	64,200	206	124	32,400
Mexico	5,360	3,770	13,500	6,600	5,350	16,900
Netherlands	55,000	26,600	121,000	23,000	13,200	85,900
New Zealand	717	397	1,530	361	212	1,930
Philippines	105	82	1,910	54	38	1,360
Singapore	1,750	1,200	801	847	1,170	578
Spain	24,500	11,200	41,500	3,000	1,700	5,890
Taiwan	32,700	17,300	5,560	25,100	13,900	2,900
Thailand	4,700	2,650	8,830	2,850	1,620	6,340
United Kingdom	55	77	16	49	71	4
Venezuela	63	104	522	82	198	501
Vietnam	1,380	772	3,240	3,280	2,040	4,230
Other	3,300	2,010	17,300	2,990	2,620	10,700
Total	303,000	165,000	519,000	171,000	109,000	417,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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

[3]Free alongside ship valuation.

[4]HTS codes 2840.19.0000, 2840.20.0000, and 2840.30.0000.

Source: U.S. Census Bureau.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY[1]

	2008		2009	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Argentina	112	$95	841	$637
Bolivia	2,480	1,830	2,440	1,550
Chile	6,650	4,430	6,550	4,390
China	222	141	125	228
France	716	1,210	750	1,190
Germany	35	51	21	20
India	275	289	192	257
Italy	1,310	1,550	1,110	1,250
Japan	13	30	82	77
Peru	2,170	1,760	1,140	896
Russia	--	--	4,380	2,920
Turkey	35,900	14,600	18,300	12,600
United Kingdom	216	218	54	54
Other	5	18	46	43
Total	50,100	26,200	36,100	26,100

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]U.S. customs declared values.

Source: U.S. Census Bureau.

TABLE 6

BORON MINERALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2005	2006	2007	2008	2009[e]
Argentina	633	534	670	786	750
Bolivia, ulexite	63	51 [r]	64 [r]	56	83 [p, 3]
Chile, ulexite	461	460	528	583	608 [3]
China[e, 4]	140	145	145	140	145
Iran, borax[e, 5]	2	2	2 [3]	2	2
Kazakhstan[e]	30	30	30	30	30
Peru	120	191	234	350	187 [3]
Russia[e, 6]	400	400	400	400	400
Turkey[7]	1,953	1,948	2,128	1,500 [r, e]	1,300
United States[8]	1,148	W	W	W	W
Total	4,950	3,760	4,200	3,850 [r]	3,510

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data, not included in total.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 23, 2010.

[3]Reported figure.

[4]Boron oxide (B_2O_3) equivalent.

[5]Data are for years beginning March 21 of that stated.

[6]Blended Russian datolite ore that reportedly grades 8.6% B_2O_3.

[7]Concentrates from ore.

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