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2007 Minerals Yearbook

BORON [ADVANCE RELEASE]

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Boron

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U.S. consumption of minerals and compounds reported in boron oxide content continued to increase in a similar pattern as was reported for previous years and has been withheld to avoid disclosing company proprietary data (table 1). Boron products are priced and sold based on the boric oxide content, which varies by ore and compound, and on the absence or presence of sodium and calcium (table 3). Boron compounds exported by producers were boric acid [248,000 metric tons (t)] and sodium borate (446,000 t) (tables 1, 4). Boron imports consisted primarily of borax, boric acid, colemanite, and ulexite (tables 1, 5). Turkey and the United States were the world's leading producers of boron minerals (table 6). The largest colemanite and ulexite deposits in the world are located in Turkey.

Elemental boron is a nonmetal that is marketed in grades from 90% to 99% purity. There are as many as 60 known boron minerals, occurring as borates or complex boro-silicates. Borax is a white crystalline substance chemically known as sodium tetraborate decahydrate and found in nature as the mineral tincal. Borax is also one of the most important boron minerals for industrial use. Boric acid, also known as orthoboric acid or boracic acid, is a white, colorless crystalline solid containing 56% boron oxide (B_2O_3) and sold in technical national formulary and special quality grades as granules or powder. Boron oxide is a colorless hard, brittle, solid resembling glass that is ground and marketed most often under the name anhydrous boric acid. The most common minerals of commercial importance in the United States were colemanite (hydrated calcium borate), kernite (hydrated sodium borate), tincal, and ulexite (hydrated sodium calcium borate) (table 2). Boron compounds and minerals were produced by surface and underground mining and from brine.

Production

More than 200 minerals contain boric oxide, but only a few were of commercial importance (table 2). Four minerals make up 90% of the borates used by industry worldwide, the sodium borates, borax and kernite; the calcium borate, colemanite; and the sodium-calcium borate, ulexite. These minerals were extracted primarily in California and Turkey and to a lesser extent in Argentina, Bolivia, Chile, China, and Peru. World production of boron minerals in 2007 was 3,840,000 t, an increase of 7% from that of 2006 (excludes U.S. production).

Domestic data for boron were derived by the U.S. Geological Survey from a voluntary survey of two U.S. operations. Both operations to which a survey request was sent responded; however, data were withheld to avoid disclosing company proprietary data (table 1).

The calcium borate mine in Newberry Springs, CA, that was owned and operated by Fort Cady Minerals Corp. has been idle since February 1, 2003. The Billie Mine at Death Valley, CA (owned by American Borate Co.), had sold product from inventory and imported borates from Turkey in 2005 but continues to be idle in 2007.

One of the active producers was Searles Valley Minerals, Inc. (SVM), which produced borax and boric acid from brines pumped from several salt layers, up to 100 meters (m) deep, in Searles Lake. Searles Lake is an evaporate basin located near the community of Trona in San Bernardino County, CA. SVM selectively pumps the brines from several of the salt layers and refines them in their plants near Trona. These brines supply other commercial salts in addition to sodium borates and boric acid.

The second active domestic producer was Rio Tinto Borax (a wholly owned subsidiary of London, United Kingdom-based Rio Tinto Minerals) which mined borate ores at Boron, CA, by open pit methods and transported the ores to a storage area by trucks. The property is the world's leading producer of refined borate products. The ore was processed into sodium borate or boric acid products in the refinery complex adjacent to the mine. An onsite plant also produced anhydrous sodium borate and boric oxide. Refinery products were shipped by railcar or truck to North American customers or to U.S. Borax, Wilmington, CA, facility at the Port of Los Angeles for international distribution. Specialty borate products are made at Borax's Wilmington plant and shipping facility located at the Los Angeles harbor.

Consumption

In 2007, U.S. imports for consumption of colemanite, borax, boric acid, and ulexite were 186,000 t, which was 31% less than the 243,000 t imported in 2006. In 2007, total U.S. consumption of all boron products increased by 3% compared with that of 2006.

