EVIDENCE FOR A UNIQUE CARBONACEOUS CHONDRITE PARENT BODY ('CX') AND ANOTHER ONE WITH A DUNITIC MANTLE. A. J. Irving[1,5], S. M. Kuehner[1], L. A. J. Garvie[2], K. Ziegler[3], M. E. Sanborn[4], Q.-Z. Yin[4], P. P. Sipiera[5], G. M. Hupé and B. Hoefnagels [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA, USA (irvingaj@uw.edu), [2]Center for Meteorite Studies, Arizona State University, Tempe, AZ, USA; [3]Inst. of Meteoritics, University of New Mexico, Albuquerque, NM, USA; [4]Dept. of Earth & Planetary Sciences, University of California, Davis, CA, USA; [5]Planetary Studies Foundation, Galena, IL, USA.

Introduction: The forensic reconstruction of former bodies which populated the early Solar System presents a considerable challenge, since it depends on the recognition of random pieces of those bodies recovered as meteorites. Although numerous bodies (some differentiated) must have existed then [e.g., 1], it is likely that many were completely disrupted by collisions, only to be sampled more recently from the remnant debris.

Since the recognition of the R chondrite parent body [2], only a few other chondritic bodies (e.g., that yielding the acapulcoite-lodranite clan [3]) have been proposed. Here we use mineralogic and isotopic evidence to make the case for Northwest Africa 11961 as a carbonaceous chondrite distinct from well-known chondrite classes. Furthermore, we argue that ungrouped achondrite Northwest Africa 12264 has affinities to (and may be a mantle sample from) yet another previously unrecognized carbonaceous chondrite parent body.

Figure 1. *Cut NWA 11961 stone showing relatively small chondrules and shiny metal. Cube is 1 cm.*

Northwest Africa 11961: This relatively fresh specimen (see Figures 1, 2) consists of relatively small (840 ± 500 µm), well-formed granular chondrules (some with partial metal-rich rims) set in a fine grained matrix (~15 vol.%). X-ray diffraction analysis of powdered samples detected no phyllosilicates and no clay minerals in the <1 µm size fraction (see Figure 3). Mafic silicates are unequilibrated [olivine $Fa_{0.9-34.0}$, clinopyroxene $Fs_{0.9-2.7}Wo_{41.9-40.6}$, rare orthopyroxene $Fs_{2.1-2.3}Wo_{1.4-0.8}$], and accessory phases include anorthite (even in chondrules), kamacite and troilite.

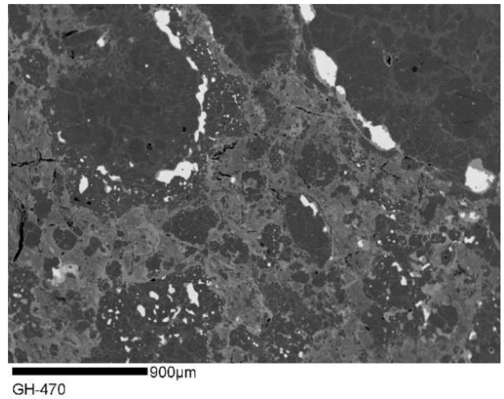

Figure 2. *BSE image of NWA 11961 showing metal-rimmed chondrules and chondrule fragments set within a very fine grained anhydrous matrix*

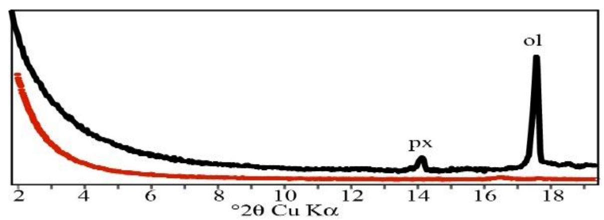

Figure 3. *Powder XRD patterns for NWA 11961 showing the low-2theta part of the profiles. (00l) basal reflections of phyllosilicates are absent in the patterns for both whole rock (black) and "clay" fraction (red).*

