

EVIDENCE FOR EXTINCT ^{135}Cs FROM Ba ISOTOPES IN ALLENDE INCLUSIONS? K.R. Bermingham^{1,2}, K. Mezger^{1,3}, M. Horstmann⁴, E.E. Scherer¹. ¹Institut für Mineralogie, Westfälische Wilhelms-Universität, Corrensstraße 24, 48149 Münster, Germany; ²Isotope Geochemistry Laboratory, Department of Geology, University of Maryland, College Park, MD-20740 USA (kberming@umd.edu); ³Institut für Geologie, Universität Bern, Baltzerstrasse 1 + 3, 3012 Bern, Switzerland; ⁴Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhem-Klemm. Str. 10, 48149 Münster, Germany.

Introduction: The abundance and distribution of isotopes throughout the Solar System can be used to constrain the number and type of nucleosynthetic events that contributed material to the early nebula. A potentially useful short-lived isotope system that has been infrequently studied is ^{135}Cs – ^{135}Ba ($t_{1/2}$ ~2.3 Ma [1]). This system comprises a volatile parent nuclide and a refractory daughter nuclide and thus may provide a high-resolution chronometer for dating condensation processes and the accretion of planetary bodies. Additionally, the difference in solubility between Cs and Ba in oxidizing fluids makes Cs–Ba suitable for dating aqueous parent body alteration. Conclusive evidence for the existence of live ^{135}Cs , however, has remained elusive as has the determination of a precise initial $^{135}\text{Cs}/^{133}\text{Cs}$ ($^{135}\text{Cs}/^{133}\text{Cs}_0$) of the Solar System.

In the present study, four Allende (CV3) calcium-aluminium-rich inclusions (CAIs), one Allende dark inclusion (DI), and two unequilibrated type 3 fragments from NWA753 (R3.9) were analyzed for Ba isotope variability to test for the former presence of ^{135}Cs .

Methods: The Institut für Planetologie (Münster) provided a sample of Allende and a piece of NWA753, from which the inclusions were isolated using a dental burr. The powdered inclusions were digested and processed to isolate Ba following [2,3]. Isotope measurements were performed on the Thermal Finnigan Triton thermal ionization mass spectrometer (TIMS) at the Zentrallabor für Geochronologie, Universität Münster, Germany. All data presented here have been corrected for mass fractionation using the exponential law with the reference ratio $^{134}\text{Ba}/^{138}\text{Ba}$ and are reported with $2\sigma_m$ uncertainties. Data is presented using the μ notation (deviations in parts per 10^6 from the terrestrial standard).

Results: The Ba isotope data collected from Allende CAIs 1, 2, and 5 show an excess of ^{135}Ba (~55 ppm) with terrestrial compositions for the remaining isotopes (Fig. 1). This anomaly is well resolved from the terrestrial standard, which was measured with an external reproducibility of 10 ppm (2σ of the population of replicate standard measurements, $n = 10$). To replicate data collected from the CAIs, each sample was measured between 2 and 4 times using new filaments.

The Ba isotope composition of NWA753 unequilibrated type 3 fragments, the Allende DI, and Allende

CAI 4 are analytically indistinguishable from the Ba standard solution (Fig. 1).

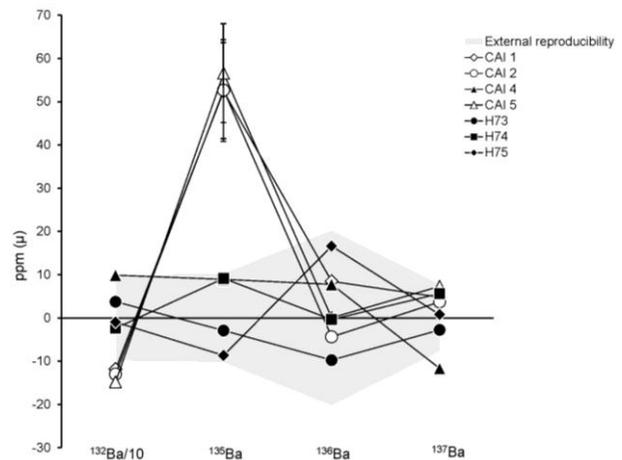


Fig. 1.

