Significance of zircon alteration index in Antarctica :an example from AS3 zircon

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U–Pb zircon geochronology is one of the most user-friendly method, thanks to a combination of favorable properties including high U content (typically hundreds of ppm), lack of initial Pb and good retention of radiogenic Pb (up to 900 °C based on thermal diffusion model; Cherniak & Watson, 2001). The paired decay scheme of ^{238}U and ^{235}U also allows us to verify the determined U–Pb zircon age, using two geochronometers. Despite its high durability and high closure temperature, discordant U–Pb data of zircon are commonly observed and verification of the concordant data is one of the most important processes. On the other hand, some workers reported that radiogenic Pb was released from zircon crystal structure at lower temperature (~200 °C) via both of laboratory experiments and nature (e.g., Geisler et al., 2003; Horie et al., 2006), which indicates that interaction between zircon and hydrothermal fluids is one of important processes for disturbance of the U–Pb system. The Pb-loss occurred with decrease of major elements, increase of non-formula elements (Ca, Mn, Fe, and Al), and rare earth element (REE) through low temperature hydrothermal alteration process. Darker domains of zircon observed in the backscattered electron images are interpreted altered domain of zircon because zircon matrix are depleted by hydrothermal alteration (Hay & Dempster, 2009). The geochronology and geochemistry of zircon even from high-temperature metamorphic rocks in the Napier Complex, East Antarctica are no exception because the altered zircons were observed in a tonalitic gneiss collected by JARE58 from the Harvey Nunatak (detailed information in poster presentation). In the last decade, zircon has been more widely used as not only U–Pb geochronometer, but also Lu–Hf geochronometer (e.g., Amelin et al. 1999), Ti geothermometer (e.g., Watson et al., 2006), Li geospeedometer (Trail et al., 2016) and geochemical indicator of magma condition by oxygen isotope composition ($\delta^{18}O$) (Valley et al., 2003). It should be carefully dealt with that these multiple analyses reflect same geological event, namely concordant information, but the redistribution and/or retention behavior of each element during the interaction with the hydrothermal fluids is questionable. Therefore, it becomes more important to understand the redistribution behaviors during the hydrothermal alteration of zircon.

In this study, U–Pb dating, oxygen isotope analysis and quantitative analysis of trace element chemistry including the non-formula elements, Li, Ti, REE by using a sensitive high–resolution ion microprobe (SHRIMP-IIe) were applied to AS3 zircon collected from a gabbroic anorthosite of the Duluth Complex (Paces & Miller., 1993). The redistribution and/or retention behavior of each element are discussed and new chemical criteria for multi-element analysis of zircon is proposed.

The altered domains, characterized by darker BSE response reflecting the depletion of Zr and Si, show discordant U-Pb data, LREE-rich patterns and higher contents of non-formula elements (Ca, Mn, Fe and Al), which is consistent with the properties of zircons affected by low temperature hydrothermal alteration. Even though any altered domains cannot be found on the cross-sectional surface, there is a possibility that the altered domains surround the fractures like a “clad”. Judging from the contents of REE, non-formula elements, Li and K, incorporation mechanism of these elements are not simple and are mutually related. The oxygen isotope compositions in the altered domains are consistent with those in the unaltered domains and are not necessarily criteria for elemental redistribution during the hydrothermal alteration, whereas the Ca contents in zircon show correlation with those of many elements and one of candidate of the criteria, which is consistent with the previous reports (e.g., Suzuki & Kato, 2008). The Ca contents indicate the thresholds depending on the valence of each element: (i) monovalent elements (Li and K) show enrichments when incorporation of Ca content is over ~ 1 ppm, (ii) trivalent elements (LREE and Al) show enrichments when incorporation of Ca content is over ~ 10 ppm, and (iii) tetravalent elements (Hf and Ti) are modified when incorporation of Ca content is over ~ 100 ppm. Therefore, our results point out a possibility that the contents of monovalent, divalent and trivalent elements are discordant with U-Pb age, even though zircon grains show concordant U-Pb age. The contents of monovalent elements, such as K, are also a potential indicator of hydrothermal alteration in zircon by using as K/Li ratio.

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