Boron: From Cosmic Scarcity to 300 Minerals
Edward S. Grew

Boron Behavior During the Evolution of the Early Solar System: The First 180 Million Years
Charles K. Shearer and Steven B. Simon

Boron Cycling in Subduction Zones
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Boron Isotopes: A “Paleo-pH Meter” for Tracking Ancient Atmospheric CO₂
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Origin and Distribution of Evaporite Borates: The Primary Economic Sources of Boron
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Tripping the Light Fantastic: Organoboron Compounds
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In 2004, I assumed an administrative role in my university, thus joining what is commonly referred to as the “Dark Side” of academia. I have only just returned to my position as a faculty member. Some pursue administration as a career path and expect to move up the academic ladder, progressing from department head, to dean, to provost, and, perhaps, even to president. Others, like myself, view administration as an intriguing experiment: I certainly didn’t anticipate staying away from a faculty role for so long (almost 13 years). Like many faculty, I had little experience with organizational leadership when I joined the Dark Side. I was like a Padawan apprentice (another reference from *Star Wars*) aspiring to be a Jedi and greatly in need of master Yoda’s training.

I share below what I have learned from my experience, not only for those considering a position in academic administration but also for others to gain an appreciation of this important role:

- **Administrators create an atmosphere that allows faculty members to exercise their dreams and accomplish their goals.** This is accomplished by taking care of the day-to-day routine administrative tasks that ensure the smooth running of a department. As a former Dean told me, it is like “making sure there is toilet paper in the bathroom”.
- The pace and workload that an administrator handles is unrelenting. E-mails, reports, budgets, and phone calls come in steadily. You will always have an internal list of things that must be done right away, projects to start, and projects that you should start. To be successful, an administrator needs to prioritize and to balance output versus perfection.
- **Administrators operate within an organizational unit.** Life will no longer be as flexible as when you were a faculty member. You will have a supervisor to whom you will report on a regular basis. You, in turn, will supervise administrative and/or technical staff. You are held accountable for both the good and the bad of your unit.
- As an administrator, you will develop a new network of relationships. This network will be invaluable when you are troubleshooting an unfamiliar problem, but it may also mean that you may have to work with people who drive you crazy. As Yoda would advise, “Patience you must have, my young Padawan.”
- **Administrators have to make decisions in a timely manner.** You will need to address issues before they become emergencies by being in close touch with your faculty and staff. Results need to be communicated to all involved.
- **Administrators need to think “outside-of-the-box”.** Just when you think you have seen it all, a new and strange problem appears that demands a unique solution. Being a troubleshooter and producing practical solutions is the most creative part of an administrative assignment.
- **Administrators are often expected to get deeply involved in conflict... not by instigating it (!) but by helping to resolve it.**
One in a Million

Due to its impact on global climate, carbon is the element that currently dominates the public debate. Why publish an issue on boron when the public is focusing on carbon? As you read the articles in this issue, what you will find is that boron is a “quintessential” terrestrial element. Although rare in the Solar System, Earth’s tectonic and weathering processes have concentrated boron within the Earth’s upper continental crust, where we are completely dependent on it for everyday life.

The authors of this issue make a compelling argument that we shouldn’t undervalue boron. As an essential constituent of nearly 300 minerals such as tourmaline and colemanite in the Earth’s crust and even one in the Earth’s mantle (qingsongite), boron provides a unique indicator for deciphering Earth’s 4.6 billion-year evolution from a molten mass in the proto Solar System to a vibrant planet that can sustain life. Boron also allows us to peer into the complex dynamics of subduction zones, to trace paleoclimatic conditions and atmospheric CO₂, and to understand how the essential building blocks of life (e.g. RNA) could form in the hostile environments of the early Earth. But, boron isn’t just valuable for scientific pursuits, it also finds practical applications in glass and ceramics, detergents, fertilizers, and nuclear reactors among others.

