

# Feature

## Element of the Month

# Boron

Produced entirely by *cosmic ray spallation* rather than *stellar nucleosynthesis*, boron, a Group III metalloid with 5 protons in its nucleus, is the 41st most abundant element in the Earth's crust—rarer than many of the so-called "rare earth" elements!

Because of the nature of its production, boron is a rare element not only on Earth, but in the Universe in general. The element occurs in an uncombined state only in small amounts in cosmic dust and meteoroids. Comprising just .001% of the Earth's crust, here it is always bound to oxygen in the form of the borate ( $\text{BO}_3$ ) radical, which can be polymerized similar to  $\text{SiO}_4$ , producing  $\text{B}_2\text{O}_5$ ,  $\text{B}_3\text{O}_6$ , and  $\text{B}_2\text{O}_4$  anions, among other more complex structures. More than a hundred naturally occurring borate minerals exist with boron in the 3+ oxidation state.

Due to the easy solubility of the common borate minerals in aqueous solutions, the element becomes highly concentrated in surficial deposits as bodies of water evaporate and dry up.

These salts of boric acid include borax, colemanite, and ulexite, which are mined from economically valuable deposits found mainly in Turkey and the United States. While an estimated four million tons are used annually, proven global reserves of boron exceed a billion metric tons!



Though boron was not recognized as an element until the early 1800s, boron-bearing minerals have been in use since ancient times. Borax glazes were used in China as early as AD 300, and Marco Polo brought some glazes back to Italy in the 13th century. Borax was used as a metallurgical flux as early as 1600, and boric acid—in the form of the mineral *sassolite*—was recognized in 1777 in the hot springs at Sasso near Florence, Italy, where it was used mainly

for medicinal applications. These deposits were the main provider of European boron from 1827-72, after which it was replaced by U.S. sources.

Elemental boron was first isolated by Sir Humpfry Davy in 1808 by subjecting a borate solution to electrical currents, producing a brown precipitate deposited on one of the electrodes. He named the new element **boracium**. About the same time, Louis Jacques Thenard and Joseph Louis Gay-Lussac, both of whom have minerals named after them (called **thenardite** and **gaylussite**, respectively), used iron to reduce boric acid at especially high temperatures. Subsequently, they oxidized the precipitate with air, thus demonstrating that boric acid was an oxidation product of boron. The element became known as **boron** when it was identified by Jons Jakob Berzelius in 1824.

Similar to carbon in its capacity to form stable covalently bonded molecules, boron is found in four major polymorphs, including  $\alpha$ - and  $\beta$ -rhombohedral, plus  $\gamma$ - and

$\beta$ -tetragonal. Boron in its crystalline form is black, chemically inert, very hard, has a high melting point of 2000 °C, and is resistant to attack by hydrofluoric and hydrochloric acids. However, when finely divided, it is dissolved slowly by such solvents as hot concentrated nitric and sulfuric acids, and hot hydrogen peroxide.

Boron has 13 known isotopes, only two of which are naturally occurring and stable: Boron-11 (80.1%) and Boron-10 (19.9%).

Hydrothermal alteration of rocks preferentially leaves Boron-10 in the resulting clays, causing enrichment of Boron-11 in solutions that find their way into seawater, thus explaining the higher concentrations of Boron-11 in oceans relative to oceanic and continental crusts.

Due to its ability to capture neutrons, Boron-10 finds valuable usefulness in several applications. For instance, in the nuclear industry, it is incorporated in borosilicate rods to control the rate of fission in nuclear reactors;

boric acid is added to reactor coolant when powerplants are shut down for refueling, then slowly filtered out as the fuel is used up and becomes less reactive.

The isotope is also the primary nuclide used in **neutron capture therapy** for treating cancers, in which a compound that contains Boron-10 is incorporated into a pharmaceutical selectively absorbed by malignant tumors that are then subsequently subjected to a beam of low-energy neutrons, which in turn produce alpha particle emissions that bombard the tumor from the inside, killing the tumor cells.

An interesting theoretical use incorporates boron-10 in the structural material of a future interplanetary spacecraft, thus serving as a **radiation shield**. Space travellers are especially susceptible to cosmic rays, which are mostly high-energy protons. Secondary radiation from the interaction of these cosmic particles with the spacecraft materials would be hazardous to passengers.

