論文内容の要旨

Petrology and geochemistry of mafic rocks in the Acasta Gneiss Complex: Implications for the Hadean mantle evolution
（アカスタ片麻岩体苦鉄質岩の岩石学的・地球化学的特徴から示唆される冥王代マントル進化）

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Abstract

The first billion years' history of the earth is still poorly understood because terrestrial rocks with the ages are scarcely preserved. Especially, a period of the first 500 million years is named the Hadean, and no Hadean rocks are preserved over the world. The Hadean is well known as the most dramatic period that many drastic events such as magma-ocean, fore-formation and late heavy bombardment occurred based on geochemistry of meteorites, planetary science and numerical simulation. However, it is necessary to study the Eoarchean crusts to quantitatively unravel the early Earth's history. The Acasta Gneiss Complex (AGC) is one of the rare Eoarchean geologic bodies, located in the western margin of the Slave Craton, Canada, and is composed of felsic to intermediate gneisses with subordinate amounts of mafic rocks. The felsic to intermediate gneisses are relatively well understood, and comprise 4.03-3.6 Ga orthogneisses, including the oldest terrestrial rocks with 4.03 Ga age. On the other hand, the mafic rocks are still enigmatic because they suffered from intense metamorphisms and deformations. This study aims to obtain

physico-chemical constraints on the Hadean mantle and propose a new picture of early mantle evolution based on geological, petrological and geochemical investigations of the oldest mafic rocks in AGC.

We conducted a petrographic study of over 100 mafic rocks all over the AGC to estimate the metamorphic grade and to select the least altered samples for whole-rock analyses of major and trace element compositions. The mafic rocks mainly consist of fine to coarse-grained hornblende and plagioclase with small amount of quartz, chlorite and ilmenite. Especially, garnet-bearing mafic rocks occur at the northeastern part of the AGC. The modal amounts of the hornblende and plagioclase are variable and some samples contain quite large amounts, over 90%, of hornblende. They commonly suffered from amphibolite to upper amphibolite facies metamorphism, and differences of mineral assemblages and compositions among mafic rocks are due to difference of their whole-rock compositions, rather than difference of metamorphic grade. The mafic rocks show large variations in the major and trace element compositions, possibly due to later partial melting and infiltration of metamorphic fluids/melts derived from mafic rocks and/or surrounding granitoids. The mafic rocks are subdivided into three groups based on the rare earth element (REE) patterns: highly variable light REE-enriched pattern, flat REE pattern and slightly light REE-enriched pattern with positive Eu anomaly, respectively. The samples, which have flat REE patterns and whose high field strength element (HFSE) and REE contents are well correlated with immobile Zr contents, were selected as the least altered samples to estimate their source mantle because the infiltration of metamorphic fluids/melts increases the light REE contents relative to the middle and heavy REE contents and more severely disturbs other trace element contents than Zr contents. The least altered mafic rocks have chondritic trace element relative abundances with negative Nb and Ta anomalies. This implies that the Nb and Ta were partitioned into the metallic core to form a Nb and Ta-deficit primitive mantle.

The least altered mafic rocks show a positive correlation on a $^{187}Re/^{188}Os$ vs $^{187}Os/^{188}Os$

diagram, yielding a formation age of 4272±300 Ma. The age is consistent with the field occurrence of mafic rocks because they were intruded by orthogneisses with 4.03 to 3.6 Ga ages. The highly radiogenic initial $^{187}Os/^{188}Os$ ratio suggests that their source material was a pre-late veneer mantle with a high Re/Os ratio. However, geochemical signatures, which the initial $^{187}Os/^{188}Os$ ratio overlaps with a chondritic value within the error and their highly siderophile element (HSE) abundances are similar to those of modern basalts, indicate that their source mantle had modern mantle-like high HSE contents, implying that the late veneer event and later homogenization took place before 4.3 Ga.

Two ^{147}Sm-^{143}Nd and ^{176}Lu-^{176}Hf isotope systems of the least altered samples yield young metamorphic ages of 2020±290 Ma and 3016±560 Ma, respectively. On the other hand, their $^{142}Nd/^{144}Nd$ ratios are identical to those of a modern mantle with a suprachondritic value. Their chondritic initial $^{143}Nd/^{144}Nd$ ratio and REE patterns, and suprachondritic $^{142}Nd/^{144}Nd$ ratios indicate that their source material had a chondritic Sm/Nd ratio and a suprachondritic (modern mantle value) $^{142}Nd/^{144}Nd$ ratio at 4.3 Ga. This is the first evidence that > 3.7 Ga source mantle had a modern mantle-like (normal) $^{142}Nd/^{144}Nd$ ratio. Two possible scenarios account for the Hadean mantle with the primitive mantle-like trace element contents and normal $^{142}Nd/^{144}Nd$ ratio at 4.3 Ga. One is that the early mantle convection was rapid enough to homogenize large-scale mantle heterogeneity due to a magma ocean until 4.3 Ga. The Acasta mafic rocks was derived from the homogenized primitive mantle, whereas the 3.8-3.7 Ga Isua mafic rocks with excess $\mu^{142}Nd$ values were formed from a shallow depleted mantle possibly due to progressive extraction of primitive crusts. This scenario is supported by the HSE contents and ^{187}Re-^{187}Os isotopes. Another model suggests that the extent of a magma ocean was limited and non-melting primitive parts remained in the deep mantle, and that the Acasta mafic rocks were formed from the deep primitive mantle, whereas the Isua mafic rocks were derived from the early differentiated upper mantle.