TRACING PETROGENETIC LINKS AMONG PLANETARY MATERIALS WITH Ti-Cr-O SYSTEMATICS.

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Introduction: Mass-independent isotope variations in bulk meteorites provide critical information regarding petrogenetic links among planetary materials. Recently, [1] suggested that the Cr isotopic composition of bulk meteorites coupled with the observed range of $\Delta^{17}O$ may indicate a fundamental dichotomy among planetary materials. The bimodality previously observed between carbonaceous and non-carbonaceous materials may also indicate episodic and heterogeneous accretion of solids over a wide spatial region in the early Solar System [2].

Here, we continue our investigations using mass-independent variations in bulk meteorites to further elucidate potential petrogenetic links among planetary materials. In particular, this study extends previous investigations into achondritic meteorites (ureilites, acapulcoites, lodranites, a IAB silicate inclusion, ung. achondrites, brachinites plus eucrites, diogenites and martian meteorites) and chondritic meteorites (CI-, CR-, CO- and ungr. chondrites) by measuring their Ti and Cr isotopic compositions.

Analytical Methods: Small chips without fusion crusts were powdered using an agate mortar and pestle. The sample powders (~20-30 mg) were placed in PTFE Parr bomb capsules with a 3:1 mixture of concentrated HF and HNO_3. Each sample was placed in an oven at 190°C for 96 hours for complete dissolution of refractory phases. The separation of Cr and determination of Cr isotope ratios was completed following the procedures described in [3,4]. Chromium isotope ratios were made using a Thermo *Triton Plus* thermal ionization mass spectrometer at the University of California at Davis (UC Davis). Typical intensity for ^{52}Cr was 10V in low resolution (using 10^{11}ohm resistors). The external reproducibility (2SD) for internally normalized (to a $^{50}Cr/^{52}Cr$ ratio of 0.051859 [5]) $\varepsilon^{54}Cr$, based on repeated analyses of pure NIST SRM 979 Cr solution, was 0.10 for 12 μg of Cr.

From the same sample solutions analyzed for their Cr isotopic composition, Ti was separated from the matrix using a combination of cation and anion exchange chromatography following the methods of [6]. Titanium isotope ratios were measured with a Thermo *Neptune Plus* MC-ICPMS at UC Davis. A standard H-type skimmer cone was used, while a Jet sample cone was inserted in place of the standard sample cone. Typical intensity for ^{48}Ti was 8V (10^{11}ohm resistors) for a 1ppm solution run in medium resolution mode (MSRP ~8000) using a DSN-100 desolvating nebulizer. The isotope ratios were measured in multi-dynamic mode on Faraday cups in two peak jumping steps, measuring $^{44}Ca^+$, $^{46}Ti^+$, $^{47}Ti^+$, $^{48}Ti^+$, $^{49}Ti^+$, $^{50}Ti^+$ (in step 1) and $^{49}Ti^+$, $^{51}V^+$, $^{53}Cr^+$ (in step 2). The external reproducibilities (2SD) for internally normalized (to a
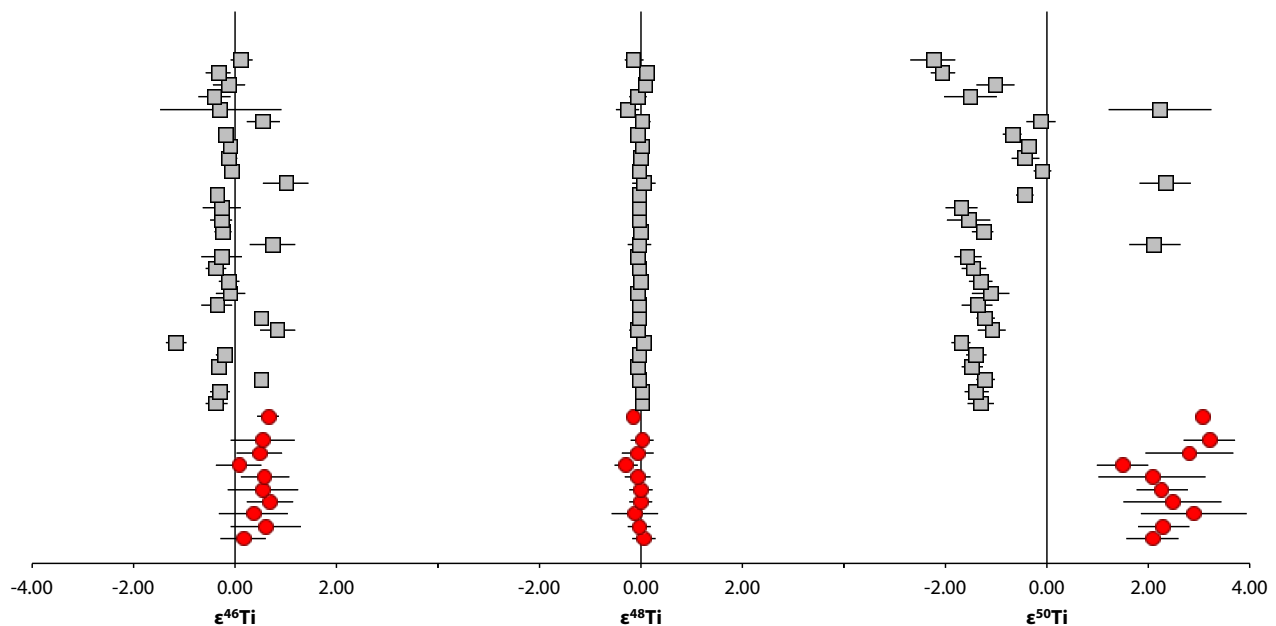

Figure 1 Titanium isotopic composition of carbonaceous chondrite (red circles) and non-carbonaceous meteorites (gray squares). Uncertainties are +/- 2SE.

