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How many boron minerals occur in Earth's upper crust?

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Abstract

The current rate of discovery of new boron minerals (65 species or potential species described from 2008 to 2017) is higher than at any prior 10 year period, implying that rates of B mineral discovery could increase further with no obvious limit to boron mineral diversity in Earth's crust. In contrast, large number of rare events (LNRE) models calculated from the 295 species of B minerals discovered through 2017 give a total predicted B mineral endowment in Earth's crust of 459 ± 65.5 and 523 species, using a finite Zipf-Mandelbrot (fZM) model and Sichel's generalized inverse Gauss-Poisson model (GIGP), respectively, i.e., there is a very real predicted limit of no more than ~500 species. As cautioned by Hazen, Hystad, and their co-authors, LNRE modeling presumes no changes in how minerals are discovered from the beginning of mineral discoveries in the late 18th century to early 2017. However this condition is clearly not the case, and thus changes could explain the discrepant indications. The most important changes are (1) the advent of the electron microprobe, which became widely used for chemical analysis of B minerals in 1978; (2) technological advances in single-crystal X-ray diffractometry, (3) technological advances in electron microscopy including advent of electron backscattered diffraction; (4) advent of micro-Raman spectroscopy; and (5) changes in mineralogical nomenclatures, particularly of the tourmaline supergroup. Changes 1 to 4 are expected to reduce the size of the mineral grains that can be studied, thereby increasing the number of species accessible to study. Furthermore, should species have a fractal distribution (i.e., diversity is independent of scale) examination of increasingly smaller grains will turn up an even larger number of species. To evaluate the impact of these changes on the LNRE modeling, we modeled the 146 B minerals discovered up through 1978, which was selected as the cutoff because of (1) the important role played subsequently by the electron microprobe and (2) the number of species was 50% of the current number. This modeling gave 306 (fZM) and 359 (GIGP) for total species, i.e., the access to smaller grains afforded by advanced analytical instrumentation has resulted in an increased estimate of total endowment by 50% from 1978, whether the fZM or GIGP distribution is applied. We doubt that the ~500 B species estimate is the end of the story, as we expect there will be further technological advances in the future. A more realistic finale might come when we reach the natural limit imposed by the minimum number of unit cells needed for new mineral to be viable, and thus LNRE modeling might yet show that Earth's total endowment of B minerals is finite.

A review of past patterns of discovery of new boron minerals, which can inform us what to expect in future discoveries, reveal that only 19% of B minerals were synthesized prior to discovery. We conclude that synthetic compounds are not a particularly promising source of potential new B minerals. In contrast, 22% of B minerals were discovered prior to synthesis and 29% have unique structures, i.e., they have no synthetic analogs and are not isostructural with a known mineral. Accordingly, 41% of B minerals could not be predicted, and we conclude that the realm of as yet undiscovered B minerals holds a significant number of surprises.

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