The first reported use of borax was in the eighth century by Arabian gold and silversmiths. Today, there are more than 300 end uses for borates with nearly two-thirds of the world's supply sold into five end uses. New uses continue to be found each year (Hamilton, 2006).

The form in which boron is consumed has changed in recent years. The use of beneficiated ores like colemanite has declined following concerns over arsenic content. Consumers have moved towards the use of refined borates or boric acid that have a lower hazardous material content.

Agriculture.—Boron is 1 of 16 nutrients essential to all plants. Boron is necessary in controlling flowering, fruit development, germination, plant reproduction, and pollen production. Domestic consumption in fertilizer was estimated to be 2%. Boron is essential to plant growth and can be applied as a spray and incorporated in fertilizer, herbicides, and irrigation water. Boron fertilizers can quadruple corn yields and increase cotton yields by more than 560 kilograms per hectare (500 pounds per acre). Boron deficiencies in crops are found primarily in soils low in organic matter and in acid, and sandy soils in humid regions. Boron applied in May and June during early growth can be combined with calcium. For early season apples, boron can be applied postharvest to provide adequate nutrition when buds begin to bloom the next growing season.

Detergents and Soaps.—Detergents and soaps are the second largest application of borates after glass. In terms of borate consumption, the most important product is sodium perborate. Many different forms of borates, mainly sodium perborate tetrahydrate and monohydrate are used as a bleaching agent or as a source of active oxygen in laundry detergents and soaps. Soaps for personal care as well as heavy duty hand soaps for industrial and agricultural users are the main source for sodium perborate. Sodium tetraborate, also sold as 20 Mule Team Borax, is a combination of boron, oxygen, and sodium. Sodium tetraborate is used as an all natural disinfectant, bug repellent, and deodorizer and does not contain chlorine or phosphates.

Substitution of sodium percarbonate for sodium perborate has effected the consumption of borates considerably. This substitution was especially felt in Western Europe where in 2005 all of Western Europe's detergent makers stopped using sodium perborate. The switch was triggered by environmental concerns about boron as well as new coating technologies making sodium percarbonate equally as effective and less expensive to use.

Ferroboron.—Ferroboron (FeB) is a binary alloy of iron with boron content between 17.5% and 24% and is the lowest cost boron additive for steel and other ferrous metals. Limited quantities of elemental boron are widely used to increase hardness in steel. Boron is also utilized in aluminum castings to refine the grain; in copper-base alloys and high-conductance copper, as a degasifier; in the nonferrous metals industry, generally as a deoxidizer. In the semiconductor industry, small, carefully controlled amounts of boron are added as a doping agent to germanium and silicon to modify electrical conductivity. Applications also include the manufacturing of neodymium iron boron magnets. In 2007, one FeB manufacturer offered one ton of 18% FeB for $3,650.

Fire Retardants.—Zinc borate was used in plastics as a multifunctional boron-base fire retardant with applications in a variety of plastics and rubber compounds. Zinc borate is mainly used in flexible and rigid PVC 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. Boric acid is used in cellulose insulation, cotton mattresses, and wood as a fire retardant.

Glass.—Glass is a generic term for a fused-silica material with many different compositions. The major glass sectors are container, flat, fiber, and specialty. The glass industry continues to remain the leading domestic market for boron production, as in previous years.

Fiberglass represents the largest single use of borates worldwide. Fiberglass is a material made from extremely fine fibers of glass. Reinforcing fibers are produced by drawing fibers from orifices in a platinum bushing, spraying the fibers with a glaze, and winding onto a spool. The fibers are mixed with thermosetting materials such as epoxy, polyester, and vinyl esters to form composites. Borax is added to the fiberglass products to improve chemical resistance. In the United States, CertainTeed Corp., Owens Corning, PPG Industries, and Saint Gobain Owens produce fiberglass.

End uses for regular fiberglass are corrosion resistant fabrics, heat resistant fabrics, high strength fabrics, insulation, reinforcement, and sound absorption. The physical properties of fiberglass make it ideal for structural building materials because it is inert, lightweight, heat resistant, and a very strong fiber. However, these same properties are also responsible for some of the hazards encountered in the workplace. Some fiberglass fibers can be inhaled, but the primary hazard associated with fiberglass is skin irritation.

