# *Major element composition of the Hadean crust: constraints from Sm-Nd isotope systematics and high-pressure melting experoments*

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## *Abstract*

The major element composition of crust formed during the Hadean silicate differentiation has two significant roles on the evolution of the Earth. The first role is that on the mantle chemical and dynamical evolution. The chemical composition and dynamics of the mantle has been evolved through extraction and recycling of the crust. The manner and timescale of crustal formation and recycling are controlled by physical properties of crust, such as density and viscosity, and these physical properties are controlled by the major element composition of the crust. Therefore, the initial condition and subsequent evolution of the mantle composition and dynamics are controlled by the major element composition of the Hadean crust. The second role is that on the habitable environment. Because the primary element for life (nutrients) such as potassium (K) and phosphorus (P) are incompatible to mantle minerals, they concentrate into melt during silicate differentiation, and the melt will from the crust. The felsic continental crust has been known to have high concentration of nutrients and long residence time at the surface due to its small density, and therefore has been an important source of nutrients. Therefore, the major element composition of the Hadean crust controls habitable environment in the era where early life emerged and evolved.

The silicate differentiation and crustal formation has been investigated in previous studies from analyses of isotopic and trace element composition of the Hadean zircons, but the data from the Hadean zircons have not revealed the major element composition of the Hadean crust. I investigated the major element composition of the Hadean crust by combining the Sm-Nd isotope systematics and high-pressure melting experiments. I estimated melting condition required to explain the Sm-Nd isotope systematics between the modern mantle, chondrites, and between the modern mantle and the Archean rocks, that requires the Hadean silicate differentiations > 4.53 Ga and > 4.42 Ga, respectively. The required melting conditions in > 4.53 Ga silicate differentiation was melting of the primitive mantle at extremely small melt fraction (<2.6%) at 3-7GPa, whereas small melt fraction (<7.2%) at 3-7 GPa was required in the 4.42-4.47 Ga silicate differentiation. I estimated the range of the composition of the melts generated in these Hadean silicate differentiations from previous experimental data at 3 and 7

GPa and by performing melting experiments of primitive peridotite at 7 GPa at near-solidus condition. As the result, the major element compositions of the melts were Ti-alkali-rich picritic to Fe-Ti-alkali-rich komatiitic. I calculated the density of the melt from its major element composition, and confirmed that the Ti-alkali-rich picritic to Fe-Ti-alkali-rich koamtiitic melt has lower density than the mantle peridotite. The viscosity of the picritic-komatiitic melt would be lower than the Archean basaltic melt, which ascended in the mantle and formed the crust. Therefore, the Hadean picritic-komatiitic melt ascended in the mantle into the lithosphere, and formed the crust. The crust formed > 4.53 Ga would have lost from the Earth by giant impact (s). The crust formed 4.42-4.47 Ga became the Hadean primary crust, and subducted into the mantle after cooling at the surface, due to its high FeO content. Since the melting of the hydrous Hadean primary crust has been suggested from the isotopic and trace element data of the Hadean zircons, I performed melting experiments of hydrous Fe-Ti-alkali-rich komatiite in order to determine the major element composition of the melt. As the result, the melt had Ti-P-rich mafic composition. The crystallization of zircon from the Ti-P-rich mafic melt is probably difficult, and more evolved melt is required for the Zr saturation. The Ti-P-rich mafic melt contains water, and has low density and viscosity enough to ascend in the Hadean lithosphere. Therefore, the Ti-P rich mafic melt formed the Hadean secondary crust, and would have played important role on concentrating and supplying nutrients to the Hadean surface environment.