THE OUTWARD DISPLACEMENT OF ROCKY PLANETISMALS IN THE EARLY SOLAR SYSTEM: OXYGEN ISOTOPE EVIDENCE FROM ANGRITES.

B. G. Rider-Stokes[1] (ben.rider-stokes@open.ac.uk), R. C. Greenwood[1], M. Anand[1,2], L. F. White[1], I. A. Franchi[1], V. Debaille[3], S. Goderis[4], L. Pittarello[5,6], A. Yamaguchi[7] T. Mikouchi[8] & P. Claeys[4].
[1]The Open University, Milton Keynes, UK.[2]Department of Mineralogy, The Natural History Museum, London, UK. [3]Laboratoire G-Time, Université Libre de Bruxelles, Belgium. [4]Department of Chemistry, Vrije Universiteit Brussel, Belgium. [5]Naturhistorisches Museum Wien, Mineralogisch-Petrographische Abteilung, Burgring, Austria. [6]University of Vienna, Department of Lithospheric Research, Althanstrasse, Austria. [7]National Institute of Polar Research, Tachikawa, Tokyo, Japan. [8]Department of Earth and Planetary Science, The University of Tokyo, Japan.

Introduction: The formation and migration of giant gas planets are crucial to the evolution of planetary systems, and yet the timing of these events in our Solar System remains largely unconstrained. Angrite meteorites represent some of the oldest materials in the inner Solar System, and therefore provide an exclusive window into the history of the early Solar System [1]. Recent oxygen isotopic analyses have redefined the angrite fractionation line (AFL) to $\Delta^{17}O = 0.064 \pm 0.018‰$ (2σ) and highlighted that the quenched angrite NWA 12320 exhibits an anomalous $\Delta^{17}O$ value of $-0.017 \pm 0.004‰$ (2σ) [2]. Mineralogically, NWA 12320 is comparable to the majority of quenched angrites, however, it lacks the usual abundance of olivine xenocrysts. Here we present evidence for an oxygen isotopic disequilibrium between the matrix and olivine xenocrysts in three quenched angrites, NWA 12320, Asuka-12209 and Asuka-881371, discussing the possible causes of this variation.

Matrials and Methods: Olivine xenocrysts in the three quenched angrites were separated from the matrix and subsequent O-isotope data of both matrix and olivine fractions were obtained at the Open University using laser-assisted fluorination following established procedures [3,4].

Results: The olivine xenocrysts of NWA 12320, Asuka 12209 and Asuka 881371 display $\Delta^{17}O$ values of $-0.065 \pm 0.018‰$, $-0.068 \pm 0.015‰$ and $-0.067 \pm 0.008‰$, respectively, indistinguishable from whole-rock angrite meteorites measured in other studies [2]. Intriguingly, the matrix fractions of all three samples reveal less negative values that are statistically distinct from the other angrite meteorites ($\Delta^{17}O = -0.024 \pm 0.016‰$, $-0.001 \pm 0.007‰$ and $-0.003 \pm 0.007‰$, respectively). While lesser amounts of matrix may result in undetectable shifts in some quenched angrites, NWA 12320 is dominated by matrix and therefore the whole-rock sample equates to a matrix separate. Electron backscatter diffraction on the olivine xenocrysts in NWA 12320 revealed granular textures. The granular olivine xenocrysts have no discernible preferred orientation and are cemented by olivine with a higher Fe content, with neighbouring grains displaying vastly distinct orientations, indicative of recrystallization, after shock-induced mosaicism or fragmentation.

Discussion: The granular textures within NWA 12320, have also been reported in the urelite JaH 422 and the howardite JaH 556 [5,6]. These meteorites have been interpreted as impact-melt rocks with the olivine grains representing unmolten relics of their precursor material. Interestingly, JaH 556 similarly displayed slight oxygen isotopic differences between the bulk-rock and matrix fractions. This textural evidence could suggest that at least some olivine grains in NWA 12320 remained as relict material and were affected by high temperature processes on the angrite parent body (APB). We therefore favor the hypothesis that NWA 12320, Asuka 12209 and Asuka 881371 have an impact-melt origin, with the matrix representing recrystallized material induced by an impact event and the olivine grains representing relict material of the original APB. The impactor is unlikely to be a carbonaceous chondrite based on the positive $\Delta^{17}O$ values of the matrix, nor an ordinary chondrite due to the lack of metal within angrite meteorites. We therefore propose that the impactor was an unsampled achondrite like NWA 11042 [7]. We conclude that this extreme dynamical excitement resulting in early, large scale mixing, is not an expected result of the classical accretion of bodies, and demands the interference of the giant gas planets.

Summary: We interpret our findings in terms of quenched angrite meteorites representing impact-melt rocks rather than shallow magmatic intrusions, recording evidence of impact-driven mixing. This mixing may have taken place in response to the inward migration of giant planets (as envisaged in the Grand Tack model [8]) and hence would represent the earliest isotopic evidence for planetary migration in the early Solar System.

References: **[1]** Keil K. (2012) Chemie der Erde. 72.191-218. **[2]** Rider-Stokes B. G et al (2021) 84th Meteoritical Society 6071. **[3]** Miller M. F. et al (1999) Rapid Communications in Mass Spectrometry. 13, 1211-1217. **[4]** Greenwood R. C. et al (2017) Chemie der Erde. 77, 1-43. **[5]** Janots E. et al (2011) Meteoritics and Planetary Science. 47, 1558-1574. **[6]** Janots E. et al (2012) Meteoritics and Planetary Science. 46, 134-148. **[7]** Vaci Z. et al. (2020) Meteoritics and Planetary Science. 55, 622-648. **[8]** Walsh K. et al (2011) Nature.