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Thermal-flow structure and fluid processes in subduction zones: implications for hydrothermal vein-type ore deposits

Hikaru Iwamori[1], Hitomi Nakamura[1*], Yuki Hieda[2], Koichiro Fujinaga[2], Yasuhiro Kato[2]

[1]Tokyo Institute of Technology, [2]The University of Tokyo

Fluid processes in subduction zones are key to understanding the Earth's fundamental features distinct from other solar planets, with respect to geological, geochemical and geophysical aspects; e.g., active tectonics including earthquake, hydrothermal activity, ore formation and arc magmatism, as well as longer-term evolution of the continental crust and orogeny, all of which are thought to be assisted or driven by presence of fluids. This subduction zone system with fluids involves the following schemes:
(1) thermal and flow structure associated with mantle convection and slab subduction,
(2) phase relation and chemical reaction, including generation of fluids,
(3) fluid migration and its interaction with the solid convective flow.
First, we discuss these schemes mainly based on numerical simulation, in which importance of non-linear feedback via water-rock interaction has been found (Horiuchi, 2012). Second, we compare the model predictions with the observations, such as geochemistry of volcanic rocks and hydrothermal fluids, which highlights the trace element and isotopic characteristics of slab-derived fluids (e.g., Nakamura et al., 2008), particularly lead geochemistry, as well as those of volcanic rocks and the arc crust.

Then, hydrothermal activity, including vein-type ore formation, is discussed in this framework of the subduction zone system. Unlike conventional studies based on isotopic compositions of hydrogen and oxygen, this study tracks directly ore-forming metals in terms of their abundances and isotopic compositions. New geochemical data on ore deposits from the Toyoha mine (Hokkaido) and the surrounding country rocks includes trace element abundances and Nd-Pb-He isotopic compositions, many of which are the first-ever data (Hieda, 2013). The results suggest that the ore deposits exhibit appreciable enrichment in "slab-fluid component" (e.g., more radiogenic Pb isotopic ratios) compared to the nearby Muine volcanic rocks contemporary with the ore deposits, together with a mantle He component. Based on the elemental partitioning and mass balance calculations, two plausible models have been proposed to explain the isotopic compositions and the total Pb reserve (5.3 x 105 ton): one assumes direct contribution of slab-fluid (Nakamura and Iwamori, 2009), whereas another involves the Muine magma-derived lead as well as slab-fluid contribution. Both models may explain the characteristics of the Toyoha ore deposits, suggesting potential importance of deep circulation with slab-derived fluid as a source of hydrothermal vein-type deposits.

Keywords: subduction zone, fluid, ore