Another glass sector is flat glass whose demand continues to increase. The glass industry has witnessed a gradual shift away from single glazing to double/insulated glazing. Added to this, implementation of new legislation for energy efficient glass has made double glazing mandatory in many parts of the world. The smart glass industry is also increasing with electrochromic, switchable glass, self-cleaning window glass, and heads-up display windscreens as examples of new smart glass products (Industrial Minerals, 2007a).

Borosilicate glass is the foundation for all heat-resistant container glass applications. Borosilicate refers to glass which contains between 5% and 30% boric oxide. Borosilicate glass is most known for having a very low coefficient of thermal expansion, making it resistant to thermal shock, more so than any other common glass. Typically borosilicate glass has a composition of 70% silica, 10% boron oxide, 8% sodium oxide, 8% potassium oxide, and 1% calcium oxide. Borosilicate glass is less dense than ordinary glass. For most scientific glassware, low-expansion borosilicate glass is used because it is inert to most chemicals and can withstand changes in temperature. After Corning Glass Works introduced Pyrex® in 1915, it became a synonym for borosilicate glass. However, since 1998, Pyrex® kitchen brand is no longer made of borosilicate but of soda-lime glass. Various brands of borosilicate glass are Corning Inc.'s Pyrex®, Kimbel Glass Co.'s Kimax, and Schott North America Inc.'s Duran®.

Borosilicate glass is also used in the processing of high-level nuclear waste, where the waste is immobilized in the glass through a process known as vitrification. Cleanup of defense sites, including those in France, Germany, Japan, the United Kingdom, and the United States, emphasizes use of glass technology to immobilize contaminated materials. The glass encased waste is encased in a nickel-based alloy that provides protective barriers against chemical and physical stresses during disposal, interim storage, and transportation.

Other.—Boron oxide is incorporated into cellulose materials, as borates change the oxidation reactions and promote the formation of "char," thereby inhibiting combustion. Boric acid is effective in reducing the flammability of cellulose insulation, cotton batting used in mattresses, and wood composites. Borates are a part of the starch adhesive formulation for corrugated paper and paperboard and peptizing agent in the manufacture of casein-based and dextrin-based adhesive.

Borate treated wood is used in the construction of homes to protect against wood destroying organisms. 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. Borates prevent fungal decay and are deadly to carpenter ants, roaches, and termites.

Boron fiber is a wire of tungsten with elemental boron deposited during a reaction of boron trichloride and hydrogen gas at 800° to 2,000° C. Boron fiber is so stiff and strong that it has been used to patch across the fuselage of jet fighter aircraft to hold the wings on. The primary structural member of the B-1 bomber is a single lengthwise beam constructed of boron fiber.

Borazine and polyborazylene can be used as precursor chemicals to boron nitride coatings and composites. 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

The Trona Railway, connected to the Southern Pacific Railroad between Trona and Searles Stations in California, provided a dedicated line with access to the national rail systems for the borate and soda ash markets.

Almost all U.S. Borax bulk products were shipped in North America by rail. The Boron Mine at Boron is 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, which is served by the Union Pacific Railroad. Trucks of product from Boron are driven to Cantil, about 64 kilometers (km) (40 miles) northwest of Boron and loaded into dedicated railcars to be shipped to customers. SVM ships by rail from its plant at Trona.

Prices for rail haulage depended on a number of factors, including the ability of customers to load and unload efficiently, the ability to use whole unit trains, and the ability to supply their own railcars. The recent increase in fuel prices is another factor affecting cost, with carriers passing on surcharges to customers.

Ocean transport of U.S. Borax products was from the Port of Wilmington, where the company had a privately owned berth in the harbor. Products destined for Europe were shipped from the bulk terminal in Wilmington to a company-owned facility in the Port of Rotterdam, Netherlands, to company facilities in Spain, and to contracted warehouses. Borax Group also maintains secondary stock points that include Austria, Germany, Norway, the Republic of Korea, Singapore, Taiwan, and Ukraine. The most centrally located U.S. 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 service needed, and prices.

