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Features

Boron: From Fishing Rods To Flares

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High-tech and low tech, boron's on the rise. But can you get access?

"Boron is a truly schizophrenic element. It's an element of complete frustration. It doesn't know what it wants to do. The outcome is something horribly complicated."

—Professor Artem R. Oganov, Stony Brook University, New York as quoted in the New York Times on Feb. 2, 2009

While boron may not know what it wants to do with itself (there are more than 200 naturally occurring boron-bearing minerals), we as humans certainly know what to do with it. We have been using it now, in different guises, for about 4,000 years. Estimates of the number of its different uses range anywhere from 300 to 500. And, currently, its most publicized use, if not its most useful, is in those rare-earth, neodymium-iron-boron magnets that go into wind turbines and other important industrial applications.

What Is Boron?

Designated number 5 (and on the top right-hand side) in the periodic table, and extraordinarily simple in atomic structure, boron is, however, one of those problematic elements categorized, along with antimony, arsenic, germanium, polonium (arguably), silicon and tellurium, as a metalloid; that is, it is neither true metal nor nonmetal. And this, perhaps, accounts for a great deal of its versatility.

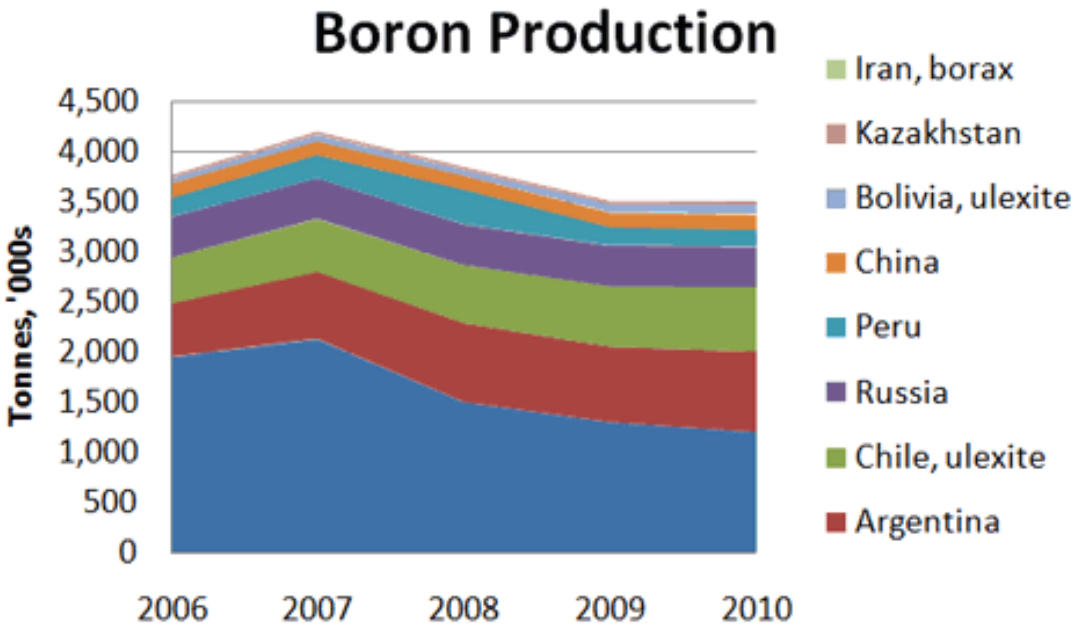
Boron was discovered relatively recently—in 1808 by the triumvirate of England's Sir Humphrey Davy, and Joseph Louis Gay-Lussac and Louis-Jacques Thénard from France. It occurs naturally only in boron-bearing compounds, not conveniently lying around in pure ores, and is extremely difficult to separate and purify into its elemental form. Following false claims to have done so by chemist Henri Moissan, it was only in 1909 that William Weintraub actually produced 99 percent pure boron.

At low temperatures, crystalline boron is an insulator and, at higher temperatures a conductor. It is also highly refractory, with its melting and boiling points given by one source as 2,076 °C and 3,927 °C, respectively. (The Los Alamos National Laboratory gives its boiling point as 4,000 °C.)

Whence Boron?

