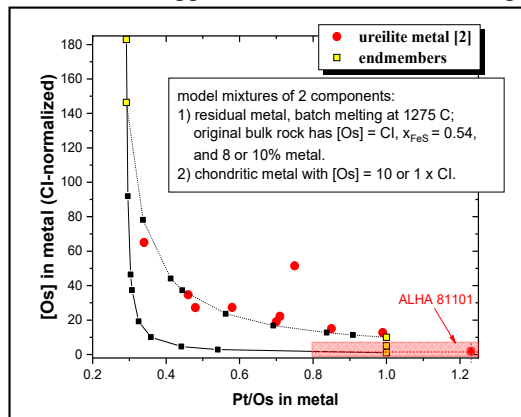# EXOGENOUS METAL IN UREILITES.

C. A. Goodrich[1] and S. J. Desch[2], [1]Lunar and Planetary Institute, USRA, Houston, TX 77058 USA, goodrich@lpi.usra.edu; [2]School of Earth and Space Exploration, Arizona State University, Tempe AZ 85287 USA

Introduction: Main group ureilites, which are ultramafic achondrites interpreted to represent the mantle of a differentiated asteroid, typically contain a few % metal (kamacite) as strips along silicate grain boundaries [1,2]. Siderophile elements in bulk ureilites suggest mixing between two distinct metallic components, but hypotheses for the origins of these components vary [3-9]. [7-10] argued that extraction of S-enriched metallic liquid played a major role, and [7] argued for mixing between an FeS-depleted metallic residue and a broadly chondritic 2nd component.

More stringent constraints are provided by in situ analyses of siderophile elements in ureilite metal [2], which allow the use of absolute abundances in addition to ratios (bulk rock absolute abundances are not reliable due to terrestrial weathering). HSE in ureilite metal show a correlation between degree of fractionation (e.g., Pt/Os) and absolute abundance (e.g., [Os]), which suggests mixing between an indigenous highly-fractionated residue and an unfractionated component [2]. Modeling in the Fe-FeS system showed that if the most fractionated ureilite metal represents the indigenous endmember, then very high degrees of batch Fe-S melt extraction (≥98%) are required, implying temperatures of 1250-1275°C and high x_{FeS} (= wt. FeS/[Fe+FeS]) of ~0.5 in the precursors. These temperatures are consistent with peak temperatures inferred from ureilite silicates [1], and x_{FeS} = ~0.5 is consistent with values in ordinary chondrites. However, to match abundances of HSE in this metal ([Os] ~65×CI), initial metal abundances of ≥20 wt.% are required. Such metal + sulfide contents (~40 wt.% Fe+FeS) are not observed in any chondrite, and seem implausible [2]. In addition, because the mixing is seen in the metal itself, it must have occurred when the metal was liquid [2]. Thus, addition of exogenous metal in a "late-veneer" scenario [3-9] seems implausible.

Catastrophic Disruption of the Ureilite Parent Body (UPB): Various lines of evidence suggest that the UPB was catastrophically disrupted by a major impact after differentiation but while still hot (~1050-1100°C), with subsets of its fragments reassembling into daughter bodies (UDB) from which ureilites are derived [11-15]. Recently, [16] proposed that metal (and other components) from the impactor was added to the UDB, mixing with indignenous metal to became the metal now present in ureilites. A mass ratio of 0.3:1 between the impactor and the UPB is typically assumed [15]. If the UDBs contained the same proportion of hot UPB and cold (~0°C) impactor materials, the UDBs would form with temperatures of 800±50°C, plus the increase generated by the impact, which for 5 km s^{-1} relative velocity might be 300±50 °C [17], yielding UDB assembly temperatures of 1100±100 °C. This is hot enough that metal would have been molten (but not most silicates) and flowed along silicate grain boundaries [16]. This scenario suggests a re-evaluation of mixing models for siderophile elements in ureilite metal.

Mixing Calculations: We carried out two-component mixing calculations. One endmember (indigenous) was the residue from batch partial melting in the Fe-FeS system at 1275°C, for 8-10% initial metal and x_{FeS} = 0.54 [2]. The other endmember was unfractionated chondritic metal (exogenous) with [Os]=10×CI (consistent with several types of CC). Results (Fig. 1) show that ~50:50 to 1:99 (indigenous:exogenous) mixtures provide a good match to the ureilite metal, except ALHA 81101 whose metal has ~1×CI HSE abundances [2]. ALHA 81101 is highly shocked and its metal may have been diluted by pure Fe from shock-smelting.

Discussion: This model can explain the correlation of siderophile element fractionation and HSE abundances for ureilite metal [2] with plausible starting material for the UPB (OC-like in metal-sulfide content, consistent with [18,19]), solving several of the problems discussed in [2]. Mixing of indigenous and exogeneous metal in the liquid state (while silicates are solid) during assembly of UDB explains the location of ureilite metal along silicate grain boundaries and the lack of correlation of siderophile elements with mg# of silicates. It is also consistent with the argument that ureilite metal is exogenous based on Ni and Co disequilibrium between metal and silicates [20,21].

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