U.S. Borax used barges to ship borates from Rotterdam, Netherlands, to customers in Belgium, Eastern Europe, France, Germany, and countries even farther away. Barges were the most efficient and reliable method of transporting goods in Europe because most of the large industrial areas could be reached on waterways that link the Baltic, Black, Mediterranean, and North Seas as well as the Atlantic Ocean.

Imports from South America and Turkey enter into the United States principally through the ports of Charleston, SC, and Houston, TX.

Prices

Yearend prices of boron minerals and compounds produced in the United States are listed in table 3. Prices for borates have been flat for the past few years, reflecting competition in the marketplace and a balance between supply and demand. Table 4 lists the free alongside ship values for U.S exports of boric acid and refined sodium borate compounds to various countries. The Netherlands receives the largest amount of both boric acid and sodium borates from the United States owing to the fact that U.S. Borax has one of its main facilities located in the Port of Rotterdam, Netherlands, which receives products from its U.S. facility in California.

World Review

Argentina.—In 2007, Argentina was the leading producer of boron minerals in South America (table 6). Borax Argentina S.A. (a subsidiary of Rio Tinto Minerals) was the country's leading producer of borates. Borax Argentina mined borates at four deposits—Tincalayu and Sijes in Salta Province, at more than 4,270 m (14,000 feet) above sea level, and two dry lake beds, Salars Cauchari and Diabillo in Jujuy Province at 3,370 m. Yacimiento de Borato El Porvenir at the Salar Cauchari produces ulexite that grades 37% boron oxide. The Tincalayu Mine, originally developed in 1976, was Argentina's largest open pit operation. Commercial borates mined were colemanite, hydroborocite, kernite, tincal, and ulexite. The clay overburden averages 50 m and typically overlies 30 to 40 m of ore. Tailings from the company's ulexite concentration operation were used as feedstock to supply 8,000 t of boric acid production.

Recent capital investments of $2.4 million were used to upgrade equipment to improve efficiency and lower environmental impact. Future mine investments have been discouraged owing to a new export tax (10%) on mineral exports despite a 30-year guarantee of tax stability.

In 1998, Minera Santa Rita S.R.L. bought the boric acid manufacturing plant in Campo Quijano and had doubled production in 1999. In 2005, boric acid sales were reported to be 27,657 kilograms (kg). The company produced derivatives products for specific applications such as granular deca- and penta-hydrate borax, technical-grade boric acid power, and various grades and sizes of the natural boron minerals. The products are sold in 25 kg and 1 t bags. The ore was mined from Salar de Pozuelos at Mina San Mateo, Salar de Pastos Grandes at Mina San Cayetona, and Salar de Ratones at Mina Isla. The company reported a reserve of more than 1 million metric tons (Mt) of boron minerals. At the beginning of 2007, a new ulexite stratum with a thickness of 7 m was discovered in the Hombre Muerto Salt flats owned by Santa Rita S.R.L. (Minera Santa Rita S.R.L., 2006; 2008).

Other borate producers in the Province of Juyuy included Procesadora de Boratos Argentina S.A. (owned by Ferro Corp. and Canadian JEM Resources & Engineering, Inc.), which produced borates from 2-m thick layers of tincal and ulexite interbedded with clay and lenses of inyoite; Cía Minera Gavenda S.A., which produced borates at the La Inundada Mine at Salar Cauchari from layers of ulexite up to 1-m thick that grade between 11% and 35% B_2O_3; and Triboro S.A., which operated the Irene Mine where ulexite was mined that contained between 11% and 35% B_2O_3. Coop. de Borateros, Moncholi y Guijarro, Ramiro Martinez, and Viento Blanco S.R.L. were other producers in Argentina. Manufacturas Los Andes S.A., a newly formed company, produced boric acid at a plant located in the town of Olacapato. The mine and plant were located in the Andes Mountain Range at an elevation of 3,700 m, near the border with Chile. Ulexite from Salar de Diabillo was mined and produced into 99.5% pure boric acid. The total production of the plant's boric acid is 1,000 metric tons per month (Gruposaenz, 2006; Manufacturas Los Andes, 2008).

