CHRONOLOGICAL ANCHOR(S) AWEIGH: POSSIBLE EVIDENCE OF THERMAL PROCESSING OF D'ORBIGNY ANGRITE SUGGESTS CAUTION WITH ISOCHRON CONSTRUCTION. B. G. Rider-Stokes[1], L. Pittarello[2,3], L. F. White[1], M. Anand[1,4], Degli-Alessandrini, G.[1], I. A. Franchi[1], & R. C. Greenwood[1]. [1]The Open University, Milton Keynes, MK7 6AA, UK. (ben.rider-stokes@open.ac.uk). [2]Naturhistorisches Museum Wien, Mineralogisch-Petrographische Abteilung, Burgring 7,A-1010 Vienna, Austria. [3]University of Vienna, Department of Lithospheric Research, Josef-Holaubek-Platz 2, A-1090 Vienna, Austria. [4]Department of Earth Sciences, The Natural History Museum, London, SW7 5BD.

Introduction: The ancient, achondritic, quenched (rapidly-cooled) angrite meteorites have been used in several previous studies as a lead-lead (Pb-Pb) age anchor for the short-lived chronometers [1,2,3]. The quenched angrite, D'Orbigny, has been singled out as an ideal anchor due to crystallizing from a single magmatic source, the lack of metamorphism and secondary processing [4].

The petrogenesis of D'Orbigny and the quenched angrites, however, is a matter of debate. While the prevailing view is that D'Orbigny and all quenched angrites are igneous rocks that formed by melting and differentiation of an asteroidal body [5], a controversial non-igneous origin for D'Orbigny and all other angrites has been proposed based on the compositional features of glass [6,7].

More recently, an oxygen isotopic disequilibrium between the relict olivine grains and groundmass fractions of three quenched angrites, Asuka-881371, Asuka (A) 12209 and NWA 12320 has been identified [8]. It is suggested that the isotopic disequilibrium, as supported by microstructural evidence of recrystallization, appears to be the result of impact melting. In these samples only the olivine grains represent relict material from the original angrite parent body (APB), while the groundmass is an impact melt contaminated with some small percentage of impactor material [8]. As such, the quenched angrites appear not to be pristine, unbrecciated and unmetamorphosed rocks. The incongruences in the interpretation of quenched angrites as simple igneous rocks has already been discussed for D'Orbigny [9].

The disputed heritage of D'Orbigny raises questions on the suitability of quenched angrites as Pb-Pb anchors. This has important consequences for accurately defining the absolute timeline of early Solar System events. We present mineralogical and crystallographic variations in D'Orbigny to gain new insights into its petrogenesis.

Methods: Following established procedures [7], a polished mount from D'Orbigny was carbon coated using a Safematic CCU-010 Compact Coating Unit (<5 nm). The sample was then subsequently investigated using a Zeiss Crossbeam 550 SEM with an Oxford Instruments Symmetry 2 EBSD detector at The Open University. The sample was tilted to 70° and an electron beam was used to generate EBSD "maps", consisting of electron backscatter diffraction patterns (EBSPs) acquired at step-sizes ranging from 0.4 to 1 µm. The beam conditions used for both EDS and EBSD analyses comprised an incident beam ranging between 1-2 nA current and a 20 kV accelerating voltage at a working distance of 12 mm.

The same sample has been investigated with a field-emission electron microprobe analyser (FE-EMPA) at the Naturhistorisches Museum of Vienna (Austria) using a JEOL JXA-8530-F instrument, equipped with five wavelength-dispersive spectrometers (WDS) and two energy-dispersive spectrometers (EDS), operated at 15 kV acceleration voltage, 20 nA beam current, and on a fully focused beam. For quantification, a ZAF correction was applied, and the content was calculated as oxides. Natural and synthetic reference minerals were used for calibration. In addition, Raman spectroscopy was performed at the Institute of Mineralogy and Crystallography, University of Vienna (Austria).

Results: Grain-relative orientation distribution (GROD) angle maps derived from EBSD measurements of D'Orbigny reveal that much of the sample is microstructurally undeformed, with olivine present in the groundmass demonstrating little internal misorientation (<1° to 2°) (Figure 1). The upper most relict olivine grain similarly demonstrates little internal misorientation (<1° to 2°) (Figure 1). However, a large portion of the relict olivine grain appears to display minor deformation bands (Figure 1), but no Raman peak broadening and Raman intensity lowering, typical of shocked olivine, was observed.

Inverse pole figure (IPF) maps derived from EBSD measurements of D'Orbigny reveal a lack of twinning in both the olivine present in the groundmass and the large relict olivine grains.