The average Ba isotope ratios of samples (ppm) analysed in the present study. The error bars and shaded area indicates the external precision as determined from the 2σ of the population of replicate standard measurements. The values and uncertainties for ^{132}Ba have been divided by 10 to plot on this scale.

Discussion: The Ba isotope abundances for Allende CAI 1, 2, and 5 reveal an unusual pattern that is characterized by resolvable ^{135}Ba excesses without corresponding ^{137}Ba excesses. The terrestrial abundances of ^{137}Ba observed in these samples are significant because, to date, reported ^{135}Ba excesses in bulk samples have always been coupled with enrichments in ^{137}Ba [4-7].

We considered three scenarios that could potentially modify the abundance of ^{135}Ba :

(1) *Neutron capture reactions:* All stable Ba isotopes, however, have low neutron capture cross sections thus it is unlikely that secondary neutron reactions could have enriched ^{135}Ba alone or resulted in the burnout of all other Ba isotopes, producing an apparent enrichment in ^{135}Ba .

(2) *Nucleosynthetic anomalies:* Incomplete mixing of freshly synthesized material (e.g., presolar grains and nucleosynthetic ejecta) in the solar nebula has been invoked to explain the magnitude and typical pattern of coupled $^{135,137}\text{Ba}$ excesses in unequilibrated chondrites [4,6,7]. Larger variations are observed in

^{135}Ba than for ^{137}Ba , which has a lower natural abundance. It is possible that our data contain a ^{137}Ba anomaly which is unresolved at the level of analytical precision for $^{137}\text{Ba}/^{138}\text{Ba}$ (~ 8 ppm) in this study. The stellar production ratio, $^{135}\text{Ba}/^{137}\text{Ba}_{\text{PR-Hidaka}}$ ($\sim 0.81 \pm 0.05$, where the subscript refers to the production ratio of [1]) can also be used to estimate the expected excess of ^{137}Ba associated with a ^{135}Ba anomaly of ~ 55 ppm. The resulting ^{137}Ba excess of ~ 68 ppm should be well resolved given the reproducibility of the terrestrial standard (Fig. 2). Alternatively, the $^{135}\text{Ba}/^{137}\text{Ba}$ production ratio can also be estimated from the Ba isotope composition of bulk meteorite samples and corresponds to $^{135}\text{Ba}/^{137}\text{Ba}_{\text{PR-Bulk}} \sim 1.2$ (Fig. 2). In this case, a ~ 46 ppm excess in ^{137}Ba would be expected and would also be easily resolvable.

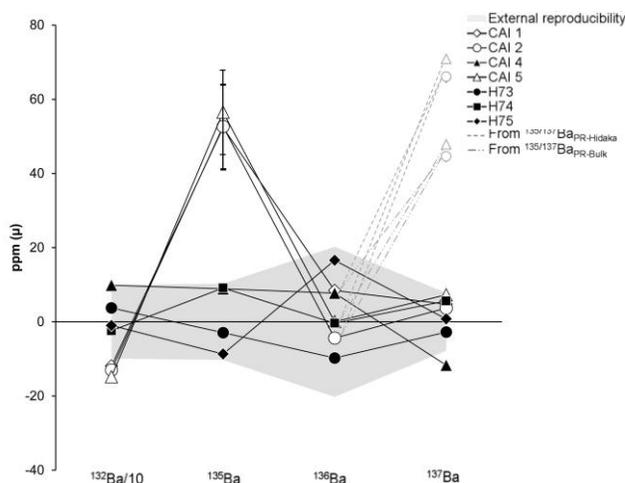


Fig. 2.