Uncertainty over taxation levels has recently emerged as a significant disincentive to new investment in the Argentine mining sector. In December 2007, customs agents lifted their 30-year tax exemption and demanded new 5% to 10% export tax payments. In response, many of the major export companies have started legal action to oppose the new taxes (Sociedad, 2007).

Bolivia.—The Bolivian government and Chilean industrial minerals producer Química e Industrial del Bórax Limitada (Quiborax) are close to reaching an agreement to settle an international arbitration case the company presented after its concession was withdrawn at the Salar de Uyuni salt flat, where the company mined ulexite. Quiborax is the Chilean parent of Bolivian company Non Metallic Minerals (NMM). However, since 2004, the company has been in various disputes with the Bolivian government about mining exploration locations owing to environmental protection conflicts (Industrial Minerals, 2006a; Yahoo News, 2008).

Chile.—In 2007, Chile was the second leading producer of boron minerals in South America (table 6). The Chilean borate producers are all located in the northern portion of the country. The most productive area is the Salar de Ascotan in Antofagasta Province. The largest, Quiborax, produces a number of products, including boric acid.

Quiborax began exploration in the protected natural reserve salt flat of Salar de Surire, without receiving authorization from the National Forestry Corporation (CONAF). The company's work could threaten one of the most important flamingo nesting spots in Chile. After Quiborax ignored CONAF restrictions, CONAF officially reported the mining company to the Agricultural and Mining Regional Ministerial Offices, which have greater judicial power than CONAF (Mines and Communities, 2008; Santiago Times, The, 2008).

China.—More than 100 borate deposits have been reported in 14 Provinces in China. The northeastern Province of Liaoning and the western Province of Qinghai together account for more than 80% of the resources, mostly in the form of borax decahydrate and boric acid. Boron resources in Liaoning were estimated to be 330 Mt, representing 57% of China's total resources (Industrial Minerals, 2006d). The resources are mostly consumed domestically, although there are some exports to the neighboring countries of India, Indonesia, North Korea, and Pakistan. The glass and porcelain enamel industries are the main consumers of borates in China.

India.—Boron carbide containing boron enriched in isotope B^{10} will be used in the control rods of the first Indian Prototype Fast Breeder Reactor (PFBR). This reactor was in the advance stages of completion and will probably be ready in September 2010. The reactor is located in Manuguru, India, and was being endorsed by the Heavy Water Board, a constituent unit under India's Department of Atomic Energy (Heavy Water Board, 2007; Economic Times, The, 2007). The fast breeder reactor will help meet India's fast growing energy needs.

Indo Borax & Chemicals Ltd., whose profits continued to rise each quarter of 2007, produces borax and boric acid. The company is the leading producer of boric acid in India and is referred to as the industry standard for many comparisons made in the boron industry.

Kazakhstan.—The Satimola borates deposit in western Kazakhstan was under development by Borates PLC of the United Kingdom. The deposit is about 220 km from the Caspian Sea Port of Atyrau and 210 km from the railhead at Makat. Solution mining appears to be the most cost-effective method of mining. The project was scheduled to produce 75,000 metric tons per year (t/yr) of boric acid, 50,000 t/yr of ulexite-hydroboracite concentrates, and 25,000 t/yr of anhydrous boric acid. Sodium borates also could be produced if a local source of trona can be found (Industrial Minerals, 2006c).

Russia.—The Bor deposit in far-eastern Russia is mined by open pit. Much of Russia's boric acid production is still shipped by rail to the Moscow area. Exports are shipped from the small, nearby port of Rudnaya Pristan. The Verchniny Mine in Dalnegorsk is one of the few places in Russia where datolite, a naturally occurring boron source, is mined.

