Introduction: Radiogenic ingrowth of \(^{40}\text{Ca}\) due to decay of \(^{40}\text{K}\) occurred early in the solar system history causing the \(^{40}\text{Ca}\) abundance to vary within different early-former reservoirs. Marshall and DePaolo [1,2] demonstrated that the \(^{40}\text{K}-^{40}\text{Ca}\) decay system could be a useful radiogenic tracer for studies of terrestrial rocks. Shih et al. [3,4] determined \(^{40}\text{K}-^{40}\text{Ca}\) ages of lunar gra-
vised 4.563 Ga (age-corrected) that are slightly larger than the \(\varepsilon^{40}\text{Ca}\) value of D’Orbigny (−1.0 ± 0.2 ε; age-corrected), implying that the initial \(^{40}\text{Ca}/^{44}\text{Ca}\) ratio of APB is lower than those of OC parent bodies. Mixing of a chondritic component with an alkali-rich component formed in the early solar nebula [9] would have modified the age-corrected \(\varepsilon^{40}\text{Ca}\) values for Y-74442 and Bhola. Alternatively, some early solar system material remained heterogeneous in \(\varepsilon^{40}\text{Ca}\) such that observed in Dhajala (H3.8) (± 1.7 ε) [10,11].

The \(\text{K}/\text{Ca}\) ratio of the source of alkali-rich fragments can be estimated using the more precise Rb-Sr age of 4.420 Ga [5]. We obtain an age-corrected initial \(^{40}\text{Ca}/^{44}\text{Ca}\) ratio of 47.1621 ± 0.0009 using the present-day \(^{40}\text{Ca}/^{44}\text{Ca}\) values of the fragments, which is within uncertainty of the initial \(^{40}\text{Ca}/^{44}\text{Ca}\) ratio obtained from the \(\gamma\)-intercept (Fig. 2). Using the initial \(^{40}\text{Ca}/^{44}\text{Ca}\) value of the D’Orbigny angrite at 4.563 Ga, a source \(\text{K}/\text{Ca}\) value of 0.44 for the Y-74442 fragments is obtained (Fig. 3), although the associated error (± 0.18 ε) is slightly large due to the narrow range of \(^{40}\text{K}/^{44}\text{Ca}\) ratios. If we adopt this value as the source \(\text{K}/\text{Ca}\) value for the Y-74442 alkali-rich fragments, it is seven times larger than that of the LL-chondrite parent body (\(\text{K}/\text{Ca} = 0.061 \pm 0.006\)) [12]). The results are generally consistent with the Rb-Sr systematics of the fragments [9], and suggest that the potassium enrichment may have also occurred in the early solar system.

If calcium and strontium contents in the parental melt at 4.420 Ga are chondritic, a \(\text{K}/\text{Rb}\) ratio of the precursor material is calculated to be ~170, which is approximately thirty percent less than that of the LL-chondrite ((\(\text{K}/\text{Rb}\)) \(_{\text{LL}} = 255\)) or CI ((\(\text{K}/\text{Rb}\)) \(_{\text{CI}} = 235\)).
values. This indicates that mutual fractionations (i.e., an enrichment of heavier alkalis) could have occurred during the formation of the alkali-rich component (via alkali enrichment on a planetesimal or by early nebular condensates [9]). Abundance ratios of potassium and rubidium for the Y-74442 fragments are fairly constant \((K/Rb)_{\text{fragments}} = 41–79\), suggesting that further enrichments of rubidium (and possibly cesium) over potassium may have occurred just after a mixing event [9].

Figure 1. \(^{40}\text{Ca}/^{44}\text{Ca}\) results, normalized to \(^{42}\text{Ca}/^{44}\text{Ca} = 0.31221\) [6], for seven OCs and D’Orbigny (solid symbols, errors are \(2\sigma_m\)). Assuming OC parent bodies formed contemporaneously with the APB at 4.563 Ga [16], age-corrected \(\varepsilon^{40}\text{Ca}\) values are calculated from the present-day \(^{40}\text{Ca}/^{44}\text{Ca}\) and K/Ca values of the whole-rock samples (open symbols). The correction for \textit{in situ} \(^{40}\text{K}\) decay for D’Orbigny is insensitive to the age assumed.

Figure 2. Potassium-calcium isochron diagram for alkali-rich igneous rock fragments in Y-74442 [5]. Thirteen data points define a linear array corresponding to a K-Ca age of 4.42 ± 0.28 Ga (95% C.L., MSWD = 9.5) for \(\lambda(^{40}\text{K}) = 0.5543\) Ga \(^{-1}\) [14] using the Isoplot/Ex program [15]. Bhola (LL3–6) fragment, 1806-2 (solid square, blue) is plotted for comparison.

Figure 3. Initial \(^{40}\text{Ca}/^{44}\text{Ca}\) (I\(_{\text{Ca}}\)) versus age (\(T\)) for alkali-rich fragments in Y-74442. We used the more reliable Rb-Sr age of 4.420 Ga [5] as a crystallization age of the fragments, and obtained an initial \(^{40}\text{Ca}/^{44}\text{Ca}\) ratio of 47.1597 ± 0.0009 by back calculations from the present-day \(^{40}\text{Ca}/^{44}\text{Ca}\) and K/Ca values of the fragments. Lines represent the K/Ca growth curves. A time-averaged K/Ca value for the source of the Y-74442 fragments is calculated to be 0.44 ± 0.18 for the D’Orbigny initial \(^{40}\text{Ca}/^{44}\text{Ca}\) ratio of 47.1599 (K = 69 ppm and Ca = 10.72% [7]) and the crystallization age of 4.563 Ga [16]. A large enrichment of the K/Ca ratio is required during the formation of the fragments. Radiogenic ingrowths of \(^{40}\text{Ca}/^{44}\text{Ca}\) in CI- and LL-chondrites and Earth’s mantle are shown.


Acknowledgements: We would like to thank Katsuyuki Yamashita of Okayama Univ. for supply of the D’Orbigny sample.