^{49}Ti/^{47}Ti ratio of 0.749766 [7]) ε^{46}Ti, ε^{48}Ti, and ε^{50}Ti, based on repeated analyses of pure SPEX Ti solution, are 0.63, 0.33, and 0.72, respectively, for 75 ng of Ti.

Results and Discussion: The Ti-Cr isotopic compositions are shown in Figures 1-3. All samples investigated here display terrestrial-like ε^{48}Ti values, but variable ε^{46}Ti and ε^{50}Ti values. The carbonaceous chondrites typically display positive ε^{46}Ti and ε^{50}Ti (Fig.1), whereas, the majority of the non-carbonaceous meteorites display negative ε^{46}Ti and ε^{50}Ti values relative to the terrestrial standard, though excesses characterize a few samples (e.g., NWA 7822, NWA 2788, and NWA 6704), which shows strong carbonaceous chondrite affinity.

Plotting the Ti-Cr data versus Δ^{17}O values (Figure 2) shows the carbonaceous and non-carbonaceous materials cluster into two distinct isotopic groups - although the carbonaceous group is not exclusively characterized by carbonaceous materials, but also includes achondrites with carbonaceous affinities (see Figures 1-3). When plotted relative to one another (Figure 3), the Ti-Cr isotopic compositions of non-carbonaceous materials form a positive trend similar to that observed previously (e.g., [2,3,8]). In contrast, the majority of carbonaceous chondrites and their achondrite affinities display a strong negative correlation orthogonal to that

which characterizes the non-carbonaceous chondrites.

Previously, observations such as these have been suggested to result from either episodic accretion or a division between materials that originally accreted in the inner solar system (i.e. non-carbonaceous materials including most achondrites, ordinary chondrite and enstatite chondrites) and materials that accreted in the outer solar system (i.e., carbonaceous chondrites and their achondrite affinities) [2]. The Ti-Cr-O isotope systematics of carbonaceous materials also includes achondritic meteorites with carbonaceous chondrite affinities (Figures 1-3). On the other hand, its plausible that thermal processing of early solar system materials led to decoupling of the Ti-Cr isotope systematics. Incomplete (isotopic) homogenization or episodic accretion could lead to the formation of planetary materials that retain distinct signatures of these processes. These preliminary data demonstrate the utility of coupling multiple geochemical datasets along with petrologic information for use in sample classification and the identification of early solar system processes [2]. The Ti-Cr-O isotope systematics of bulk meteorites will undoubtedly reveal further information regarding the petrogenesis of planetary materials.
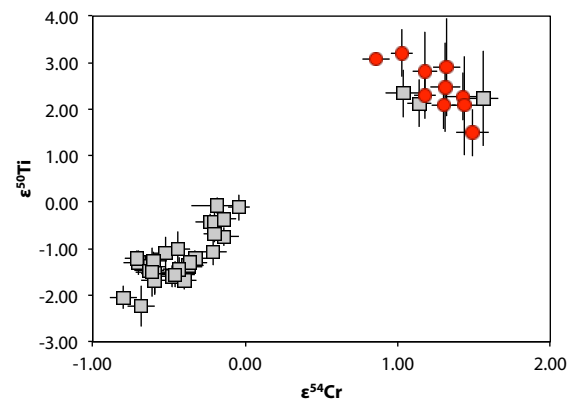
Figure 3 Titanium-Chromium isotope systematics of carbonaceous (red circles) and non-carbonaceous (gray squares) materials. Uncertainties are +/- 2SE.

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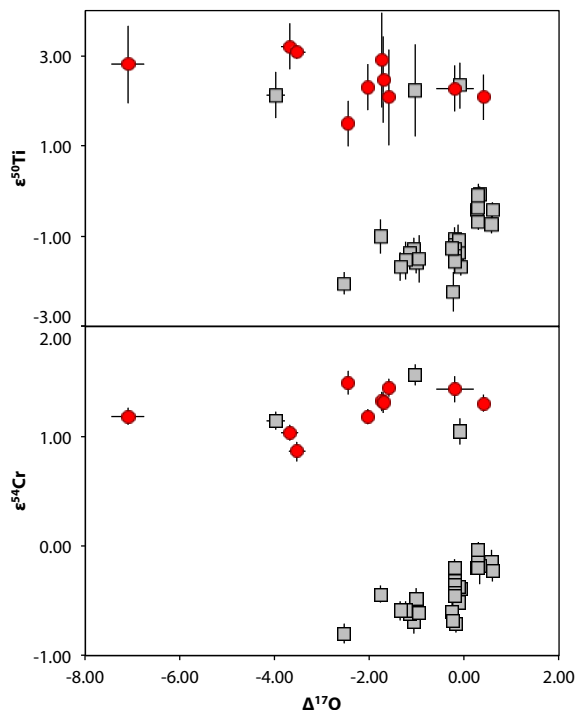

Figure 2 Top panel: Titanium-Oxygen isotope systematics. Bottom panel: Chromium-Oxygen isotope systematics. Symbols similar to those in Figure 1. Uncertainties are +/- 2SE.