Boron is literally “one-in-a-million.” The rarest and purest of diamonds, such as the Hope diamond, are blue because of boron. It rarely takes more than 1 boron atom per million carbon atoms to produce that sought after blue color. Registering on average ~11 ppm in soils, boron allows us to peer into the complex dynamics of subduction zones, to trace paleoclimatic conditions and atmospheric CO₂, and to understand how the essential building blocks of life (e.g. RNA) could form in the hostile environments of the early Earth. But, boron isn’t just valuable for scientific pursuits, it also finds practical applications in glass and ceramics, detergents, fertilizers, and nuclear reactors among others.

Boron is literally “one-in-a-million.” The rarest and purest of diamonds, such as the Hope diamond, are blue because of boron. It rarely takes more than 1 boron atom per million carbon atoms to produce that sought after blue color. Registering on average ~11 ppm in soils, boron may not be the first nutrient you think of but it is critical to many plant functions. A plant can have all the carbon, nitrogen, and phosphorus it needs, but without boron, plants can’t thrive. Without boron, there would be no chloroplasts, no cell walls, no processes such as cell division, metabolism, or moving sugars through a plant. To put it bluntly, without boron there would be no such thing as plants.

So, before anyone dismisses boron as not deserving our attention ... think again. The articles in this issue give a fascinating glimpse into the many and varied roles played by this light but important element.

For another summary of the importance of boron, check out Ed Grew’s article published in the June 2015 issue of Elements. You can find it online at http://elements.nsc.org/2015/06/01/boron-the-crustal-element/
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Penelope J. Brothers is a New Zealander educated at the University of Auckland (New Zealand) and Stanford University (California, USA). She has been a professor in the School of Chemical Sciences at the University of Auckland since 1988 and has been a visiting professor at several institutions, including both the Davis and Berkeley campuses of the University of California (USA), the University of Heidelberg (Germany), the University of Münster (Germany), the University of Burgundy (France), the Peking University (China), and the Arctic University of Norway. Penelope was a Fulbright Senior Scholar at Los Alamos National Laboratory (New Mexico, USA) and is an Associate Editor of Chemical Communications. She is currently investigating the chemistry of boron coordinated to porphyrin and corrole ligands, boron dipyrin (BODIPY) fluorophores for sugar recognition, and surface patterning using molecular pentagons.

Yoshihiro Furukawa is an assistant professor in the Department of Earth Science at Tohoku University (Japan). He received his PhD from Tohoku University in 1995. He was one of the first to recognize the origin of such minerals, backed up by mineralogical, sedimentological, and paleontological studies of these elements. In 2014, as a visiting international scholar, he investigated abiotic RNA formation at the Foundation for Applied Molecular Evolution (Florida, USA).

Edward S. Grew is a research professor at the University of Guelph (Canada). He received his BA from Dartmouth College (New Hampshire, USA) and in 1971 earned a PhD from Harvard University (Massachusetts, USA). He participated in nine expeditions to Antarctica supported by the US, the former Soviet Union, Japan, and Australia. He was a Fulbright Scholar at the University of Melbourne (Australia) and a Humboldt Fellow at the Ruhr University (Bochum, Germany). He has studied granulite-facies borosilicate assemblages in East Antarctica, Adirondack Mountains (New York, USA), South India, and the Aldan Shield (Siberia, Russia), as well as boron isotopes in Antarctic borosilicates and Eoarchean tourmaline from Greenland. He edited the Mineralogical Society of America’s Reviews in Mineralogy & Geochemistry volumes on boron (v33) and beryllium (v50) and has collaborated with Robert M. Hazen on the mineral evolution of these elements. In 2015, he was awarded the Collins Medal by the Mineralogical Society of Great Britain and Ireland.

Cahit Helvacı received his PhD in geology from the University of Nottingham (UK) in 1977. He was a member of Ege University (Turkey) from September 1977 to 1982, and since then has been at Dokuz Eylül University (Turkey). His primary research interests are on recent and ancient evaporites, the role of evaporates in the formation of large-scale ore deposits, hydrothermal systems, sedimentary and related industrial raw materials, Helvacı’s life-long study of borate minerals has resulted in a better understanding of the origin of such minerals, backed up by mineralogical, sedimentological, petrographic, and isotopic studies.