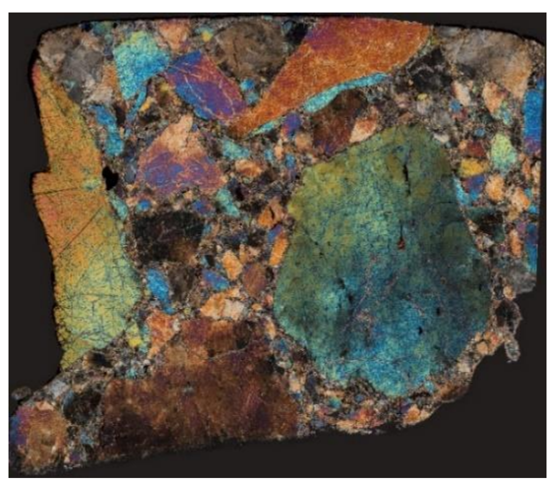

Figure 4. *Cross-polarized optical microscope image of NWA 12264 showing the cataclastic texture and predominance of deformed olivine. Width = 17.5 mm.*

Northwest Africa 12264: This ultramafic (dunitic) specimen is a cataclastic breccia dominated (>95 vol.%) by closely-packed, angular grains of olivine (up to 9 mm across, exhibiting undulose extinction, $Fa_{20.8\text{-}22.0}$, FeO/MnO = 74-88) with minor chromite, low-Ca pyroxene ($Fs_{17.6\text{-}17.7}Wo_{4.8\text{-}4.3}$, FeO/MnO = 64-69), intermediate plagioclase ($An_{51.8}Or_{2.6}$) and rare exsolved pigeonite (FeO/MnO = 51-69) – see Figure 4. Chromite + pyroxene symplectitic intergrowths are also present.

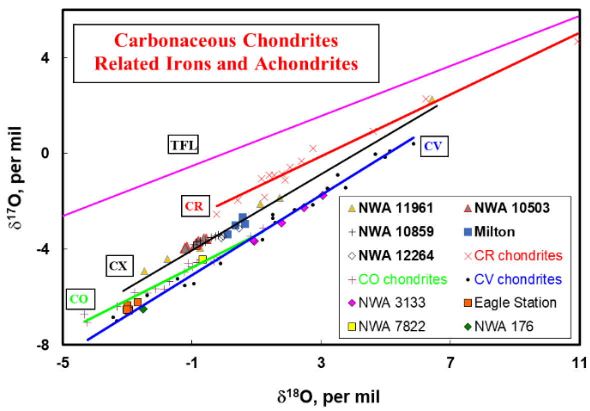

Figure 5. *Oxygen isotopic compositions of carbonaceous meteorites; data from [4-9]*

Oxygen and Chromium Isotopes: Replicate analyses of acid-washed subsamples by laser fluorination gave, respectively: NWA 11961 $\delta^{17}O$ -4.928, -4.401, -3.935, -2.101, -1.850, 2.263; $\delta^{18}O$ -2.475, -1.766, -0.748, 1.112, 1.717, 6.427; $\Delta^{17}O$ -3.621, -3.469, -3.540, -2.688, -2.757, -1.13 0 per mil; NWA 12264 $\delta^{17}O$ -2.886, -3.489, -3.605; $\delta^{18}O$ 0.467, -0.028, -0.092; $\Delta^{17}O$ -3.133, -3.474, -3.557 per mil. The NWA 11961 subsamples define a linear trend (here informally dubbed 'CX') between those for CR chondrites and CV-CK-CO chondrites (see Figure 5). Oxygen isotope values for metachondrite NWA 10503/10859 [3] and the Milton pallasite [4] also plot on the same trend, but those for NWA 12264 are offset slightly from it.

