TITANIUM ISOTOPE ANOMALIES IN CARBONACEOUS CHONDRITES: IMPLICATIONS FOR ISOTOPIC HETEROGENEITY IN THE EARLY SOLAR SYSTEM. N.D. Phelan[1], V. K. Rai[1], R. Hines[1], and M. Wadhwa[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287 (ndphelan@asu.edu)

Introduction: The isotopic compositions of meteorites provide valuable insights into the earliest history of our Solar System and, in some cases, provide constraints on presolar components that contributed to the solar nebula. In the past decade or so, mass-independent isotope anomalies in titanium and several other elements (like Cr, Ni, Mo, Ru, and W) have become particularly important geochemical tracers to study the distinct isotopic reservoirs in the early Solar System. For titanium, mass-independent anomalies in the most neutron-rich isotope (^{50}Ti) have been used to distinguish between carbonaceous chondritic (CC) and non-carbonaceous chondritic (NC) materials (e.g., [1, 2]). These two groupings likely represent distinct isotopic reservoirs in the inner (NC) and outer (CC) Solar System that are suggested to have become isolated from each other as result of the early formation of Jupiter's core [3]. While the titanium isotope compositions of CC and NC materials are clearly distinct, the full range of compositional variability within each group is less clear. In particular, only a few members of the carbonaceous chondrite (CC) group have been analyzed thus far. For instance, the ε^{50}Ti value for CK chondrites is based on just two separate measurements of the Karoonda (CK4) meteorite [1, 4] (Fig. 1).

This study is a continuation of work that we recently published [5, 6]. The goal of this work is to better characterize the variability of Ti isotope compositions within and among the carbonaceous chondrites, which has implications for the degree and potential sources of Ti isotope heterogeneity in the early Solar System. We recently improved our analytical methods to allow high-precision measurements of Ti isotope compositions of smaller sample aliquots. Utilizing these improved methods, we report here new measurements for the Ti isotope compositions of the bulk samples for several carbonaceous chondrites. We obtained these bulk fractions from homogenized powders of relatively large (~200 mg each) samples. This was done to ascertain whether variability in Ti isotope compositions previously reported within some meteorites could be a sampling artifact. In this study, we report data for some samples for which Ti isotope compositions have been previously reported (Allende and Murchison) as well as for some that have not been previously analyzed (Maralinga, Jbilet Winselwan, and Sutter's Mill).

Methods: Sample preparation and elemental purification of Ti were performed in the Isotope Cosmochemistry and Geochronology Laboratory (ICGL) at Arizona State University (ASU), with all sample handling performed within laminar flow hoods (better than Class 10). Clean interior fragments (~200 mg) were obtained for each meteorite from the Buseck Center for Meteorite Studies (BCMS) at ASU. These fragments were then powdered and homogenized before taking a smaller sample aliquot of each for chemical processing.

Approximately 20-30 mg of homogenized sample aliquot for each meteorite was digested using HF:HNO_3 in a Parr bomb, after which the samples were brought into solution in HNO_3. Prior to the Ti purification chemistry, ~2% of each sample solution were taken to measure elemental concentrations using the iCAP-Q quadrupole ICPMS in the METAL laboratory at ASU. A small aliquot of each sample solution, containing approximately 5 ug of Ti, was chemically processed using methods outlined in [5] to purify Ti. Once the column separation procedure was completed, a small aliquot of ~50 ng Ti was measured for each sample on the iCAP-Q quadrupole ICPMS to ensure that the Ti yield was >95% and that abundances of elements that could result in isobaric interference (i.e., Ca, V and Cr) were negligible [4-6].

The remaining purified Ti samples and standards were analyzed using the Thermo Neptune XT MC-ICPMS located in the ICGL at ASU. Prior to analysis, the purified Ti samples were diluted to a concentration of ~600-700 ppb. The diluted samples were introduced to the MC-ICPMS using an Aridus III desolvating nebulizer with a flow rate of 50 µl/min. Measurements were made in high-resolution mode (MRP > 8000) to avoid polyatomic interferences. Two cup configurations were used to collect Ti isotope data while monitoring and correcting for any potential isobaric interferences: first ^{44}Ca, ^{46}Ti, ^{47}Ti, ^{48}Ti, and ^{49}Ti, and then ^{47}Ti, ^{49}Ti, ^{50}Ti, ^{51}V, and ^{52}Cr. Ti isotope ratios are reported relative to the bracketing standard NIST-3162a and internally normalized to ^{49}Ti/^{47}Ti (=0.749766; [7]) using the exponential fractionation law. Aliquots from both the BCR-2 rock standard and homogenized Allende (CV3) were chemically purified and isotopically analyzed alongside the samples to assess the accuracy and precision of the analyses. The overall long-term reproducibility (2SD), based on repeat analyses of synthetic and rock standards measured during the course of this work, of mass-independent variations in Ti isotope ratios (ε^{46}Ti, ε^{48}Ti, and ε^{50}Ti) are similar to those reported previously [5,6], but for the smaller total amounts of samples utilized in this study. Errors reported for a given sample are the larger of either 2SE based on repeat analyses of the sample or

2SD of multiple synthetic and rock standards analyzed over the course of this study.