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# A Collection of Boron Minerals



IX 32 D

**Inyoite**

Sierra de la Cruces  
Chihuahua, Mexico  
1.75 x 1.88 x 1.35 inches



IX 34 C

**Colemanite**

Boraxo (Thompson) Mine  
Ryan, CA  
4.5 x 4.25 x 3 inches



IX 13 D

**Colemanite**

Widow #1 Mine  
Ryan, CA  
.8 x .9 inches



IX 11 D

**Ulexite**

US Borax Mine  
Boron, CA  
1.75 x 2.75 inches



IX 37 D

**Hydroboracite**

Boraxo (Thompson) Mine  
Ryan, CA  
2 x 2.75 inches

*All specimens from the*  
**G. Miles Lehman Collection**



XIX 07 C



**Tourmaline**  
Minas Gerias  
Brazil  
4.25 x 4 inches

IX 31 D



**Tunnellite**  
US Borax Mine  
Boron, CA  
2.5 x 1.5 x 1.9 inches

IX 26 D



**Proberite**  
Widow Mine  
Ryan, CA  
2.5 x 1.5 inches

IX 30 D



**Ulexite with Orpiment**  
US Borax Mine  
Boron, CA  
1.5 x 1 inches

IX 24 D



**Meyerhofferite**  
Mount Blanc  
Inyo, CA  
1 x .8 inches

*All specimens from the*  
**G. Miles Lehman Collection**





IX 14 D

## Strontioginorite

Oakley Mine

Ryan, CA

1.5 x 2.25 inches



IX 22 D

## Ludwigite

Big Cottonwood Canyon

Brighton, UT

2.5 x 2.5 inches



IX 38 D

## Johachidolite

Pyant Gyi Mine

Mogok District; Myanmar

1.58 x 1.38 inches

*All specimens from the*  
G. Miles Lehman Collection

Boron-10 in the structural materials would provide protection by absorbing such secondary radiation before it reaches the interior of the craft.

Boron finds additional uses in fiberglass, borosilicate glassware, ceramics, semiconductors, bleaches and detergents, insecticides, sporting goods (such as golf clubs and fishing rods), and in pyrotechnics to produce green flares, accounting for 70% of the element consumed.

While boron is an essential plant nutrient required for maintaining the integrity of cell walls, the exact physiological role of the element is not well understood for animal life, although it is known to be necessary for the optimal health of lab rats in ultratrace amounts. And while highly toxic to insects, particularly ants, fleas, and roaches—thus finding effective use as insecticides—elemental boron, boric acid, and borates are relatively non toxic to humans and animals (with a toxicity similar to common table salt).

Borates are generally unimpressive and difficult to identify one from another by ordinary methods in the absence of well-formed macrocrystals. Not only are they very similar in appearance when found massive or in aggregates of minute crystals (usually vitreous to earthy; white, tan, or colorless), but, generally speaking, a very limited suite of cations (namely Na, Ca, and Mg) constitute most borates, making chemical tests inconclusive as to the specific mineral. Even those borates that in pure form contain only single cations, such as Na in borax, purity is rarely the case in nature, and the other cations often occur as contaminants! Of course, specimens displaying large crystals are the exception, are much easier to positively identify, and are most definitely impressive.

Regardless, borates are necessary additions to any well-rounded and chemical-class-oriented collection. Even if positive identification is impossible by ordinary means, best guess is adequate and should not deter a collector from including a dubiously identified specimen in any mineral assemblage.

## Tests for Boron

*The only reliable confirmatory test for boron is the color boron-bearing minerals impart to a flame test. Most of these minerals will be borates, thus the locality will suggest identification before any tests need be performed. Boron-containing minerals such as tourmalines will not produce the flame coloration. Some references suggest solubility in hot water or HCl, but this is hardly confirmatory, as many non-boron minerals are soluble in such.*

**Flame Test:** Most boron-bearing minerals (and particularly borates) will tinge the flame a brief yellow green. Some will yield the coloration when heated alone, but most will color the flame only when first moistened with sulfuric acid. If sodium is present, the boron test will be masked by the resulting intense yellow flame, requiring a blue filter to reveal the green. This flame color is easily confused with that produced by barium minerals. It is best to compare the flame to that which is produced by a known barium-containing sample.

A variation of this test requires powdering the sample, mixing it with the *boron flux* (three parts acidic potassium sulfate to one part fluorite), then fusing the resulting mixture on a platinum wire held in a Bunsen burner flame. A momentary, but distinct yellowish green flame coloration indicates boron.