THE ORIGIN AND IGNEOUS PROCESSING OF THE UREILITE PARENT BODY CONTRAINT BY MASS-DEPENDENT AND NUCLEOSYNTHETIC TITANIUM ISOTOPE DATA.

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Introduction: Titanium isotopes are a novel tool to study the evolution of the Solar System and planetary differentiation. Mass-independent, nucleosynthetic, Ti isotope variations are used to establish genetic relationships between different planetary bodies sampled by meteorites. In contrast, mass-dependent Ti isotope data are an emerging tool for tracing magmatic processes. In this study, we apply Ti isotope systematics to the ureilite parent body (UPB). Ureilites are carbon-rich achondrites derived from a single and now-disrupted parent body e.g. [1]. Most ureilites are ultramafic and considered to represent partial melting residues of primordial material after the extraction of iron-sulphide and silicate melts e.g., [2]. They experienced variable degrees of partial melting. Moreover, it is suggested that partial melting was not rigorous enough to erase all primordial compositions e.g., [3]. For example, O and Cr isotope evidence suggest that the UPB formed from two distinct precursor reservoirs [4]. Moreover, ureilites display the largest depletions in the abundance of the neutron-rich isotopes (e.g., ^{50}Ti, ^{54}Cr) among bulk meteorites [5]. Hence, their nucleosynthetic isotope composition is key for modelling mixing processes within the protoplanetary disk. Since high-precision Ti isotope data of ureilites are scarce, we address this gap in this study.

Regarding mass-dependent Ti isotope data, considerable variations in δ^{49}Ti (the per mil deviation of the ^{49}Ti/^{47}Ti ratio relative to the Origins Laboratory (OL)-Ti standard [6]) of ~3.8 ‰ were reported for terrestrial rocks, produced by crystal-liquid fractionation during magmatic differentiation e.g., [7], and kinetic, disequilibrium isotope effects [8]. In addition, significant equilibrium Ti isotope fractionation may occur at low oxygen fugacities similar to those inferred for the UPB [9,10]. Hence, determining the Ti isotope composition of ureilites provides additional constraints on the origin and igneous processing of the UPB.

Samples and Methods: Ten monomict ureilites from Antarctica were selected for both mass-independent and mass-dependent Ti isotope analyses. The selected olivine-bearing meteorites have Fo contents 75 to 95, covering nearly the full range known for ureilites [1]. Sample analysis followed the protocol of [8,10]. After Parr bomb digestion, two aliquots were taken for mass-independent and mass-dependent Ti isotope analyses and processed in different laboratories. A ^{47}Ti-^{49}Ti double-spike was added to the aliquots for the mass-dependent analyses. Titanium was purified using a three-step ion-exchange procedure [8,10]. Isotope measurements were performed on two different Thermo Scientific Neptune Plus MC-ICP-MS at ETH Zurich

Results and Discussion: All investigated ureilites display ε^{50}Ti deficits relative to Earth. Their nucleosynthetic Ti isotope compositions overlap with each other within analytical uncertainty and define an average of -1.95 ± 0.03 (2SE) for ε^{50}Ti. The anomalous ureilite EET 87517, is not included in this average because it exhibits a distinctly different ε^{50}Ti of -1.27 ±0.08. This sample is also anomalous in its Os and Mo isotope composition [3,11]. This nucleosynthetic heterogeneity may indicate that the UPB formed by mixing of two distinct reservoirs in the protoplanetary disk [4,12]. However, it is also possible that these variations reflect the effect of partial melting, which led to the separation of isotopically distinct presolar phases [3].

New mass-dependent δ^{49}Ti values vary from -0.129 ± 0.034 to 0.089 ± 0.034 ‰ (2SD). Low δ^{49}Ti values are associated with both depleted and cumulate ureilites and likely trace Ti isotope fractionation during partial melting and fractional crystallisation on the UPB. Two depleted ureilites (EET 83225, EET 87517) display distinctly higher δ^{49}Ti of 0.062 ± 0.028 and 0.089 ± 0.034, possibly resulting from the reaction with a melt phase enriched in heavy Ti isotopes, which formed during partial melting.

References: [1] Downes et al. (2008) *Geochim. Cosmochim. Acta* 72: 4825–4844. [2] Barrat et al. (2016) *Geochim. Cosmochim. Acta* 194: 163–178. [3] Goderis et al. (2015) *Earth Planet. Sci. Lett.* 431: 110–118. [4] Zhu et al. (2020) *Astrophys. J.* 888: 126. [5] Mezger et al. (2020) *Space. Sci. Rev.* 216: 1–24. [6] Millet and Dauphas (2014) *J. Anal. At. Spectrom.* 29: 1444–1458. [7] Hoare et al. (2020) *Geochim. Cosmochim. Acta* 282: 38–54. [8] Anguelova et al. (2022) *Geochim. Cosmochim. Acta, accepted*. [9] Greber et al. (2017) *Geochim. Cosmochim. Acta* 213: 534–552. [10] Williams et al. (2021) *Chem. Geol.* 568: 120009. [11] Budde et al. (2019) *Nat. Astron.* 3: 736–741. [12] Barrat et al. (2017) *Earth Planet. Sci. Lett.* 478: 143–149.