Results & Discussion: The Ti isotope composition (i.e., ε^{50}Ti) for the meteorite samples analyzed in this study are shown in Fig 1. The ε^{50}Ti values for the Allende (CV3) chondrite fall within the expected range based on data reported previously for this meteorite (Fig. 1). The ε^{50}Ti value for the Murchison (CM2) chondrite from this study (2.77 ± 0.16) also agrees with some of the previously reported data but is at the lower end of these values [1, 6] (Fig. 1). Previous studies have suggested that presolar grains may not have a large impact on the ^{50}Ti signatures in CC materials [1]. Nevertheless, given the high abundance of presolar silicon-carbide (SiC) grains in Murchison [8], it is possible that the variations observed in previous data could result from inhomogeneous distributions of such grains on the small sampling scales of those studies.

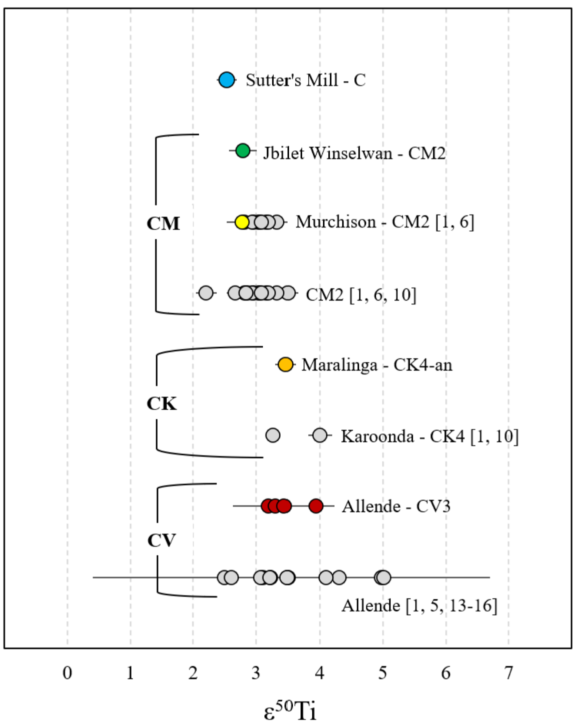

Fig 1. *ε^{50}Ti measurements for meteorite samples from this study and the literature [1,5,6,10,13-16]. Measurements from this study are in color; each data point represents an average of 4-7 repeats of a separately processed bulk sample aliquot. Literature data is displayed as grey circles. Sample names are indicated on the figure, except for the CM2 chondrites – these data include several CM2 samples from various studies [1,6,10].*

Jbilet Winselwan is classified as a CM2 chondrite [9] and its ε^{50}Ti value (2.79 ± 0.16) agrees well with that for Murchison analyzed here, as well as with some other previously measured CM2 meteorites (Fig. 1). This suggests that Jbilet Winselwan likely originated on the same or similar parent body as Murchison (and other CM2 meteorites).

Maralinga, a CK4-anomalous meteorite, has a ε^{50}Ti value of 3.46 ± 0.16) that agrees well with that reported for the Karoonda CK4 chondrite by [10] (but is resolvably lower than the value for Karoonda reported earlier by [1]). The ε^{50}Ti value reported in our work for Maralinga additionally agrees with values reported for the Allende CV3 chondrite. This is not surprising given that the CV/CK chondrites show similarities in their mineralogic-geochemical characteristics suggesting that their parent bodies originated in proximity to each other in the solar nebula [11].

Sutter's Mill is currently classified as a C meteorite, although it shares similarities to the CM chondrite group [12]. Its ε^{50}Ti value of 2.53 ± 0.16 agrees within the errors to values reported here for the Murchison and Jbilet Winselwan CM2 chondrites (Fig. 1); as such, it likely originated from the same or similar isotopic reservoir.

Conclusions: The Ti isotope data reported here show similar ε^{50}Ti values for the Allende CV3 and the Maralinga CK4-anomalous meteorites. The two CM2 chondrites, Murchison and Jbilet Winselwan, and the C chondrite Sutter's Mill have ε^{50}Ti values that are comparatively lower, but similar to each other. These likely reflect the distinct isotopic compositions of the reservoirs from which these two groups of carbonaceous chondrites originated. This work emphasizes the potential importance of representative sampling for Ti isotopic analyses for inferring the degree of isotopic heterogeneity in the solar nebula. Further investigations of such representative samples from other chondrites will be needed to better constrain such heterogeneity.

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