Serbia and Montenegro.—Rio Tinto Minerals was awarded a concession in December 2005 for the Piskanja borate deposit in southern Serbia. Erin Ventures Inc. also was pursuing development of the deposit but was unsuccessful in its bid attempt. The company was seeking monetary compensation from the Government of Serbia (Industrial Minerals, 2006b). This legal action is the result of Erin's contention that it held a valid joint-venture contract to develop a boron property in Serbia and, in spite of direct knowledge of Erin's contractual rights, the Serbian government granted the boron deposits to a third party (Erin Ventures Inc., 2007).

Researchers from Rio Tinto Minerals discovered a new unusual mineral with a formula of sodium lithium boron silicate hydroxide. Identifying its atomic structure required sophisticated analytical facilities. The new mineral will be formally named jadarite after Jadar, the name of the mine in Serbia where it was first found. Jadarite may have commercial value if deposits occur in sufficient quantity owing to the presence of both boron and lithium (BBC News, 2007).

Turkey.—Eti Maden AS, the state-owned group which operates all of Turkey's boron mines, had been urged to form as an independent organizational structure in order to resist economic and political pressures. The group also had been urged to establish connections with university research departments and private companies in order to remain competitive in the world market (Industrial Minerals, 2007b). Eti mines its large Kirka borax deposit by open pit methods, using trucks and shovels for both mining and waste removal. Similar methods are used for their colemanite mines in the Emet Valley. The major ulexite/colemanite deposits in the Bigadic Basin are also mined by both open pit and underground methods. Eti has boric acid plants at both Bigadic and Emet, but its main processing plants are at the shipping port of Bandirma, on the Sea of Marmara.

Outlook

Fire Retardants.—Worldwide flame retardants consumption will see overall growth of between 4% and 5% in the next few years with growth of halogen-free flame retardants. This growth will be because of environmental and, particularly in automotive applications, for technical reasons. Fire safety requirements are growing globally as well because of stricter fire regulations. The highest increase in use of halogen-free flame retardants will be in China, with an expected greater than 13% growth. A slightly slower growth will take place in Western Europe, and in the United States between 9% and 11%. The average global annual growth rate for halogen-free flame retardants is now greater than 10%, compared with 5% for the general flame retardants market (Industrial Minerals, 2007a).

Technology of nano-zinc borate has been developing rapidly and was being used widely in such fields as aerospace, home electrical appliances, and in the light industry. Compared with conventional crystalline zinc borate, nano-zinc borate features greater diffusivity, higher electrical resistance, greater flexibility, increased strength hardness, and lower thermal conductivity. These are all properties that can improve fire resistance.

Glass.—Demand for flat glass continues to increase. Greater use of varieties of glass by architects and car designers for civil construction and automotive applications was the main growth impetus. About 70% of flat glass was used in the construction industry. New legislation for energy efficient glass also increased demand within the flat glass industry (Industrial Minerals, 2007a).

Growth in fiberglass and borosilicate production has driven a global increase in consumption of boron. A rapid increase in the manufacture of reinforcement-grade fiberglass in Asia with a consequent increase in demand for borates offset the development of boron-free reinforcement-grade fiberglass in Europe and the United States. The continued rise in energy prices can be expected to lead to greater use of insulation-grade fiberglass, with consequent growth in the use of boron.

Other.—Boron nanotube technology continued to evolve in 2007. A new theory was developed, which may lead to the development of boron nanotubes that can act as conductors in a way that carbon nanotubes cannot (Physorg.com, 2007).

Boron neutron capture therapy (BNCT) is a new method based on an old concept that can be used to treat previously irradiated head and neck cancers that have recurred and are inoperable. BNCT is an experimental form of radiation therapy that centers on the nuclear reaction that takes place when boron-10 is irradiated with low-energy thermal neutrons. It allows for high doses of radiation to be targeted at cancer cells, provided that the malignant tissue absorbs a substantially larger amount of boron than the normal tissue. The availability of BNCT remains limited, as sufficient epithermal neutrons are attainable only from a nuclear reactor. However, researchers explained that it may soon change, as compact accelerator-based neutron generators that are compatible with hospital environments were under development (Medscape, 2007).