The $\varepsilon^{54}Cr$ value for NWA 11961 is resolvably different beyond error from values for other carbonaceous chondrites except perhaps CR chondrites (see Figure 6). Despite the compatible oxygen isotope compositions for NWA 11961, NWA 10503 and Milton, the small differences in their chromium isotopic compositions argue for their origin on two separate bodies (albeit carbonaceous ones). Achondrite NWA 12264 is isotopically distinct from all of these specimens as well as from dunitic achondrite NWA 7822 [10], yet both of these ultramafic achondrites clearly have isotopic affinities to carbonaceous chondrites too. Another olivine-rich, Cr-magnetite-bearing achondrite, NWA 8186, is now regarded as a highly recrystallized CK7 chondrite [11].

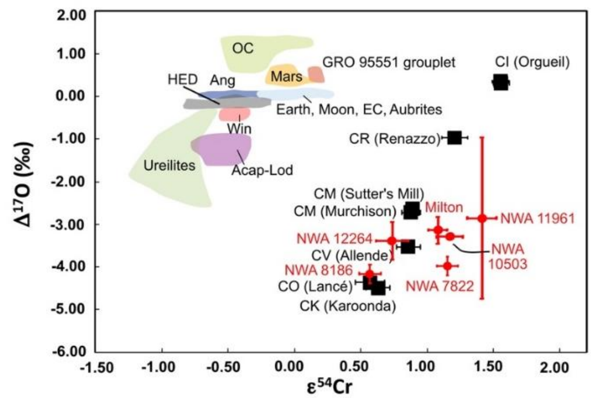

Figure 6. *Chromium-oxygen isotope plot modified from [12]. Data in red from [4-5], [10] and this study. Vertical bars are not uncertainites in measurement but show the full ranges of observed variation.*

Evidence for Multiple Layered, Differentiated Carbonaceous Parent Bodies: Building upon our previous work [6, 10] we can infer a layered structure for the CV chondrite parent body, with diverse components as a function of increasing depth, namely: CV3 chondrites, CV4 chondrites (e.g., NWA 8418 [13]), CV7 metachondrites (e.g., NWA 3133 [6, 7]), perhaps an olivine-rich achondrite mantle (akin to NWA 7822 and NWA 12264), and a pallasite±silicated iron core (e.g., Eagle Station, NWA 176). This model is also consistent with magnetic paleointensity results for Allende [14] that imply the existence of an ancient dynamo field.

We conclude that NWA 11961 and NWA 12264 are samples from two previously unrecognized carbonaceous parent bodies, which although having unequilibrated chondrite veneers were characterized by more complex metachondritic and achondritic interiors. There may well have existed many such bodies in the early Solar System, and our ability to document them is limited mostly by sampling issues.

References: [1] Chambers J. and Wetherill G. (2001) *Meteorit. Planet. Sci.* **36**, 381-399 [2] Bischoff A. et al. (2011) *Chemie Erde* **71**, 101-206 [3] Li S. et al. (2018) *GCA* **242**, 82-101 [4] Irving A. et al. (2016) *79th Meteorit. Soc. Mtg.*, #6461 [5] Jones R. et al. (2003) *LPS* **XXXIV**, #1683 [6] Irving A. et al. (2013) *76th Meteorit. Soc .Mtg.*, #6461 [7] Irving A. et al. (2004) *AGU Fall Mtg.*, #P31C-02 [8] Clayton R. et al. (1991) *GCA* **55**, 2317-2337 [9] Clayton R. and Mayeda T. (1996) *GCA* **60**, 1999-2017 [10] Sanborn M. et al. (2015) *LPS* **XLVI**, #2259 [11] Srinivasan P. et al. (2017) *LPS* **XLVIII**, #1995 [12] Sanborn M. et al. (2019) *GCA* **245**, 577-596 [13] Mallozzi L. et al. (2018) *LPS* **XLIX**, #2555 [14] Carporzen L. et al. (2011) *PNAS* **108**, 6386-6389.