Although ubiquitous, boron is still not particularly abundant in the Earth's crust, constituting only around 0.001 percent thereof—less than that of lead, but certainly more than that of hafnium, beryllium and tin. And indeed, significant, useful deposits of borates (the form in which it is most usually found) are few and, literally, far between.

The largest borate deposits currently being mined are in California's Death Valley and in central and western Turkey, with Argentina, Chile, Turkey and the U.S. constituting the world's four largest producers of boron minerals.



Source: U.S. Geological Survey (USGS)

In the U.S., the two largest boron producers are U.S. Borax Inc. (owned by Rio Tinto), mining and refining boron in California's Mojave Desert; and Searles Valley Minerals Inc. (owned by India's Gujarat-based Nirma Limited), mining out of Searles Lake, Trona, located in California's San Bernardino County, and refined in both Trona and Westend.

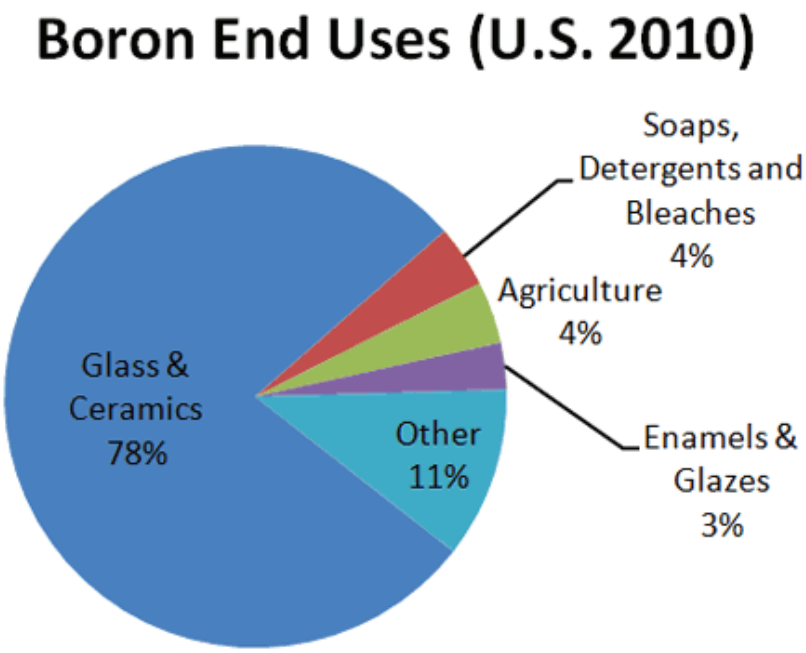
Although the USGS does not provide figures for Rio Tinto's borax operations ("to avoid disclosing company proprietary data"), in its 2010 Form 20-F, the company indicated that in that year, it produced some 815,000 product tonnes of refined borates from its boron operations (these include its high-desert operations in Argentina's Salta province) and 500,000 tonnes of boric acid (of which 483,000 tonnes were produced in California), constituting a rise in total borates production of 18 percent for the year. The company's production alone places the U.S. amongst the world's largest producers of borates.

Figures are not immediately available for boron production from Searles Valley Minerals.

Uses Of Boron

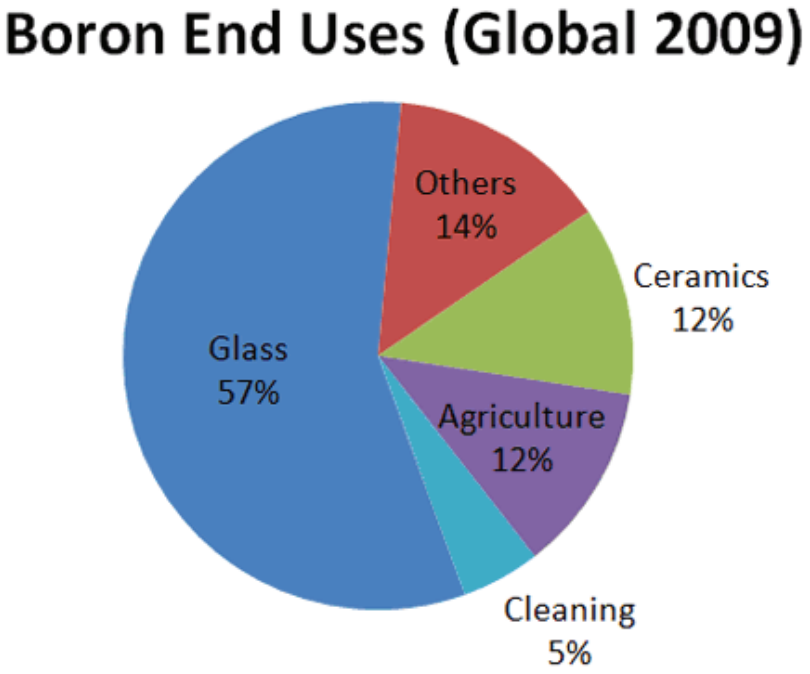
Except in a very small number of extremely specialized applications, boron is nearly always consumed either as a refined borate or as boric acid.