Boron-treated wood is becoming more widely used throughout the United States especially in the southern States. Borates interfere with termites' metabolic pathways when ingested through feeding or grooming, effectively killing them. Borate has been so successful that the Southern Building Code Congress has determined that homes built with borate-treated framing lumber do not need to be ground-poisoned. Costs run about 30% higher than comparable building products (Old House Journal, 2007).

To create more demand for its product, Turkey launched a promotional campaign for boron by seeking out new areas of use for the mineral. The Boron Institute of Turkey was continuing to sponsor multiple projects by Turkish Universities and research centers. So far, 20 projects have been completed, while another 61 projects were in progress and were likely to produce good results. Some of the successful projects so far include adding boric acid to porcelain floor tiles as well as adding boron in the production of fortified cement, doubling cement quality and lifespan. Other successful projects include bone reinforcement of laying hens; use as a fertilizer for hazelnut, kiwi, sugar beet and tomato farming; in the production of fuel cells that are 100 times structurally stronger than ordinary cells while remaining environmentally friendly; in the production of environmentally friendly batteries; as an additive to boost the traction and elongation capacity of steel; and in the treatment of breast and prostate cancer (Today's Zaman, 2008).

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TABLE 1
SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS[1]

(Thousand metric tons and thousand dollars)

	2003	2004	2005	2006	2007
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[2]	1,150	1,210	1,150	W	W
B_2O_3 content	605	637	612	W	W
Value	591,000	626,000	713,000	W	W
Exports:[3]					
Boric acid:[4]					
Quantity	70	61	183	221	248
Value	36,400	34,900	96,800	126,000 r	124,000
Sodium borates:					
Quantity	131	135	308	393	446
Value	55,400	60,200	110,000	138,000 r	146,000
Imports for consumption:					
Borax:[3]					
Quantity	(5)	(5)	1	2	1
Value	19	62	319	701	647
Boric acid:[3]					
Quantity	47	49	52	85	67
Value	19,000	20,300	22,500	34,900	27,500
Colemanite:					
Quantity[6]	24	21	31	25	26
Value	6,960	6,070	8,900	7,260	7,640
Ulexite:					
Quantity[6]	80	110	103	131	92
Value	16,000	21,900	31,000	39,200	27,600
Consumption, B_2O_3 content	366	385	W	W	W
World, production[7]	4,750 r	4,960 r	4,840 r	3,580 r	3,840 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]United States production withheld from World production in 2006 and 2007 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	$Ca_2B_6O_{11}\cdot 5H_2O$	50.8
Datolite	$CaBSiO_4OH$	24.9
Hydroboracite	$CaMgB_6O_{11}\cdot 6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7\cdot 4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19}\cdot 7H_2O$	49.8
Probertite (kramerite)	$NaCaB_3O_9\cdot 5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2OH$	41.4
Tincal (natural borax)	$Na_2B_4O_7\cdot 10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O_7\cdot 5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9\cdot 8H_2O$	43.0

[1]Parentheses include common names.

TABLE 3
YEAREND PRICES FOR BORON MINERALS AND COMPOUNDS[1]

(Dollars per metric ton)

Product	Price, December 31, 2005	Price, December 31, 2006	Price, December 31, 2007
Borax, anhydrous, 25 kg bags[2]	1,645-1,762	1,646-1,763	1,678-1,798
Borax, decahydrate[2]	340-380	340-380	340-380
Borax, decahydrate, granular[2]	783-881	784-882	799-899
Borax, pentahydrate[2]	400-430	400-430	400-430
Borax, pentahydrate, granular[2]	587-685	587-685	599-699
Borax, technical, anhydrous, 99%, bulk, carload, works[3]	900-930	NA	NA
Borax, technical, granular, decahydrate, 99%, bags, carload, works[3]	378	NA	NA
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works[3]	340-380	NA	NA
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works[3]	426	NA	NA
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, works[3]	400-425	NA	NA
Boric acid, granular[2]	685-783	686-784	699-799
Boric acid, technical, granular, 99.9%, bags, carload, works[3]	836	NA	NA
Boric acid, U.S. Borax, Inc. & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound-bags, carlots[3]	900-935	NA	NA
Colemanite, Turkish lump, 40%-42% B_2O_3[2]	270-290	270-290	270-290
Ulexite, Lima, 40% B_2O_3[2]	250-300	250-300	250-300

NA Not available.

