Elemental mobility during seafloor alteration of oceanic crust revealed by machine-learning approach

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Element transfer during seafloor alteration is an essential process for understanding the chemical linkage between the surface and interior of the Earth. Fluid-rock interaction between the oceanic plate and seawater causes a compositional change in seawater, which are linked to the formation of bioactive field (e.g., Takai et al. 2001) and hydrothermal ore deposit formations. The altered oceanic plates enter the Earth's interior through subduction zones and affect the chemical composition/isotope of island arc basalt (e.g., Pearce et al. 2005) and oceanic island basalt (e.g., Pietruszka et al. 2013). Such chemical changes of oceanic crust (i.e., element transfer) during seafloor alteration have been analyzed by comparing the composition of metabasalt with that of fresh protolith (e.g., Kelley et al. 2003). However, the exact protolith of metabasalt is rarely accessible, and the evaluation of the element transfer during seafloor alteration remains largely qualitative. To understand the global characteristics of elemental transfer during seafloor alteration, it is needed to determine the exact protolith composition for each sample.

This study evaluated the global trend of element transfer from seafloor altered basalt via machine-learning approach. The compositional dataset of seafloor altered basalt was taken from PetDB (https://search.earthchem.org/) and composed of 453 samples and 16 elements (Rb, Ba, U, K, La, Ce, Pb, Sr, Nd, Y, Yb, Lu, Zr, Th, Ti, and Nb). The location of the altered basalt covers seven oceanic plates. The quantitative elemental transfer of each altered sample was estimated by applying the Protolith Reconstruction Models (PRMs; Matsuno et al. 2022), which is a method for quantifying the protolith composition and element transfer from the immobile elements of metabasalt. The immobile elements were set as Zr, Th, Ti, and Nb, and the mobility of other 12 elements was analyzed. We particularly focused on "Pacific west" (i.e., 35°N-10°, 140°E- 160°) and "Pacific south" (i.e., 10°S-50°, 180° W-100°), where the number of samples is abundant (>100). These two areas are characterized by the age of oceanic crust and sedimentation rate (130-170 Myr and 15mm/yr for Pacific west and 13.5-103.7 Myr and 0.01-0.1 mm/yr for Pacific south), which strongly affects seafloor alteration (Zhang & Smith-Duque, 2014).

The results show that Rb, U, K, and Pb were added to metabasalt ~0% to 100% during seafloor alteration. Other elements (e.g., La, Ce, Sr) does not have significant enrichment and depletion compared to the above elements. Rb and K are highly correlated (R = 0.83), whereas other elements have relatively weak correlations. In the Pacific west and Pacific south, there are more mobility variations in the older oceanic crust for Rb, U, K, and Pb. In addition, we observed slight La, Ce, and Nd enrichment and Y depletion in the Pacific south.

The correlation of element mobility in Rb and K (R=0.83) indicates that Rb enrichment is linked to the formation of K-bearing clay minerals. More considerable variations of mobility in the older crust in the Pacific west and south (up to ~100Ma) indicate that hydrothermal activity in the oceanic crust may continue even in the old crust (>60 Ma). The La, Ce, and Nd enrichment and Y depletion in the Pacific south could be attributed to high sedimentation rates in the area. We will further quantify the diversity of elemental mobility for the global dataset, and testify their potential dependency on sedimentation rates, the age of oceanic crust, and lithology.

Keywords: Seafloor alteration , Element transfer analysis, Protolith Reconstruction Model, Machine-learning