The USGS gave the “estimated distribution pattern for boron compounds consumed” in the U.S. in 2010 as:



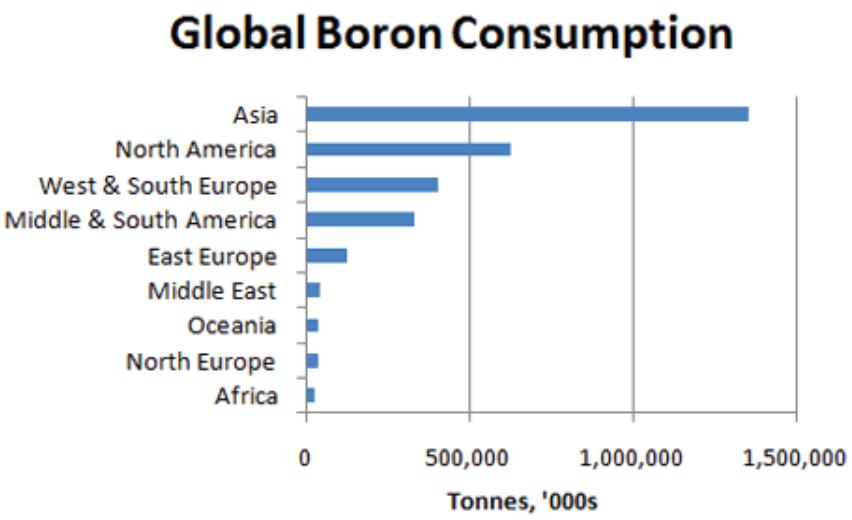
Source: USGS

In its 2009 annual report, Turkey’s state-owned mining company, Eti Maden AS, estimated that global boron consumption amounted to 2,997,103 tons.



Source: Eti Maden AS

For the same year, the company also provided figures for global consumption.



Source: Eti Maden AS

But Why Use Borates …?

… Because they can do so much. And, as importantly, they are safe. Together with some additional examples, U.S. Borax Inc. (Rio Tinto) neatly described the versatility of borates by expanding on the following functions of borates:

- *Absorb radiation:* Since boron absorbs neutrons, it can be used in the likes of shielding in reactors, nuclear fuel control rods and in radiotherapy applications. And, according to the USGS, “Boric acid is used in the cooling water surrounding nuclear reactors to absorb escaping neutrons.” (About which Futurama appears to have been fully aware!)
- *Bleach:* One of borates’ most established uses is in laundry bleaches (for example, “Borax”) and stain removers.
- *Buffer:* Borates are used as a buffer in detergents and fireworks, among other things, to balance acidity and alkalinity and, thus, to render stability in compounds.
- *Disperse:* Borates are used in paints and cosmetics to control viscosity and to ensure their ingredients are evenly dispersed therein.
- *Flameproof:* Borates can be used as a flame retardant and are used to coat electrical cables.
- Hinder metabolization: Borates can be used to control bacteria, fungi and insects. This can be especially useful in, for example, the treatment of wood against bugs.
- *Inhibit:* Borates form a protective coating on surfaces containing iron. They are, in this context, to be found in both aerosol cans and antifreeze.
- *Micronutrient:* Boron-containing fertilizers are used in agriculture, especially in seed production.
- *Vitrify:* Borates “vitrify” glass, making it both heat resistant (for example, Pyrex) and resistant to chemical corrosion. They are used for this purpose in ceramic tiles and glazes, insulation and textile fiberglass (currently the largest single use of borates globally) and ultra-thin LCD screens.