[1]U.S. f.o.b. 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]Sources: Industrial Minerals, no 459, December 2005, p. 70; no. 471, December 2006, p. 74; no. 483, December 2007, p. 76.

[3]Source: Chemical Market Reporter, pricelist June 18-24, 2007.

TABLE 4

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

	2006			2007		
	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	1,990	$1,130	7,620	2,520	$1,270	7,070
Belgium	23	29	44	45	31	31
Brazil	1,650	978	1,570	1,990	1,150	866
Canada	4,800	4,530	54,900	4,350	3,150	40,300
China	22,400	11,100	69,900	50,200	24,700	88,100
Colombia	192	157	4,770	242	199	5,150
France	1,460	987	548	7,960	5,370	679
Germany	701	1,380	20	1,410	2,010	17
Hong Kong	1,460	748	--	1,520	752	21
India	1,160	447	16,500	1,470	525	19,700
Indonesia	1,040	608	531	921	468	1,820
Italy	--	--	1,820	--	--	1,440
Japan	34,900	36,500	26,100	29,700	17,600	26,100
Korea, Republic of	22,400	11,900	13,400	25,600	13,800	15,500
Malaysia	869	722	30,400	1,630	858	50,900
Mexico	2,310	1,580	8,390	3,200	1,890	10,600
Netherlands	64,600	25,900	91,200	54,900	21,300	127,000
New Zealand	992	606	1,420	403	208	1,430
Philippines	190	125	1,050	117	89	1,400
Singapore	1,290	791	799	1,500	1,070	619
Spain	24,200	8,880	42,500	16,500	5,970	24,600
Taiwan	25,100	13,800	3,140	31,300	15,400	4,290
Thailand	4,140	2,380	6,670	3,830	2,120	6,600
United Kingdom	46	57	37	60	58	72
Venezuela	74	91	449	71	83	479
Vietnam	429	247	1,720	1,380	677	2,810
Other	2,210	1,020	7,510	4,960	2,970	9,160
Total	221,000	127,000	393,000	248,000	124,000	446,000

-- 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]

Country	2006 Quantity (metric tons)	2006 Value[2] (thousands)	2007 Quantity (metric tons)	2007 Value[2] (thousands)
Argentina	849	$360	--	--
Australia	19	29	4	$28
Bolivia	7,600	2,770	7,210	2,860
Chile	20,600	7,790	12,800	5,140
China	134	204	268	472
France	527	811	738	1,230
Germany	42	67	13	34
India	180	198	181	187
Italy	962	1,370	954	1,370
Japan	22	57	56	124
Korea, Republic of	21	12	--	--
Peru	3,740	1,470	1,510	651
Russia	3,420	1,520	1	6
Turkey	47,000	18,100	43,000	15,100
United Kingdom	95	133	270	284
Other	27	40	17	16
Total	85,300	34,900	67,000	27,500

-- 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	2003	2004	2005	2006	2007[e]
Argentina	512	821	633	534 [r]	550
Bolivia, ulexite	110	68	63	48 [r, e]	50
Chile, ulexite	401	594	461	460	528 [3]
China[e, 4]	130	135	140	145	145
Iran, borax[5]	3	2	2 [r, e]	2 [r, e]	2
Kazakhstan[e]	30	30	30	30	30
Peru	9	10	10	10	10
Russia[e, 6]	1,000	500	400	400	400
Turkey[7]	1,399 [r]	1,588 [r]	1,953 [r]	1,948 [r]	2,128 [3]
United States[8]	1,150 [r]	1,210	1,150 [r]	W	W
Total	4,750 [r]	4,960 [r]	4,840 [r]	3,580 [r]	3,840

[e]Estimated. [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 May 20, 2008.

[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.