Origin of Cenozoic basaltic magmatism at Changbaishan volcanic field, northeast China

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In NE China, Cenozoic intraplate basalts are widely distributed, and Changbaishan is one of the largest volcanic fields. This intraplate magmatism is unique because the stagnant slab of the subducted Pacific plate is present in the mantle transition zone (MTZ). Therefore, the geodynamic and geochemical processes in relation to the stagnant slab and their effects on the magmatism have received considerable attention (e.g., Zou et al., 2008; Ohtani and Zhao, 2009). This paper summarizes the results of our recent studies on the Cenozoic basalts in NE China (Kuritani et al., 2009, 2011, 2013), and integrates them toward understanding the origin of the basaltic magmatism at Changbaishan.

A prominent low-velocity anomaly with a plume-like shape was imaged in the upper mantle beneath Changbaishan by P-wave tomography, and was suggested as an upwelling of wet materials from the MTZ (Zhao et al., 2009). We have compiled geochemical data of Quaternary basalts from Changbaishan and the surrounding volcanic fields (e.g., Jingbohu and Kuandian), and found a spatial correlation between the basalt chemistry and the distribution of the low-velocity zone. Namely, the Ba/Th and Pb/U ratios of the basalts tend to decrease with increasing distance from Changbaishan. Furthermore, the basalts from Changbaishan have Sr, Nd, and Pb isotopic ratios similar to the EM1 endmember and the rests are from more depleted source.

One possible source of the EM1-like component is the lower part of the sub-continental lithospheric mantle (SCLM). However, this is unlikely because the lower part of the SCLM beneath NE China formed in Cenozoic times, precluding prolonged isotopic ingrowth. Alternatively, the component was proposed to be derived from the MTZ. In the subducted materials, K-hollandite in metamorphosed sediments can be a major reservoir of incompatible elements such as Sr, Ba, and Pb. Elements released by breakdown of sedimentary K-hollandite would be high-Ba/Th and Pb/U, and thus, a suitable metasomatic agent to form EM1-like mantle in the MTZ (Rapp et al., 2008). Because the formation of the EM1 isotopic signature requires a timescales of >1 Ga, sediments in an ancient stagnant slab, as well as those in the Pacific plate stagnant slab, may have been involved in the source materials for the Changbaishan basalts.

Assuming that the age of the ancient slab sediment is 1.5 Ga, the isotopic ratios of the Changbaishan basalts can be explained by mixing of a depleted mantle with a 0.5% sediment component which consists of a 1:2 to 1:3 mixture of the recent and the ancient sediments. The MTZ beneath NE China is remarkably hydrous, as evidenced from the electrical conductivity observations (Kelbert et al., 2009). Therefore, it is plausible that a hydrous mantle plume ascended from the hydrated MTZ, and that partial melting occurred in the ascending plume in the asthenospheric mantle, leading to the basaltic magmatism at Changbaishan and its surrounding volcanic fields.