In the sporting world (taking, perhaps, a lead from the aerospace industry), boron is also used in quite expensive golf clubs and fly-fishing rods. In these applications it contributes both to toughness and lightness—each an attractive characteristic.

Boron also has a number of interesting niche uses. These include:

- A *dopant* in semiconductors. Boron is used to dope semiconductors such as germanium and silicon carbide to transform them into p-type conductors.
- In *armor* and *bulletproof clothing*. These sometimes use boron carbide (B_4C) because of its exceptional hardness (9.3 on the mohs scale) and light weight.
- *Magnets*: Boron is used in neodymium-iron-boron ($Nd_2Fe_{14}B$) magnets, the super-strong magnets about which there has been so much press over the past year or so and that are to be found in, e.g., wind turbines, speakers, automobiles and computer hard disks.
- *Flares*: Flares containing boron burn with an intense green color.

The Future for Boron

After a fearful end to the years 2008 and 2009, in 2010 the market for boron brightened with increased consumption and production. The demand for boron, in fiberglass (high-tech and insulation) in particular, is expected to rise steadily over the next several years. According to the USGS, high-tech fiberglass demand is forecast to be strong both in North America and Europe, while demand for insulation fiberglass will likewise be strong in Europe as well as the emerging economies.

In China, increases in demand for boron are likely to stem from borate use not only in glass, but also in ceramics, especially tiles. China's imports of borates are expected to increase too, not least because of the poor quality of its own boron reserves.

World Boron Reserves ('000 Tons - Boric Oxide)

Country	Proven Reserve	Possible Reserve	Total Reserve	Percent
Turkey	227,000	624,000	851,000	72.2
U.S.	40,000	40,000	80,000	6.8
Russia	40,000	60,000	100,000	8.5
China	27,000	9,000	36,000	3.1
Chile	8,000	33,000	41,000	3.5
Bolivia	4,000	15,000	19,000	1.6
Peru	4,000	18,000	22,000	1.9
Argentina	2,000	7,000	9,000	0.8
Kazakhstan	14,000	1,000	15,000	1.3
Serbia	3,000	-	3,000	0.3
Totals	**369,000**	**807,000**	**1,176,000**	**100**

Source: Eti Maden AS

Boron Mining Companies

Of the largest boron mining companies, none, unfortunately, is both a pure play and investable: Eti Maden of Turkey is state owned; Rio Tinto (with its boron operations in the U.S. and Argentina) has many other lines of business; and, Searles Valley Minerals is owned by Indian giant Nirma. Minera Santa Rita S.R.L. in Argentina is privately held and also mines other minerals. And Chile's Quiborax, S.A., although a pure play, is also not available for investment.

Opportunities In Boron

While there are currently few opportunities to invest in boron mining companies, for those who wish to keep an eye on developments in the use of the element and its compounds, there are a number of areas upon which to watch. These include:

- Nanotechnology using boron nitride nanotubes: They may, in certain instances, replace carbon nanotubes.
- Neodymium-iron-boron magnets: If China is going to increase its stranglehold on the market for such magnets, it will need the ferroboron with which to make them. As, indeed, will others, if they intend to break such a stranglehold.
- Fuel cells: Certain fuel cells use boron.

And Boron's Schizophrenia?

Much like pure carbon (diamond and graphite), antimony and arsenic, pure boron can assume a number of different forms, or allotropes. Until recently, it was thought there were but three: dark, transparent, red alpha boron; black, coal-like, beta boron; and, a tetragonal, pure phase form of boron called T-192.

However, following the independent production in 2004 of a new boron phase by two scientists—Jiuhua Chen of Florida International University and Vladimir L. Solozhenko of the National Council for Scientific Research in France—it was Professor Oganov who actually identified it as a fourth allotrope—gamma boron.

It appears that this "new" form of boron is not only stable at extremely high pressures, but is also more heat resistant than diamond, if not just as hard.

With its four (so far) allotropes, each with a very different structure from the other, it is hardly surprising that Professor Oganov describes it as "horribly complicated" and not knowing "what it wants to do."

All very surprising, perhaps, for a simple atom with just five electrons, five or six neutrons and five protons.

Resources

U.S. Geological Survey (USGS)