Ancient magmatic brine origin of boron-rich fluids in northwestern Iwate prefecture in Japan

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Geochemical studies of boron have an importance not only to constrain magmatic processes but also to understand the origin of prebiotic organic molecules. Extreme enrichment of boron is often found in nature. On the other hand, it has been unclear how boron is enriched in specific geological environments. In order to approach these problems, geochemical studies were performed on boron-rich saline geothermal water and associated rocks in northwestern Iwate prefecture in Japan.

Water samples were obtained from 3 sites. Boron concentrations ranged from 471 to 961 ppm, which are the highest among Japan's geothermal fluids. All samples contain high NaCl and CO_2 concentrations.

Boron isotope compositions ($\delta^{11}B$) of dissolved borate ranged from +4.2 to +6.0 ‰. Carbon isotope compositions ($\delta^{13}C$) of dissolved carbon ranged from -6.2 to -5.2 ‰. These values are indicative of a magmatic origin. On the other hand, sulfur isotope compositions ($\delta^{34}S$) of SO_4^{2-} species in the waters at site 1 and 2 were +26.9 ‰and +28.7 ‰, respectively, values which are more ^{34}S enriched than Paleozoic seawater. Extensive sulfur isotope fractionation may have occurred during the event where hydrothermal reaction occurred between the felsic magma and overlying strata.

A cluster of the late Cenozoic calderas is present in the region where boron-rich fluids are found [1]. Deep magma solidified forming a massive felsic pluton beneath the caldera cluster. A part of the late Cenozoic granitic rocks is exposed in Anihata to Tayama regions. They show extensive interaction with surrounding basement shale and chert. Granitic rocks and sedimentary rocks at this site are altered by hydrothermal fluids, forming chlorite, pyrite and secondary phosphate and carbonate. The initial boron-rich fluid most likely originated from such magmatic fluid that was segregated from the felsic pluton and interacted with basement rocks.

Besides high B, NaCl and CO_2 concentrations, the examined water samples had high concentrations of light ion lithophile (up to 330 ppm) and total rare earth element (up to 4.43 ppb). Phosphorous concentration was also relatively high (up to 207 ppb) and correlated well with light rare earth element concentrations. Such high concentrations cannot be explained by simple magmatic hydrothermal processes alone, and it is likely that deep magmatic fluids evolved into brine and concentrated boron and other elements. This further implies the essential role of felsic magmas followed by deep fluidal processes to create boron-rich fluids on the ancient Earth.

[1] Yoshida, T. et al. (2020) Journal of Geography, 129(4) 529-563

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