Understanding the mineral diversity of boron, a quintessential element of the evolving continental crust

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Boron is rare in the Cosmos because its nucleus is “fragile,” so how do we get from the interstellar medium, where B was first produced, to Earth’s upper continental crust, where nearly 300 B minerals have been found? Cosmic scarcity of B resulted in a low B concentration in the solar system, where B remained scarce as it was not produced by nucleosynthesis. Estimates for primitive mantle give as little as 0.19 µg/g. Processes that lead to the formation of continental crust also concentrated B, which is preferentially incorporated in melts and aqueous fluids. With the evolution of the continental crust, the possibility for B to be concentrated to levels well above the 17 µg/g B upper crustal average also increases, resulting in more opportunities for mineralogical diversity. We have no constraints on B contents of the continental crust until deposition of the Isua supracrustal belt, Greenland at 3.7-3.8 Ga, the age of the oldest rocks to contain sufficient B (at least 10-100 µg/g) to form tourmaline during amphibolite-facies metamorphism. Increase in the diversity of B minerals with geologic time can be expressed either (1) cumulatively by showing the increase in the total number of species inferred to have formed by a given time in Earth’s history or (2) existing at a given time in Earth’s history, i.e., the number of species inferred to have been present during a given 50 Myr interval. Comparing the proportion of exposed continental crust at a given geologic period with cumulative diversity suggests at first that mineral diversity is simply a matter of exposed area, even if we deduct the 30% of B minerals considered to be ephemeral, i.e., soluble in water or broken down at low temperatures, which are with rare exception restricted to the Phanerozoic. A closer look reveals that the increase in cumulative diversity is punctuated by steps of which the three oldest correspond to the collisional phases of the supercontinent cycles of Kenorland, Nuna, and Rodinia. Li-Cs-Ta pegmatites, typical for settings of crustal thickening associated with subduction and continental collision, host a variety of B minerals. Steep increases in diversity between 2.7 Ga and 1.85 Ga followed by a near leveling off at 40-50 species from 1.85 to 0.55 Ga imply that many of the minerals first reported in the geologic record prior to 1.85 Ga have been forming ever since in the crust; B also has participated in the recycling of continental lithosphere through deep foundering in the mantle.