REFINING THEORIES OF ACCRETION IN THE EARLY SOLAR SYSTEM: PETROGRAPHIC, MAJOR-, PLATINUM-GROUP ELEMENT, AND OSMIUM ISOTOPE CHARACTERISTICS OF ANGRITE METALS. *A. J.V. Riches[1], K.W. Burton[1], G. M. Nowell[1], C.W. Dale[1], A. J. Irving[2],and A. R. Santos[3]. [1]Dept. of Earth Sciences, University of Durham, South Road, Durham, DH1 3LE, United Kingdom. *amy.j.riches@durham.ac.uk. [2]Earth & Space Science, University of Washington, Seattle, Washington, WA 98195-1310, United States. Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico, NM 87131, United States.

Introduction: Platinum group element (PGE) abundances & osmium-isotope compositions determined for magmas of Earth, the Moon, Mars, & asteroidal bodies place important constraints on planetary evolution and these data are a fundamental basis for theories concerning the addition of material to planetary mantles following core formation [e.g., 1-3]. The absolute and relative abundances of PGE reported for Earth's mantle, and generally calculated for the mantles of other planetary bodies, are widely considered to be inconsistent with core formation alone and provide critical evidence of accretion of broadly chondritic materials [e.g., 4]. Such accretion processes are potentially linked to the delivery volatiles and organic molecules on planets such as Earth [5] where complex carbon-based life has subsequently arisen. However, existing planetary PGE data, and current analytical approaches, have largely focused on whole-rock investigations. New methods to enable quantitative determination of mineral-scale PGE-abundances and osmium-isotope compositions in precious meteorite materials are key to advancing understanding of planetary PGE fractionation and crucial to refining accretion theories.

Angrites are ancient achondrites characterised by oxygen isotope compoistions distinct from the Earth-Moon system and other meteorite groups considered to sample the inner Solar System bodies of Mars and the howardite-eucrite-diogenite (HED) parent body[6]. As some of the oldest recognised differentiated Solar System materials, angrites place important constraints on the early phases of planetary evolution. Angrite magmas are generally considered to have been produced under relatively oxidizing conditions ($\log f0_2$ = IW+1 to +2; 7-9) on a volatile-depleted body [e.g., 10-12]. Prior major-l, trace-, and platinum-group-element abundance and osmium-isotope studies of both coarse-grained and quenched angrite textural groups [13] have placed critical constraints on the evolution of the angrite parent body (APB) and provided powerful evidence of accretion to differentiated bodies in the early Solar System following rapid and early core formation evidenced by Hf-W isotope systematics [14-15].

We here provide new petrographic and compositional data pertaining to metals in several distinct portions of coarse-grained metal-bearing angrites NWA 4590, NWA 4801, and 'dunitic' NWA 8535 [16]. These observations are supported by platinum-group-element abundance and osmium-isotope data for metals extracted using pioneering new sampling procedures. These innovative protocols have enabled the first texturally-controlled mineral-scale Os-isotope study of planetary materials; a vital investigation to constrain magmatic PGE partitioning and to further interpretations of corresponding bulk powder data.

Petrographic characteristics: The studied angrite portions are distinct from those described by [13] and provide larger surface areas for the present study. The polished surfaces of two chips of NWA 4590 and NWA 4801 have been investigated along with a single chip of NWA 8535. In each case, 1-inch epoxy billets containing each chip were subjected to electron microprobe analyses at the University of Edinburgh, UK.

Fe-Ni metals (taenite; ≤50 μm) in the studied portions of NWA 4590 generally occur in trails and/or clusters associated with fassaitic pyroxenes (≥500 μm) ± merrilite (≤75 μm). In detail, two distinct metal populations have been identified in NWA 4590 based on their textural characteristics. Group-1 Fe-Ni metals in NWA 4590 occur as Fe-Ni metals exsolved or in close association with troilite sulphide (generally ≤150 μm) and small oxide grains. Group-2 Fe-Ni metals (~10 vol. % of NWA 4590 metals) occur as disseminated alloys and do not occur in close association with sulphide or oxide.

NWA 4801 contains heterogeneously distributed Fe-Ni metals (≤50 μm) disseminated throughout the studied surface areas and lacking the appearance of trails. NWA 4801 metals are ubiquitously characterised by Group-1 textural characteritics, and Group-2 metals appear lacking.

Fe-Ni metals of NWA 8535 (≤50 μm) are heterogeneously distributed and disseminated throughout the studied area. Fe-Ni metals of NWA 8535 (≤50 μm) occur as two populations - Group-3 and Group -4. Group-3 metals are typified by their occurrence at silicate grain boundaries or in cracks (≤ 50 width); these metals are closely associated with troilite sulphide (≤175 μm) but volumetrically minor associated oxide. Group-4 metals account for the majority (>80%) of Fe-Ni metals identified in NWA 8535 and predominantly occur as isolated alloys enclosed within silicates.

