# The formation mechanism of alkali-rich fragments in Yamato-74442 and Bhola LL chondritic breccias

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Alkali-rich glassy igneous fragments were found in some brecciated LL-chondrites. For example, Krahenberg (LL5) [1] and Bhola (LL3-6) [2, 3] contain large, cm-sized, fragments with high abundances of K (~x12), Rb (~x45), Cs (~x70) relative to LL chondrites, while concentrations of the rare earth elements (REEs) are chondritic except for a negative Eu anomaly [4]. Because Na is depleted (~0.5x chondrite), the alkali-rich fragments are treated as K-rich fragments. The K-rich fragments were also found in Yamato-74442 (LL4) [5, 6]. Ikeda and Takeda [6] reported the compositions of major constituent materials and the fragments. Wlotzka et al. [4] suggested that alkali differentiation of the fragments has resulted from an exchange between Na and K in feldspar via a vapor phase at the surface of their parent bodies on the basis of their bulk compositions including REEs.

Rb-Sr isochron ages of the K-rich fragments in Krahenberg and Y-74442 are 4.662+/-0.014 Ga [1] and 4.571+/-0.22 Ga [7], respectively (recalculated using decay constant of Rb; $1.402 \times 10^{-11} y^{-1}$). Ar-Ar ages of Krahenberg and Bhola are approximately 4.2 Ga [2], suggesting that the fragments were formed in the early solar system and partially degassed by the collisions at their parent bodies.

There are unsolved issues; when the K-rich fragments were formed and bracciated at their parent bodies, and how the alkaline element fractionation occurred. In order to establish mechanisms of alkali differentiation and formation of the fragments, we have undertaken mineralogical and petrological studies on K-rich fragments in Y-74442 and Bhola. We examined four thin sections (Y-74442, 101-3 and 101-4; Bhola, USNM #1805-5 and #1806-3). Both meteorites are composed of host, mineral fragments, igneous K-rich dark fragments, and chondrules.

In Y-74442, the K-rich dark fragments, a few millimeters in size, are composed of euhedral olivine and groundmass of brown glasses. The boundaries between fragments and the host are sharp. Opaque minerals (~10 micrometer in diameter), troilite and dendritic chromite, are observed in the groundmass of K-rich fragments, and dendritic pyroxenes (~1 micrometer in diameter) are often observed as quenched crystals. In Bhola, the K-rich dark fragments (some of which are a few centimeters in size) are composed of euhedral olivine, troilite and groundmass of brown glasses. Troilite, chromite, and quenched pyroxenes are also observed in the groundmass. The olivine grains in the K-rich fragments of Bhola are often cracked. Cracks (~10 micrometer thick) extending over several mm in one direction through the fragment are sometimes filled with troilite. There is no detectable Fe-Mg zoning in olivine in both K-rich fragments. The fragments in Bhola are different from those of Y-74442 in their size, the presence of cracks, and the presence of troilite, as a major constituent material. The Fe/(Fe+Mg) ratios of the olivine in the K-rich fragments of Y-74442 are 25.2-30.2; they are within the compositional range of LL-chondrites [8]. Plotting compositions of major constituent materials of Krahenberg, Bhola, and Y-74442 on a Na+K+Al-oxides, Ca+Mg+Fe-oxides, and SiO2 diagram, they are overlapping. Similarities of texture and compositions of the K-rich fragments in Y-74442 and Bhola suggest that the fragments are genetically related.

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