The predicted ^{137}Ba isotope anomaly (grey symbols) accompanying an excess of ^{135}Ba (55 ppm) observed in this study. The predicted ^{137}Ba isotope anomaly is calculated: (a) from the $^{135}\text{Ba}/^{137}\text{Ba}$ stellar production ratio ($^{135}\text{Ba}/^{137}\text{Ba}_{\text{PR-Hidaka}}$); (b) from the $^{135}\text{Ba}/^{137}\text{Ba}$ stellar production ratio determined from the Ba isotope composition of bulk meteorite samples ($^{135}\text{Ba}/^{137}\text{Ba}_{\text{PR-Bulk}}$). The values and uncertainties for ^{132}Ba have been divided by 10 to plot on this scale.

(3) Radioactive decay of ^{135}Cs to ^{135}Ba :

Three Allende CAIs display excesses ^{135}Ba that are not accompanied by ^{137}Ba anomalies, the absence of which is here interpreted to indicate that the ^{135}Ba anomaly is not nucleosynthetic in origin but rather developed from the decay of short-lived ^{135}Cs . It is unlikely, however, that this contribution to ^{135}Ba occurred via *in situ* decay of live ^{135}Cs because there is no correlation between ^{135}Ba excess and a superchondritic Cs/Ba. Rather, it is suggested that a transient, high Cs/Ba ($> \text{CI}$) reservoir existed in the early Solar System when ^{135}Cs was extant and that in this setting, some early condensates recorded the presence of live ^{135}Cs as a ^{135}Ba excess. The nucleosynthetic source of ^{135}Cs can be de-

termined by reconciling the predicted astrophysical ^{135}Cs abundance with its measured abundance in meteorites. The currently accepted value for the $^{135}\text{Cs}/^{133}\text{Cs}_0 \sim 4.8 \pm 0.8 \times 10^{-4}$ [1] of the Solar System, however, may be underestimated because live ^{135}Cs could have been extinct by the time the nebula had cooled enough to condense $\text{Cs}_{(\text{g})}$. If the initial meteoritic abundance of ^{135}Cs was indeed higher than is currently thought, it is feasible that ^{135}Cs was added to the Solar System along with ^{41}Ca and ^{26}Al from contamination of the pre-solar molecular cloud by a single stellar source (e.g., a Wolf-Rayet star).

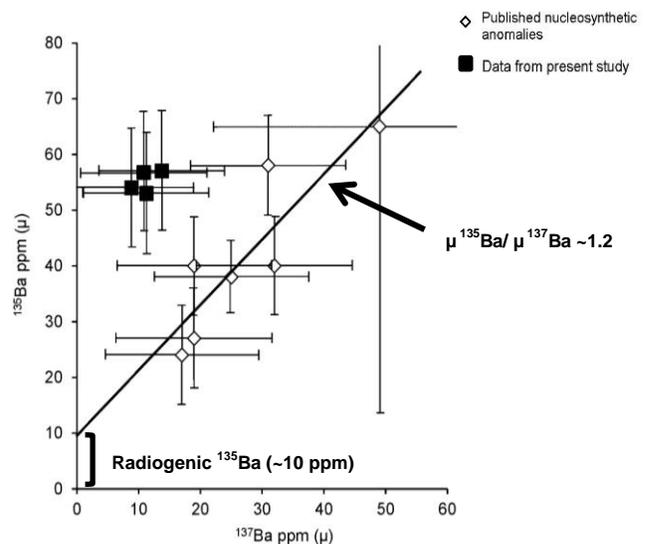


Fig. 3

The ^{135}Ba and ^{137}Ba compositions (in ppm) of Allende CAIs from the present study and published whole rock meteorites [4,6,7]. The estimated $^{135}\text{Ba}/^{137}\text{Ba}$ production ratio from whole rock meteorite samples ($^{135}\text{Ba}/^{137}\text{Ba}_{\text{PR}} \sim 1.2$) is shown and the amount of ^{135}Ba originating from a process other than nucleosynthesis is indicated (~ 10 ppm).

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