N. Gary Hemming is a geochemist working on the development and application of boron isotopes in marine carbonates as a proxy for the paleo-pH of the oceans and applying this method to paleoclimatic studies. He developed an improved method for boron isotope analysis as a student at the Department of Earth and Space Sciences at Stony Brook University (New York, USA), where he received his PhD in 1995. He was one of the first to recognize the potential for using the offset in boron isotopes between minerals and fluids as a paleo-pH probe. He went on to the Lamont-Doherty Earth Observatory of Columbia University (New York, USA) as a post-doc in 1995 and continues there as an adjunct research scientist. He has been a professor at Queens College CUNY (USA) since 1999, and is also a visiting professor at Stony Brook University.

Takeshi Kakegawa is Professor of Geochemistry at Tohoku University (Japan). He received his BS in mineralogy, petrology, and economic geology from Tohoku University and his PhD in geochemistry from Pennsylvania State University (USA). His research interests include experimental studies on the origin of life, Precambrian geology, tracing life in early Archean rocks, biological elemental cycles on the early Earth, biogeochemistry and biomineralization in terrestrial and submarine hydrothermal systems, petroleum genesis in diatomite, and submarine hydrothermal processes on ancient and modern ocean floors.

Martin R. Palmer has been Professor of Geochemistry at the University of Southampton (UK) since 2000. After studying for a BSc in chemistry at the University of East Anglia (UK), he received his PhD in geochemistry from the University of Leeds (UK) in 1985. He first started working on boron isotopes as a tracer of geological processes while a post-doc at the Massachusetts Institute of Technology (USA) in 1987. Since that time, he has applied boron isotopes to a wide variety of processes, including paleoceanography, non-marine evaporites, tourmalines from granites and ore deposits, and island arc petrogenesis. His present boron isotope project involves working with Yalçın Ersoy and Cahit Helvacı from Dokuz Eylül University (Turkey) to use boron isotopes in volcanic rocks from western Anatolia (Turkey) to gain insight into crustal formation and recycling processes during continental collision.

E. Troy Rasbury received his PhD in geosciences from Stony Brook University (SBU) (New York, USA) in 1998. She was on the faculty at Queens College CUNY (USA) from 1998 to 1999 before returning to Stony Brook University as a faculty member in 1999. She is also a member of the Interdepartmental Doctoral Program in Anthropological Sciences at SBU. She specializes in isotope and trace element analyses of carbonates. Much of her work has focused on U–Pb dating of carbonates, but she has become increasingly interested in secular evolution of seawater chemistry, particularly how a high-resolution record of boron isotopes might help deconvolve climate and tectonic questions during the Paleozoic.

Charles “Chip” Shearer is an igneous petrologist–geochemist–mineralogist with a focus on the formation and evolution of the terrestrial planets. Chip is a senior research scientist and research professor in the Institute of Meteoritics and Department of Earth and Planetary Sciences at the University of New Mexico (USA). He is currently the deputy principle investigator for NASA’s MoonRise mission. The goal of this mission is to reconstruct the timing and planetary-scale effects of the late heavy bombardment of the inner Solar System by returning samples from the South Pole–Aitken Basin on the southern far side of the Moon.

Steven B. Simon received his PhD in geology from the South Dakota School of Mines & Technology (USA) in 1988. He is currently a senior research scientist in the Institute of Meteoritics at the University of New Mexico (USA), having recently relocated there after 28 years at the University of Chicago (Illinois, USA). He investigates the early history of the Solar System through petrologic studies of chondritic meteorites, concentrating on chondrules and refractory inclusions. He is also interested in redox (reduction–oxidation) conditions in the early Solar System and the Moon as recorded by the valences of Ti, Cr, and V in lunar rocks and chondrules.
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