ALKALI-RICH FRAGMENTS IN LL-CHONDRITIC BRECCIAS.

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Introduction: Alkaline elements (potassium, rubidium, and cesium) are classified as large ion lithophiles and are enriched in residual liquid during crystallization. Sodium, potassium, rubidium, and cesium are also classified as moderately volatile elements and large fractionations are expected as a result of evaporation/condensation.

Alkali-rich igneous fragments were identified in the brecciated LL-chonderites, Krähenberg (LL5) [1], Bhola (LL3-6) [2], and Yamato (Y)-74442 (LL4) [3–5], and show characteristic fractionation patterns of alkaline elements (e.g., Na~0.5xCI, K~12xCI, Rb~45xCI, and Cs~70xCI [6]). The alkali-rich fragments in Krähenberg, Bhola, and Y-74442 are very similar in mineralogy, petrography, and mineral chemistry, implying that they could have formed from related precursor materials [5] (Fig. 1). In order to understand origin of these alkali-rich fragments as well as to constrain timing of their formation, we have undertaken Rb-Sr isotopic studies on alkali-rich fragments in Bhola and Y-74442.

Experimental: About 141 mg and 366 mg of samples were taken as whole-rock (WR) samples of Y-74442 and Bhola, respectively. Four alkali-rich fragments from Y-74442 (87-94, 87-99, 87-101, and 87-114) (1–2 mg in weight) and one alkali-rich fragment from Bhola (USNM 1806-1) (~3 mg in weight) were used in this study. All samples were analyzed for rubidium and strontium using a Finnigan-MAT 262 at Okayama Univ. The isochron parameters are calculated by use of $\lambda(^{87}\mathrm{Rb})=1.402\mathrm{x}10^{-11}$ a^{-1} and adjusted by NBS-987 $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ to 0.710250.

Results and Discussion: Abundances of rubidium in the whole-rock samples of Bhola and Y-74442 are 2–10 times of those of ordinary chondrites, indicating a contribution of alkaline-rich fragments. Rubidium in four fragments from Y-74442 are highly enriced; 20–180 times of those of ordinary chondrites (Fig. 2). Two fragments (87-94 and -99) show rubidium enrichments (~80–180xOC) and depletions of strontium (~0.2–0.3xOC) (Figs. 2 and 4).

Model ages of Bhola and Y-74442 whole-rock samples are calculated to be 4.67 and 4.63 Ga, respectively, when the $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ initial ratio of 0.69900 [7] is used. Bhola and Y-74442 (including three data points of [8]) yield a whole-rock Rb-Sr age of 4596±96 Ma (2σ, n=5) with an initial $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ of 0.7000±0.0046 (Fig. 3). Alkali-rich fragments (Y-74442,87-101 and -114) yield a two-point isochron age of 4441±30 Ma (2σ, n=2) with an initial $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ ratio of 0.7082±0.0085 (Fig. 3), indicating a young age with a slightly elevated initial $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}$ ratio compared with those of Krähenberg (T=4656±33 Ma, $(^{87}\mathrm{Sr}/^{86}\mathrm{Sr})_{\mathrm{I}}=0.6994\pm0.0011$; recalculated by $\lambda(^{87}\mathrm{Rb})=1.402\mathrm{x}10^{-11}$ a^{-1})[1]. Relatively young $^{39}\mathrm{Ar}$-$^{40}\mathrm{Ar}$ ages of ~4200 Ma were reported for alkali-rich fragments in Bhola [9] and the whole-rock sample of Y-74442 [10], which suggests that they and their alkali-rich fragments suffered impact event(s) with the partial degassing of argon, and that their alkaline fractionation have been caused prior to the impact event(s).

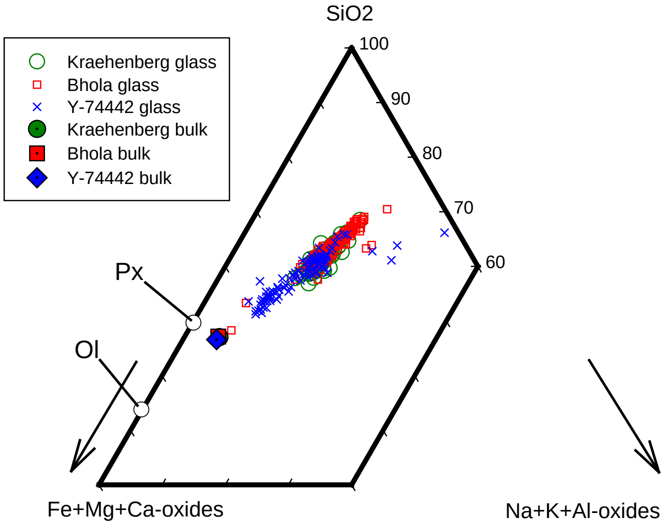

Fig. 1. Chemical compositions of grandmass glass+microcrystalline pyroxene in Kraehenberg, Bhola, and Yamato-74442 [5]. Calculated bulk compositions are based on the variability in modal mineralogy and mineral compositions (obtained by point-counting method).

