A CASE FOR NEBULA SCALE MIXING BETWEEN NON-CARBONACEOUS AND CARBONACEOUS CHONDRITE RESERVOIRS: TESTING THE GRAND TACK MODEL WITH CHROMIUM ISOTOPIC COMPOSITION OF ALMAHATA SITTA STONE 91A

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Introduction: There is an increasing number of Cr-O-Ti isotope studies [1-6] that show solar system materials are divided into two main populations, one carbonaceous chondrite (CC)-like and the other is non-carbonecous (NC)-like, with minimal mixing attributed to a gap opened in the propoplanetary disk due to Jupiter's formation [5,7,8]. The Grand Tack model [9] suggests there should be large-scale mixing between S- and C-type asteroids, an idea supported by our recent work on chondrule Δ^{17}O-ε^{54}Cr isotope systematics [10].

The Almahata Sitta (AhS) meteorite provides a unique opportunity to test the Grand Tack model. The meteorite fell to Earth in October 2008 and has been linked to the asteroid 2008 TC_3 which was discovered just prior to the fall of the AhS stones [11-13]. The AhS meteorite is composed of up to 700 individual pieces with ~140 of those pieces having some geochemical and/or petrologic studies [14]. Almahata Sitta is an anomalous polymict ureilite with other meteorite components, including enstatite, ordinary, and carbonaceous chondrites with an approximate abundance of 70% ureilites and 30% chondrites [14,15]. This observation has lead to the suggestion that TC_3 2008 was a loosely aggregated rubble pile-like asteroid with the non-ureilite sample clasts within the rubble-pile (e.g., [14,15] and references therein). Due to the loosely-aggregated nature of AhS, the object disintegrated during atmospheric entry resulting in the weakly held clasts falling predominantly as individual stones in the AhS collection area. However, recent work [16] has identified one sample of AhS, sample 91A, which may represent two different lithologies co-existing within a single stone. The predominate lithology type in 91A appears to be that of a C2 chondrite based on mineralogy but also contains olivine, pyroxene, and albite that have ureilite-like compositions.

Previous Cr isotope investigations into AhS stones are sparse and what data is available show nearly uniform isotopic composition similar to that of typical ureilites with negative ε^{54}Cr values [17,18].

Methods: The aliquot for Cr isotopic analysis (24.77 mg) was prepared from a small chip of material from Almahata Sitta 91A. Chromium was separated from the sample matrix using a three-column chromatography procedure [19]. The Cr isotopic composition was measured using a Thermo *Triton Plus* thermal ionization mass spectrometer at the University of California, Davis.

Results and Discussion: The Cr isotopic composition of AhS 91A shows clearly resolved excesses in both ^{53}Cr and ^{54}Cr with an ε^{53}Cr = +0.09 ± 0.05 and ε^{54}Cr = +1.83 ± 0.08. This is the highest ε^{54}Cr value observed thus far in any CC-like reservoir. In fact it is the highest ε^{54}Cr in any bulk planetary materials in hand. This ε^{54}Cr is clearly resolved from ureilites that have negative ε^{54}Cr ~ -0.90 [18] as the extreme end member of the NC reservoir in terms of ε^{54}Cr value. The difference indicates that the AhS 91A fragment originated from a Cr isotopic reservoir distinct from ureilties. The recent work studying the bulk mineralogy inferred that AhS 91A was likely comprised of material similar to C2 chondrites [16]. However, the ε^{54}Cr of AhS 91A is higher than CI, CM, and CR chondrites and has a ε^{54}Cr composition higher than any observed in any carbonaceous materials ([4,6] and references therein). This would indicate that the material that comprises AhS 91A is not typical CI-like material and instead is a carbonaceous chondrite material that we have yet to sample in our collections as a separate meteorite. Oxygen isotopes are still pending, but even if oxygen isotopes were similar to CI, CM, or CR chondrites or another carbonaceous chondrite group, the difference in ε^{54}Cr would indicate a unique source. The observation of a different ε^{54}Cr in AhS 91A compared to ureilites or the other AhS samples [17] has implications for large scale nebular wide mixing between NC and CC-like reservoirs, as suggested by the Grand Tack model [9]. This is supported by a rubble-pile like nature of the AhS asteroid.

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