Investigation of calcium stable isotopes in ureilites

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Ureilites are coarse-grained, highly equilibrated, ultramafic rocks thought to represent the residual mantle of a partially melted (15-30%), C-rich asteroid [1]. However, their petrogenesis and parent body make-up remain unresolved primarily because they exhibit such a peculiar composite of igneous and primitive characteristics.

Although the ureilites' non-chondritic textures, mineralogies, and chemical compositions are taken to be clear evidence of igneous processing, their remarkably high C contents and broadly varying O-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 (CC), which is considered characteristic of unprocessed nebular material [2]. This has long been taken as evidence for ureilite derivation from CC-like material.

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 (OC) or R-chondrites [3]. Additionally, recent high-precision isotopic data (Cr, Ti, Ni) show that ureilites are similar in composition to (suggesting derivation from) OC- and enstatite chondrite (EC)-like material, and not at all to CC-like material [4].

Valdes et al. (2014) showed that resolvably different Ca isotopic signatures exist for the various chondrite groups and subgroups [5]. 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 Ca stable isotopes in six monomict ureilites. We observe that ureilites (average δ^{44}Ca = 0.69‰) clearly do not resemble CC material (average δ^{44}Ca = 0.09‰) or, indeed, any chondritic material (δ^{44}Ca = -0.31 – 0.26‰). These results support the idea that parent body processes (e.g. partial melting) can express isotopic heterogeneity on the UPB, as has recently been determined for Os [6]. Though, the degree of partial melting required to explain the erasure of any chondritic Ca isotopic signature would be high enough to homogenize O isotopes also. This conundrum may require the invocation of a more complicated UPB formation model.

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