INVESTIGATION OF CALCIUM STABLE ISOTOPES IN UREILITES
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Introduction: Ureilites are coarse-grained, highly equilibrated, ultramafic rocks thought to represent the residual mantle of a partially melted carbon-rich asteroid [1]. However, ureilite petrogenesis and parent body make-up remain unresolved primarily because they exhibit such a peculiar and incongruent composite of igneous and primitive characteristics.

Although the ureilites’ non-chondritic textures, mineralogies, and chemical compositions are taken to be clear evidence of large-scale parent body igneous processing (e.g metal component enrichment in compatible highly siderophile elements, which points to metallic liquid extraction [2]), their remarkably high carbon contents and broadly varying oxygen isotopic compositions indicate the preservation of some primitive features as well [1]. Oxygen isotopes in ureilites scatter along the mixing line defined by CAIs (CCAM) in carbonaceous chondrites, which is considered characteristic of primordial, unprocessed nebular material [3]. This has long been taken as evidence for ureilite derivation from a carbonaceous chondrite-like precursor.

However, ureilite parent body (UPB) Si/Mg and Mg/Mn ratios required by partial melting models in order to yield residues with mineral ratios observed in ureilites are similar to those of ordinary chondrites or R-chondrites [4]. Additionally, recent high-precision isotopic data (e.g chromium, titanium, nickel) show that ureilites are similar in composition to (suggesting derivation from) ordinary and enstatite chondrite-like material, and not at all to carbonaceous chondrite-like material [5].

Results: Valdes et al. (2014) showed that resolvably different calcium isotopic signatures exist for the various chondrite groups and subgroups [6]. Calcium is a refractory lithophile element and an ideal tool for tracing genetic links between planetary materials because its isotopes are minimally affected by the post-accretionary processes of impact-induced volatilization and core formation. To gain insight into UPB composition and further investigate which, if any, chondrite type the ureilites resemble, we measured calcium stable isotopes by MC-ICP-MS in six bulk monomict ureilites. We observe that ureilites have widely variable calcium isotopic compositions (0.58‰ < δ44Ca < 1.3‰) and clearly do not resemble carbonaceous chondrite material (average δ44Ca = 0.09‰) or, indeed, any chondritic material (δ44Ca = -0.31 – 0.26‰).

It has recently been shown that parent body processing can result in osmium isotopic heterogeneity on the UPB. Unlike all measured bulk chondrites, ureilites exhibit s-process osmium excesses relative to Earth, which can be explained by s-deficit osmium loss into metallic liquids during localized partial melting of and core formation in the UPB [7]. However, planetary differentiation cannot so succinctly explain calcium isotope fractionation, so the processes resulting in the broadly varying, non-chondritic calcium isotopic compositions of ureilites still need to be explored. Fractionation resulting from partial melting is possible, and we may consider that ureilites sample mixtures of distinct and variably-melted UPB reservoirs combined in variable proportions.