Geology and petrology of the oldest continental flood basalt in Pilbara Craton

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Several recent geochemical and geological studies have reported anomalous thermal events at 2.7 Ga. The distribution of large igneous provinces (LIPs) in almost every craton around 2.7 Ga shows the plume activity occurred worldwide. Moreover, the present distribution should represent the minimum because many continental basalts such as the Fortescue Group in Pilbara have already eroded out in many places. Their high proportion and worldwide distribution indicate that the great magmatism occurred globally, and leads us to deduce hypothesis of mantle overturn.

The Mount Roe Basalt and the related rocks in the Fortescue Group are the oldest continental flood basalt at 2.7 Ga in Pilbara Craton. We study geology, petrology and geochemistry of the rocks. The Fortescue Group contains three stratigraphies of basaltic volcanism, the Mount Roe, Kylena and Maddina Formations in ascending order and sedimentary rocks at the hiatuses. The duration of the basaltic magmatism reached about 1 Gyr. We made detailed geological maps and lithostratigraphic sections in ten areas over the Pilbara Craton, and collected the freshest rock samples every flow in all areas in order to study the spatiotemporal variation of their compositions. The rocks samples reached 3000.

We analyzed major, trace and rare earth elements of the freshest samples with XRF and LA-ICP-MS. Especially, we selected rock samples from all the areas, and many samples at each area, in order to deduce the parental magmas in each area. In addition, we made in-situ analyses of major and rare earth elements of relict igneous clinopyroxenes in order to eliminate the secondary alteration and estimate the original melt compositions. Their liquid lines of descent are explained by not only simple fractional crystallization but also by crustal contamination. However, high magnesian samples plot on the olivine fractionation line, and are influenced by only the olivine crystallization. There are two liquid lines of descent on Zr variation diagrams of Nb and Y contents, consistent with two primary magmas as show below. We separated the influence of crustal contamination from the fractional crystallization on the magmas using the Nb/La-La/Yb diagrams because fractional crystallization does not change the ratios. We found two differentiation trends of the magmas on the Nb/La-La/Yb diagrams. One is caused by the differentiation from the most primitive magma through assimilation and fractional crystallization. Others plot between a rock sample with high Nb/La ratio and Archean granites in Pilbara Craton. Trace element composition of the former is similar to a ferropicritic magma of modern continental basalts in the Deccan Trap. We deduced that the ferropicritic basalt also originated from subducted Archean basalts because the modern ferropicrite was formed by partial melting of subducted ancient basalt. The result shows that there are two primary magmas in the Mount Roe Basalts magmatism: One was formed by partial melting of peridotite mantle with minor subducted basalt, whereas another by selective partial melting of subducted basalt. They were influenced by both assimilation and fractional crystallization. We investigated the exact localities and stratigraphies of two types of magmas in our detailed geological maps and lithostratigraphic sections, and firstly discovered that the ferropicritic magmas and the evolved rocks occurred only at the early and final stages of the basaltic sequences in the western areas. Moreover, the ferropicritic magmas are predominant despite of the stratigraphies in the eastern areas whereas the ferropicritic magma lacks in the westernmost area. The occurrence indicates that the plume head was located to the western area, and that the plume was originally larger than the extent of the Pilbara Craton. The large extent of the plume and many occurrences of plume-related magmatism imply the mantle overturn at 2.7 Ga.