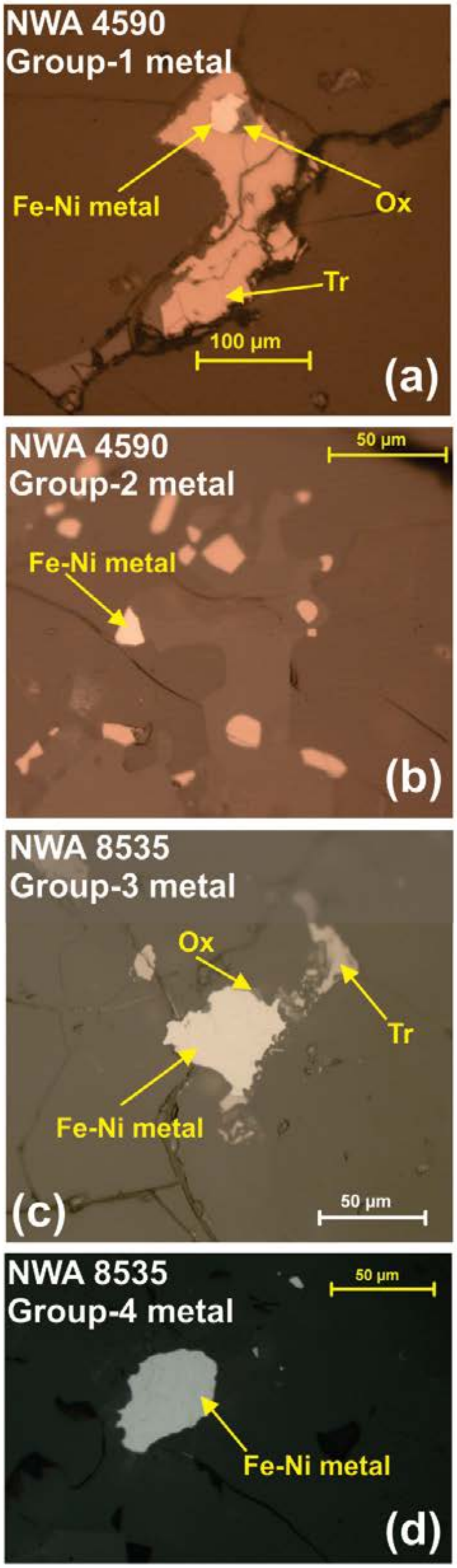

Figure 1: *Reflected light images of Fe-Ni metals in angrites NWA 4590 and NWA 8535 illustrating the textural diversity of metal occurrences. Key phases are identified for simplicity. Ox = oxide. Tr = troilite.*

Innovative technical advances: Wafers were prepared of those samples in which suitable Fe-Ni metal grains were identified for extraction. These wafers were mounted on glass plates. A series of blank tests were performed prior to extracting individual metals for digestion and analyses of PGE-concentrations and osmium-isotope compositions. These highly-novel data place important new constraints on internal sample PGE partitioning and Os-isotope compositions. Crucially, our new grain scale data is compared to the reproducible measurements previously made on multiple powder fractions of NWA 4590 and NWA 4801 [12], thereby providing a means of quantitatively assessing this new mineral-scale approach. Importantly, examples of all petrographic groups of metals were sampled.

Summary: Identification of four distinct textural groups of Fe-Ni metals in three coarse-grained metal-bearing angrites is of profound import for understanding of corresponding bulk-rock PGE-abundance and osmium-isotope data. These observations, combined with new mineral-scale data, lead us to re-evaluate; 1) existing theories concerning the origin and evolution of the angrite parent body, and; 2) conclusions drawn from prior comparative petrology assessments of broader inner Solar System datasets.

References: [1] Dale et al., 2012, *Science*, 336 (6077), 72-75. [2] Day et al., 2012, *Nat.GeoSci.*, 5, 614-617. [3] Brandon et al., 2012, GCA, 76, 206-235. [4] Walker, 2009, *Chemie der Erede*, 69 (2), 101-125. [5] Herd et al., 2011, *Science*, 332 (6035), 1304-1307. [6] Greenwood et al., 2005, *Nature*, 435, 916-918. [7] Jurewicz et al., 1993, *GCA*, 57, 2123-2139. [8] McKay et al., 1994, *GCA*, 58(13), 2911-2919. [9] Longhi et al., 1999, *GCA*, 63, 573-585. [10] Hans et al., 2013, *EPSL*, 347, 204-214. [11] Pringle et al., 2014, *PNAS*, 111(48), 17029-17032. [12] Sanborn et al., GCA, 171, 80-99. [13] Riches et al., 2012, *GCA*, 353-354, 208-218. [14] Markowski et al., 2007, *EPSL*, 262, 214-229. [15] Kleine et al., 2012, *GCA*, 84(1), 186-203. [16] Agee et al., 2015, LPSC abstract# 2681.