

Th/U systematics of Allende chondrules with implications for the age of the Solar System

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After the complication of the variable $^{238}\text{U}/^{235}\text{U}$ ratio of CAIs and chondrules had been resolved, it seemed that so too had the absolute age of the Solar System as defined by the U-Pb age of CAIs [1-3]. Here we report Pb isotope compositions of 14 single and six pooled Allende (CV3) chondrules targeting their Th/U ratios. Since high-precision, low-blank Pb isotope data on Allende chondrules have been published previously [1-4], the present study does not aim at proposing a new Pb-Pb age. Still, 13 of the single-chondrule residues define an isochron age of 4.564 ± 4 Ga with the most radiogenic samples falling within the range of ages published so far. The error on the 13-point residue isochron arises from the small size of the single chondrules containing only ppt worth of Pb after severe multi-step leaching. The residues and their leachates plot on a line going through Canyon Diablo initial Pb [5] in $^{208}\text{Pb}/^{206}\text{Pb}$ - $^{204}\text{Pb}/^{206}\text{Pb}$ space. The intercept with the y-axis of the line joining the point representative of primordial Pb and the residue or leachate in question gives an estimate of the radiogenic $^{208}\text{Pb}^*/^{206}\text{Pb}^*$ and, therefore, the Th/U ratio of each fraction. Most single chondrule residues have Th/U ranging from 3.0 to 5.2, consistent with the planetary value of 3.876 ± 0.016 [5], but with spectacular outliers at 0.65 and 14.7. Likewise, the Th/U of the six pooled chondrule samples vary between 2.9 and 5.1. There is no correlation between $^{208}\text{Pb}^*/^{206}\text{Pb}^*$ and $^{207}\text{Pb}^*/^{206}\text{Pb}^*$, i.e. no correlation between model Th/U and Pb-Pb ages. The observed scatter of Th/U in Allende chondrules reflects the presence of refractory phases within the chondrule precursors and thus possible mixing between unrelated nucleosynthetic components. The implications for the age of the Solar System and chondrules therefore are significant: The Pb-Pb alignments so far considered isochrons contain an undetermined contribution of mixing and, hence, the absolute age used so far to ‘anchor’ extinct radioactivities needs further clarification.

[1] Amelin et al. (2010) EPSL 300, 343–350 [2] Connelly et al. (2012) Science 338, 651–655 [3] Connelly et al. (2017) GCA 201, 345–363 [4] Bollard et al. (2017) Science Adv. 3, e1700407 [5] Blichert-Toft et al. (2010) EPSL 300, 152–163.