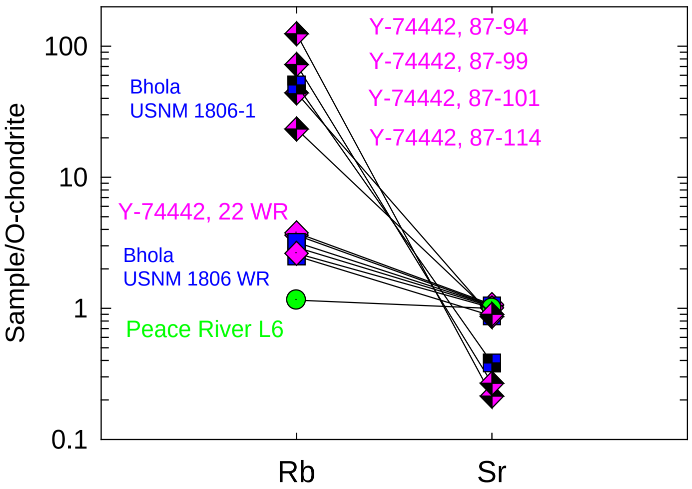

Fig. 2. Rubidium and strontium abundances of whole-rock and fragment samples of Y-74442 and Bhola (OC-normalized). WR samples of Y-74442 and Bhola are enriched in rubidium. Y-74442,87-94, 87-99, and Bhola USNM 1806-1 are depleted in strontium. A whole-rock sample of Peace River (L6) was measured for comparison.

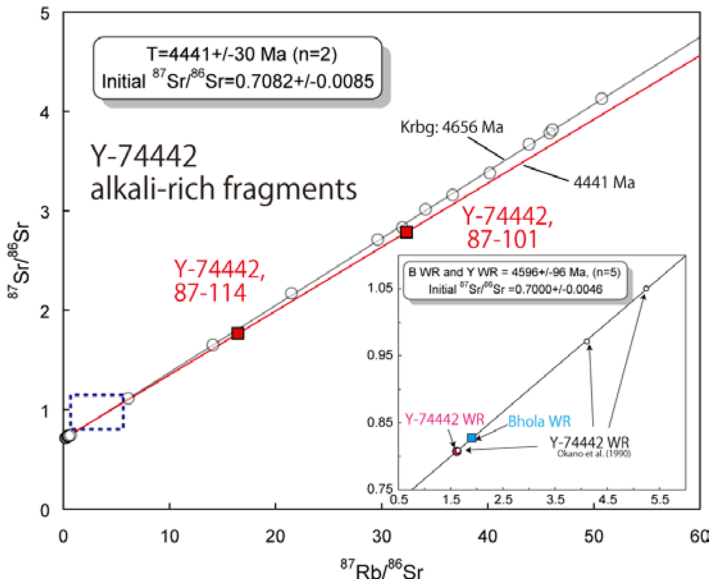

Fig. 3. Rb-Sr isochron for two alkali-rich fragments of Y-74442. Open circles are alkali-rich fragements in Krähenberg. The inset is Rb-Sr isochron for whole-rock samples of Y-74442 (n=4) and Bhola (n=1).

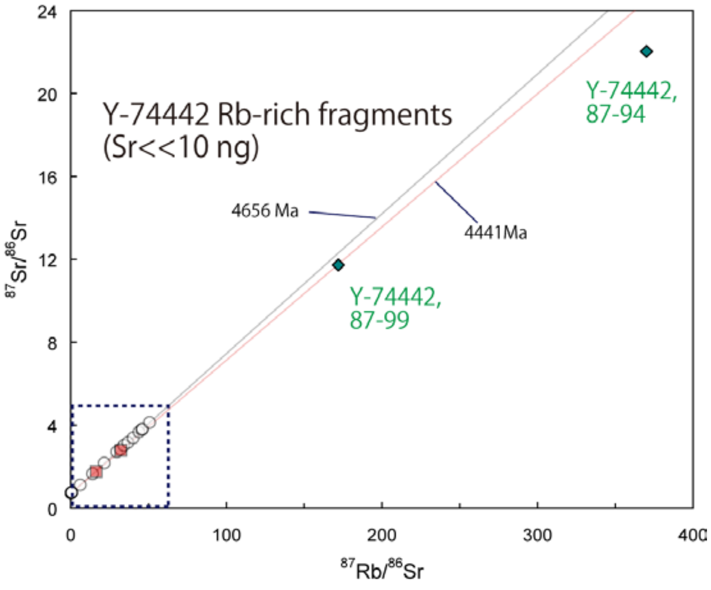

Fig. 4. Rb-Sr isochron diagram. Some alkali-rich fragments show a large Rb/Sr fractionation. As a result, their ^{87}Rb/^{86}Sr ratioas exceed up to 170. The region enclosed by broken line is shown in Fig. 3.

Similarities in textures and chemical compositions of alkali-rich fragments in LL chondritic breccias suggest that they might be formed from common precursor materials with related processes [5]. Similar alkali-rich fragments were reported in Siena (LL5) [11] and Acfer 111 (H3-6) [12]. Thus, the unique LIL fractionation may be a common feature of this type of fragments.

The alkali-rich fragments in Krähenberg and Bhola possess flat REE patterns, which is different from the alkali-rich early planetary objects, Graves Nunatak 06128/06129, showing LREE/HREE fractionations [13]. Geochemistry (i.e., solid/liquid fractionation process) could not be responsible for the enrichments of heavier alkalis in the Krähenberg, Bhola, and Y-74442 fragments. Taking into account for the lack of detectable potassium isotopic fractionation in the Krähenberg fragment [14] along with the old formation ages of ~4.56 Ga for the Krähenberg [1], an alkali-rich component could have formed during an early stage of solar system evolution and might be incorporated into precursor materials of fragments prior to a final melting event.

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