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Origin of B- and P-rich thermal waters in northeastern Japan: Modern analogue of nucleotide-forming environments on the early Earth

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Prebiotic nucleotides are preferentially synthesized with high abundance of B and P (1). This leads to a hypothesis that Hadean B- and P-rich environments were ideal to promote chemical evolution for the origin of life (2). On the other hand, it has been unclear how to accumulate B and P in high concentrations under geological conditions. Extremely high concentrations of B, up to 2000 ppm, are found in thermal waters at the Ashiro area in Japan. Those waters are also enriched in sodium chloride (3 wt. %), bicarbonate (1 wt. %) and phosphorous (400 ppm). B- and P-rich carbonate sinters also deposited around vents. Multiple isotope and geochemical studies were performed on the water and sinter samples to examine mechanisms to accumulate B and P.

Felsic volcanisms formed the terrestrial caldera complex between 8 to 4 Ma in the studied area. Granitic rocks and epithermal hydrothermal deposits were also formed during this period. $^{87}Sr/^{86}Sr$ and $^{88}Sr/^{86}Sr$ analyses of water samples indicate that roots of B-rich fluids were the granite/hydrothermal system, excluding the possibility of the fossil seawater origin. d^{15}B values of dissolved borate ranged from +4.2 to +6.0 ‰. d^{13}C of bicarbonate ranged from -6.2 to -5.2 ‰. Those values are within the typical magmatic hydrothermal compositions.

Water and sinter samples also had high concentrations of LIL, REE, Fe, U, Sn, Sb and Li. d^{7}Li values of water samples indicate high temperature water/rock interactions around the deep granite to accumulate Li at the early hydrothermal stage. This is followed by the liquid/vapor phase separation resulting in the formation of saline B-and P-rich brines in depth. This ancient brines is now discharging on the surface. This new model suggests significant roles of granitic activities and brine formation for the genesis of modern borate deposits. In addition, magmatic characteristics of boron isotope compositions of ca. 3.7 Ga tourmalines are also explained this model. B- and P-rich environments were most likely created on the surface of proto-continents of the early Earth by venting deep B- and P-rich brines.

(1) Furukawa and Kakegawa (2017) Elements, (2) Benner et al. (2022) ChemSystemsChem