Major element composition of the Hadean crust: constraint from high-pressure melting experiments

*Nozomi Kondo[1], Tetsu Kogiso[1]

1. Graduate School of Human and Environmental Studies, Kyoto University

Processes of the mantle-crust differentiation and composition of the crust in the Hadean era (> 4.0 Ga) are essential to understand the early stage of the chemical mantle evolution due to the extraction and recycling of the crust. The existence of the granitic-andesitic crust has been vigorously debated from analyses of the Hadean zircon and early Archean pelitic gneiss (Hopkins et al. 2010; Kemp et al. 2010; Iizuka et al. 2015; Komiya et al. 2015; Reimink et al. 2016), but the processes to form the Hadean crust and its quantitative composition are still unclear. In this study, we aim to determine the major element composition of the Hadean crust and constrain the early stage of the mantle-crust differentiation in the Hadean era.

Previous studies have suggested that the Hadean mantle would have had high potential temperature (Korenaga 2013), and that the crust generated through melting of the mantle peridotite at high mantle potential temperature (MPT) has komatiitic composition (Takahashi & Scalfe 1985). Because the existence of liquid water has been implied from the oxygen isotope composition of the Hadean zircon (Mojzsis et al. 2001), and the hot Hadean mantle could have generated steep thermal gradient in the crust, the Hadean mafic-ultramafic crust could have experienced hydrous melting upon subduction, and generated granitic-andesitic melt.

We estimated style of the igneous activity in Hadean era and composition of the crust generated through melting of the primitive mantle peridotite, referring previous mantle convection models at high MPT (Korenaga 2009; Foley et al. 2014). The crust would have formed from the melt generated through near-solidus melting just under a thick (-200km) lithosphere before the onset of the plate-tectonics, and after the onset of the plate-tectonics, from the melt generated through large-scale melting under ridges. Then, the composition of the crust was estimated from high pressure melting experiments (Kondo et al. 2016) in the case before the onset of the plate-tectonics, and from calculations with pMELTS (Ghiorso et al. 2002) in the case after the onset of the plate-tectonics. The compositions of the melt were estimated to be komatiitic in both cases, though the FeO, TiO2, Na2O, and K2O contents are higher in the melt for the case of the pre-plate-tectonics. We refer this Fe, Ti, and alkali-rich komatiite composition as S(solidus)-komatiitic.

We assumed the pre-plate-tectonic regime involving intermittent and drip-like subduction (Foley et al. 2014), and hydrous melting of the S-komatiitic crust. Hydrous melting of komatiite has been scarcely investigated, and we performed high-pressure hydrous melting experiments of the S-komatiite. We synthesized starting powders of the S-komatiitic composition from oxide and carbonate powders. Then, we performed hydrous melting experiments at 1-3 GPa and 1000-1300 °C with the piston-cylinder high pressure apparatus. In these experiments, the oxygen fugacity was carefully controlled and assessed. The major element composition of the melt generated through the hydrous melting of the S-komatiite was revealed to be picritic and rich in Ti and alkali elements, reflecting the composition of the starting material. Thus, in the Hadean era before the plate-tectonics, the S-komatiitic crust was generated firstly from the melting of the primitive mantle peridotite, and then subduction-related hydrous melting of the S-komatiitic crust generated Ti- and alkali-rich picritic crust.

Keywords: Hadean, crust, major element composition, high-pressure melting experiment