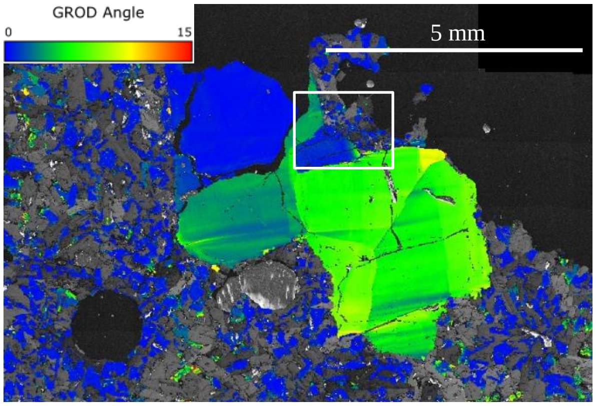

Figure 1: Olivine GROD map demonstrating the microstructural variation between the relict olivine grain and the groundmass. Locality of Figure 2 is highlighted by the white square.

Recrystallization is not identified in the large relict olivine grain, however, triple junctions and lobate grain boundaries is observed near the relict olivine (Figure 2a). Melt consisting of anorthite and pyroxene also appears to quench into part of the relict olivine grain (Figure 2b). Chemically, the mineral compositions determined in previous works [9] were confirmed.

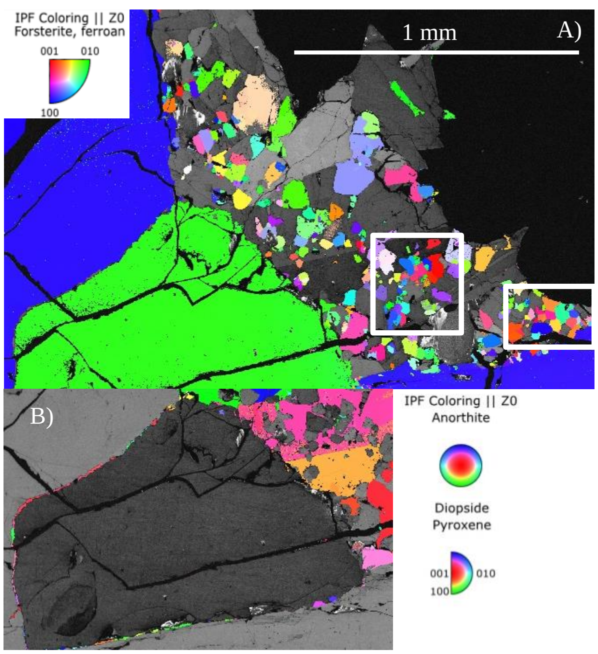

Figure 2: A) IPF map demonstrating triple junctions and lobate grain boundaries (highlighted by the white squares) adjacent to the large relict olivine grain(s) (left & below). **B)** IPF map demonstrating the melt consisting of anorthite and pyroxene melt.

Discussion: Unlike NWA 12320 and A 12209, partial recrystallization of the large relict olivine grains is not observed. However, adjacent to the relict olivine, multiple grains demonstrating triple junctions and lobate grain boundaries are identified (Figure 2a).

The granular-like textures may be indicative of recrystallization of olivine or, more likely, remelting. Based on shock pressures alone, recrystallization of olivine occurs at pressures of $\geq$ 60 GPa [10].

The likely recrystallized domain shown in Figure 2a, presents some peculiar features, such as strongly zoned olivine grains, with a wider compositional range (Fa 13-88) than the olivine in the groundmass (Fa 38-98), locally containing pyroxene inclusions, and evidence of melting (subrounded shape of some olivine grains and zoned cores, presence of glass pockets containing metal-rich droplets) and overgrowth (euhedral margins).

While D'Orbigny does not appear to demonstrate measurable evidence of impactor contamination in its whole-rock O-isotope composition [8], the similarity in textures and chemical compositions with the A 12209, A-881371 and NWA 12320 samples strongly indicates a common origin. Subsequently, chronological constraints taken from the groundmass are possibly representative of the timing of thermal metamorphism, rather than primary magmatic crystallization.

It is noted that [11] point out the disturbed nature and/or uneven distribution of ^{26}Al in D'Orbigny and similarly suggest that D'Orbigny should not be used as a universal age anchor, suggesting NWA 6704/6693 as an alternative.

Any adjustments to the time anchor would require a corresponding correction to the 'model ages' of all materials dated using D'Orbigny as an anchor. This, in turn, has consequences for accurately defining the absolute timeline of Solar System events.

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