UREILITES PROVIDE A NEW MODEL FOR PLANETESIMAL FORMATION.

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Introduction: Ureilites show correlations between their bulk rock chemistry and oxygen isotopes which are not evident in other achondrite groups. Compared to ureilites, the bulk chemistry and oxygen isotopes of other achondrite groups are well homogenized, probably because their parent bodies experienced a high temperature magma ocean stage in which their silicate mantles were mostly or completely molten [1]. In contrast ureilites show a negative correlation between Fe-rich compositions with high $\Delta^{17}O$ ratios, and high-Mg compositions with low $\Delta^{17}O$ ratios [2,3]. This correlation must be explained in any model of formation of their parent planetesimal.

A new way to form planetesimals: We used Monte Carlo modelling to determine which combinations of primitive meteorites could generate the observed range of oxygen isotope ratios and bulk chemistry of ureilite meteorites. Our modelling showed that all combinations of primitive meteorites fail to generate both the observed oxygen isotope signatures and the chemical trends of ureilite meteorites. However, a model using a combination of Mg-rich and Fe-rich chondrules could perfectly generate the oxygen isotope trend found in ureilites. We then evaluated the possibility that the range of compositions generated on the basis of this combination of Mg-rich and Fe-rich chondrules could account for the bulk compositional trends of the ureilite parent planetesimal.

Ureilites are largely derived from the silicate mantle of the ureilite parent body. Their LREE-depletion indicates that they represent the depleted mantle from which a silicate melt has been extracted [4]. Thus in order to construct the composition of the undepleted mantle of the ureilite parent planetesimal, it is essential to add back a silicate partial melt component (which could be either basaltic or trachyandesitic) to the major element compositions of ureilites [4]. Furthermore, to achieve the original bulk composition of the parent planetesimal before core-mantle differentiation and to account for siderophile element depletion, it is necessary to add-back a metallic core component. Using this approach, we propose a new compositional model for the ureilite parent planetesimal based on a combination of Mg-rich and Fe-rich chondrules. Our model generates the observed range of oxygen isotope and bulk chemistry, but most significantly it suggests that the original ureilite parent body was compositionally zoned.

When condensation and accretion were occurring in the solar nebula, the Mg-rich end-members of silicate mineals such as olivine and pyroxene would have condensed at slightly higher temperatures than those with more Fe-rich compsitions. Thus a growing planetesimal would have been formed of Mg-rich silicate minerals in its inner regions, and somewhat more Fe-rich minerals towards its outer margins, i.e. having a layered bulk chemical structure. Mg-rich and Fe-rich chondrules show differences in oxygen isotope ratios between them, such that the ureilite parent body would also have been zoned from low $\Delta^{17}O$ ratios in its centre and high $\Delta^{17}O$ ratios in its outer regions.

Geothermometry suggests that the Mg-rich centre reached temperatures of 1320°C, while the Fe-rich outer parts reached ~1190°C [4], well above the solidus in the Fe-FeS system so that a metal-sulfide melt would have formed and percolated downwards to form a core. The temperatures are also near the onset of peridotite melting at low pressures, so silicate partial melts would also have formed and moved upwards towards the surface of the body. It is possible that all differentiated planetesimals began with a compositionally layered structure as described here, but they continued to heat up (by decay of ^{26}Al or by kinetic energy of impacts) to a point where the peridotite liquidus was approached and a magma ocean was formed. In this case, all evidence of the prevous layered structure would have been destroyed. However, the ureilite parent planetesimal did not reach this point. Instead, while still hot and probably partially molten, it was disrupted by an impact with another body, and then partially reaccreted to form the present-day Ureilite Parent Body, thus preserving evidence of the initial primary layered structure in the observed distribution of ureilite compositional varieties [3].

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