[JJ] Evening Poster | B (Biogeosciences) | B-CG Complex & General

[B-CG09]Decoding the history of Earth: From Hadean to the present

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The latest results of Earth's evolution and geological processes through 4.6 billion years from Hadean to Modern, based on various approaches including fieldworks, chemical analyses, experiments and computer simulation, will be presented. In this session, we aim to discuss and understand causal relationships and interplay among the evolution of Earth's deep interior, changes in the surface environments, and development and evolution of life. Wide-ranging topics are accepted.

[BCG09-P03]Major element composition of the Hadean oceanic crust: constraints from Sm-Nd isotope systematics in the early Earth and high-pressure melting experiments of a primitive peridotite

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In order to reveal the early stage of the Earth’s evolution, it is essential to investigate the major element composition of the Hadean crust. The major element composition of a melt/crust controls its physical properties such as density and viscosity, which controls the formation and recycling of the crust. Since the mantle chemical and dynamical evolution has been controlled by the crustal formation and recycling, the major element composition of the Hadean crust controls the initial condition and subsequent evolution of the mantle chemical and dynamical evolution. The major element composition of the Hadean crust also controls the concentration and supply of primary elements for life (nutrients) such as phosphorous (P) and potassium (K), and so controls the habitable environment in the early Earth.

In this study, we combined Sm-Nd isotope systematics and high-pressure melting experiments, and estimated the major element composition of the Hadean oceanic crust. Given that the ^{142}Nd was generated from radiogenic decay of short-lived extinct radionuclide ^{146}Sm ($T_{1/2}$ = 68 Myr, Kinoshita et al. 2012) and Sm is less incompatible than Nd to mantle minerals, with lithophile and refractory nature of Sm and Nd, differences in ^{142}Nd/^{144}Nd ratio can be attributed to difference in the initial ^{142}Nd/^{144}Nd ratio and difference in ^{146}Sm/^{144}Nd ratio which was generated by the silicate differentiation in the Hadean. Since the degree of Sm/Nd differentiation depends on the melting condition such as pressure, temperature, and, melt fraction, we can estimate the melting condition at the Hadean silicate differentiation from the differences in ^{142}Nd/^{144}Nd ratio. Then, we can estimate the major element composition of the low Sm/Nd melt from melting experiments of a primitive mantle peridotite at the obtained melting condition.

The ^{142}Nd/^{144}Nd differences between accessible silicate Earth (ASE, a region in the mantle from which we can obtain rock samples) and the Archean rocks requires 4.47-4.42 Ga silicate differentiation and subsequent re-mixing of the high Sm/Nd and low Sm/Nd reservoirs. We refer the low Sm/Nd reservoir as the Hadean Enriched reservoir (HER). We estimated the melting condition for the HER formation to be small at shallow mantle pressures (<6.4% at 1 GPa, <7.2% at 3 GPa, <3.2% at 7 GPa). Then, we determined the range of the major element composition of the melt with experimental data from Falloon et al. (2008), Hirose and Kushiro (1993), Davis et al. (2011), and Kondo et al. (2016), and with interpolate calculations in melt fraction-melt composition plane by using experimental data from Walter (1998), Davis et al. (2011), and Kondo et al. (2016). As the result, the major element composition of the melts at the obtained melting conditions are Na-rich basaltic at 1 GPa, Ti-alkali-rich picritic at 3 GPa, and Fe-Ti-alkali-rich komatiitic at 7 GPa. We calculated the density of the melt at 1, 3, and 7 GPa from their major element composition with the method in Matsukage et al. (2005), and concluded that these melts have lower density than the primitive mantle peridotite.

The potential range of the major element composition of the HER melt can be constrained from the mantle potential temperature (MPT) in the Hadean. At the Hadean MPT of 1500-1700 °C (Silver and Behn 2008; Korenaga 2011), partial melting of the adiabatically ascending mantle would have started at 3-7 GPa, and the potential compositional range of the HER melt is Ti-alkali-rich picritic at 3 GPa to Fe-Ti-alkali-rich komatiitic at 7 GPa, since the melt fraction gets larger at lower pressures and the HER melt cannot be generated. The segregation of the HER melt at small melt fraction requires a thick lithosphere whose base is just above the depth where the adiabatically ascending mantle starts melting (100 km at MPT of 1500 °C and 200 km at MPT of 1700 °C). A thick lithosphere can be generated both in the plate-tectonic (Korenaga 2006) and stagnant-lid regime (Foley et al. 2014), but the requirement of small malt fraction for the generation of the HER melt is consistent with the stagnant-lid convection regime. Thus, the HER melt would have generated at small melt fraction at 3-7 GPa and segregated under the thick lithosphere of 100-200 km. Then, the HER melt would have had sufficiently low density and viscosity, and ascended in the mantle and formed the Hadean oceanic crust of Ti-alkali-rich picritic to Fe-Ti-alkali-rich komatiitic composition. After the formation and cooling at the surface, the picritic-komatiitic crust would have got high density similar to or higher than the Archean mid ocean ridge basalts, and potentially subducted into the mantle.