

HETEROGENEITY IN THE $^{238}\text{U}/^{235}\text{U}$ RATIOS OF ANGRITES.F.L.H. Tissot^{1,2}, N. Dauphas¹ and T.L. Grove²

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Introduction: Angrites are differentiated meteorites of basaltic composition, of either volcanic or plutonic origin, that display minimal post-crystallization alteration, metamorphism, shock or impact brecciation (e.g., [1] and references therein). The crystallization ages of angrites range from ~4 to 11 Myr after CAI formation (e.g., [2-3]), and as such, these achondrites provide insights into early stages of planetary melting and differentiation. Because quenched angrites cooled very rapidly, with cooling rate estimates ranging between 7 and 50 °C/h [4-5], all radiometric systems closed simultaneously in these samples [6]. Quenched angrites have therefore been used as anchors for cross-calibrating short-lived dating methods (e.g., ^{26}Al - ^{26}Mg , ^{53}Mn - ^{53}Cr , ^{182}Hf - ^{182}W) with the absolute dating techniques (i.e., U-Pb, Pb-Pb). Due to the constancy of the $^{238}\text{U}/^{235}\text{U}$ ratio in natural samples, Pb-Pb ages have long been calculated using an assumed “consensus” $^{238}\text{U}/^{235}\text{U}$ ratio of 137.88. But the discovery a decade ago of resolvable variations in the $^{238}\text{U}/^{235}\text{U}$ ratio of natural samples (e.g., [7-8]), means that the U isotopic composition of the material to date also has to be determined in order to obtain high-precision Pb-Pb ages.

Our first goal was therefore to measure at high-precision the U isotope composition of a large array of angrites in order to correct their Pb-Pb ages. The second aim of this work was concerned with identifying whether all angrites have a similar U isotopic composition, and, if not, what is(are) the process(es) responsible for this variability. Recently, Brenneka and Wadhwa (2012) [9] measured a series of angrite samples and suggested that the angrite-parent body had a homogeneous U isotopic composition. They reached this conclusion partly because they propagated the uncertainties of the U isotopic composition of the various U double spikes that they used onto the final $^{238}\text{U}/^{235}\text{U}$ ratio of each sample. Because this error is systematic (i.e., it affects all samples similarly) differences in the U isotopic compositions of samples corrected by the same double spike are better known than one would be led to believe if uncertainties on the spike composition are propagated. When only the error on the isotopic measurement is considered, some variability in the angrite $^{238}\text{U}/^{235}\text{U}$ ratio data set of [9] is visible.

Methods: Samples of six angrites (NWA 4590, NWA 4801, NWA 6291, Angra dos Reis, D’Orbigny, and Sahara 99555), were obtained for this work. A thin slice of each was cut along the long axis, inspected for signs of alteration, and recut so as to retain only the least altered areas. Each sample was crushed manually in an agate mortar after having being sonicated for 5 min in a methanol bath. Sample powder was transferred into a clean Teflon beaker and spiked with IRMM-3636 (^{233}U - ^{236}U spike), aiming for a $U_{\text{spike}}/U_{\text{sample}}$ ratio of ~ 3 %. The sample masses digested ranged from 140 mg for high U concentration samples to 1.4 g for low U concentration samples. The digestion and chemical purification on U/Teva followed the methodology presented in [10]. Each sample was processed through chemistry three times to ensure full matrix removal from the U cut. All U isotope measurements were performed in low-resolution mode using a static cup configuration [10] on a ThermoFinnigan Neptune MC-ICPMS upgraded with an OnTool Booster 150 Jet pump (Pfeiffer) at the Origins Laboratory of the University of Chicago. The measurements were done at U concentrations between 14 and 30 ppb in 0.5 to 10 mL solutions and the uncertainties on the $\delta^{238}\text{U}$ values therefore range from ± 0.04 ‰ to ± 0.14 ‰ (95 % confidence interval).

Results: At the conference, we will present the results of the high-precision U isotope analyses for the six angrite samples we studied (NWA 4590, NWA 4801, NWA 6291, Angra dos Reis, D’Orbigny, and Sahara 99555). We will show that there is some variability in the $\delta^{238}\text{U}$ values of these samples and argue that the angrite-parent body was heterogeneous with regards to U isotopes. We will discuss the possible processes by which different angrite samples can acquire different U isotopic compositions. The U isotope data will then be used to correct Pb-Pb ages of angrites estimated using an assumed $^{238}\text{U}/^{235}\text{U}$ ratio. These ages will be used to discuss the degree of concordance between short-lived nuclides systems and the absolute Pb-Pb clock in early Solar System materials.

References: [1] Keil K. 2012. *Chemie der Erde - Geochemistry* 72, 191-218. [2] Amelin Y. 2008. *Geochimica Cosmochimica Acta* 72, 221-232. [3] Baker J. et al. 2005. *Nature* 436, 1127-1131. [4] Mikouchi T. et al. 2000. 31st Lunar and Planetary Science Conference, pp. 1970. [5] Mikouchi T. et al. 2001. 64th Annual Meteoritical Society Meeting, pp. A134. [6] Dodson M.H. 1973. *Contributions to Mineralogy and Petrology* 40, 259-274. [7] Stirling C.H. et al. 2007. *Earth and Planetary Science Letters* 264, 208-225. [8] Weyer S. et al. 2008. *Geochimica Cosmochimica Acta* 72, 345-359. [9] Brenneka G.A. and Wadhwa M. 2012. *Proceedings of the National Academy of Sciences* 109, 9299-9303. [10] Tissot F.L.H. and Dauphas N. 2015. *Geochimica Cosmochimica Acta* 167, 113-143.