COLLISIONAL DISRUPTION OF A LAYERED, DIFFERENTIATED CR PARENT BODY CONTAINING METAMORPHIC AND IGNEOUS LITHOLOGIES OVERLAIN BY A CHONDRITE VENEER. A. J. Irving[1], S. M. Kuehner[1], R. Tanaka[2], D. Rumble[3], K. Ziegler[4], M. Sanborn[5] and Q. Yin[5] [1]Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irving@ess.washington.edu), [2]Inst. for Study of Earth's Interior, Okayama University, Japan, [3]Geophysical Laboratory, Carnegie Institution, Washington, DC, [4]Insitute of Meteoritics, University of New Mexico, Albuquerque, NM, [5]Earth & Planetary Sciences, University of California Davis, CA.

Introduction: Previously [1] we have contended that the CR parent body is (or was) composed of much more than the well-known CR2 chondrites (typified by the 1824 Renazzo fall). It is quite possible that a chondritic, regolithic outer layer is (or was) underlain by a much more complex, evolved interior (even including a core), thus implying a larger and hence longer-lived parent body than formerly envisioned. Newly discovered meteorite specimens, plus the added insights from chromium isotopes in concert with oxygen isotopes [2], now permit a more sophisticated model to be proposed.

Highly Equilibrated and Metasomatized Chondrites: At least two separate finds from Northwest Africa - NWA 2994 (plus paired stones NWA 3250, NWA 6721, NWA 6901, NWA 7317) and NWA 3100 – are fresh, highly recrystallized CR6 chondrites containing sparse remnant chondrules [1, 3]. Tafassasset, a fall from Niger containing poikiloblastic aggregates interpreted as former chondrules, can be described as a CR7 chondrite or CR metachondrite [1].

Not only are these highly recrystallized specimens indisputably related to CR chondrite precursors, they have fractionated compositions [1] indicative of open chemical system behavior (i.e., metasomatism). Since the most common CR chondrite specimens are all hydrated, it is likely that there was a role for water in promoting such metasomatism on the CR parent body.

Figure 1. *Cut interior of NWA 7317. Photo © M. Cimala.*

Plutonic Igneous Rocks: There is good evidence based on both oxygen and chromium isotopes that NWA 011 and paired specimens (NWA 2400, NWA 2976, NWA 4587, NWA 4901, NWA 5644, NWA 7129) are related to the CR parent body [1, 2, 4]. The tendency to regard these specimens as eucrites has obscured appreciation of their unique characteristics and potential significance. To be sure they have some resemblance to gabbroic eucrites in being relatively coarse-grained igneous rocks composed predominantly of exsolved pigeonite and bytownitic plagioclase.

Figure 2. *Slice of NWA 4901 showing cinnamon-brown pyroxene and white plagioclase. Accessory phases include ilmenite, merrillite, Ti-chromite, sulfides and rare kamacite. Photo © S. Ralew.*

However, the constituent pyroxenes are very different from those in "typical" eucrites in being much more Ti-rich (0.5-0.9 wt.% TiO_2) and having higher FeO/MnO ratios (60-69 [4]). Furthermore, this material has a much more ancient formation age of 4,563.2 Ma (based on both Al-Mg and Pb-Pb chronometry [5]).

Silicated Iron Northwest Africa 468: We previously suggested [1] that unique metal+silicate specimen NWA 468 (see Figure 3) also might be related to the CR parent body. New laser fluorination analyses (at GL) of oxygen isotopes ($\delta^{17}O$ = -0.11, -0.12; $\delta^{18}O$ = 2.12, 2.16; $\Delta^{17}O$ = -1.225, -1.256 per mil) plot close to (but slightly above) the trend for CR chondrites (see Figure 5). One interpretation of this specimen is that it was produced by impact melting of a "metal-rich carbonaceous chondrite precursor" [6]. However, other than CH chondrites, there are no known metal-rich carbonaceous chondrite specimens, and evidence of shock or other impact effects in CR chondrites is lacking. An alternative hypothesis to explain the separation of metal and silicates in NWA 468 (see Figure 3) would be that it is a sample from a partially segregated core on the CR parent body. We will be more confident of this after chromium isotopes are analyzed.

Figure 3. *Slice of NWA 468 (ROM specimen) showing abundant metal and olivine-pyroxene-rich regions (brown). Width 20 cm. Photo by I. Nicklin.*

A Lesson From Northwest Africa 8054: Our caution regarding interpretation of NWA 468 is justified based on our findings for another ultramafic achondite. NWA 8054 is a relatively coarse grained (0.4-1 mm), protogranular aggregate of olivine ($Fa_{4.0-4.2}$, rims, Cr_2O_3 = 0.3 wt.%), orthopyroxene ($Fs_{1.1}Wo_{2.5}$) and clinopyroxene ($Fs_{2.3-2.4}Wo_{35.6-36.1}$) with minor intermediate plagioclase and Cr-troilite. Both olivine and orthopyroxene are compositionally zoned and exhibit more magnesian rims (olivine $Fa_{2.2-2.9}$), but without blebs of metal so typical of reduced rims in these phases in ureilites. Kamacite occurs on grain boundaries and as inclusions within mafic silicate grains.

Analyses (at UNM) of acid-washed silicates by laser fluorination gave: $\delta^{17}O$ = -1.599, -1.551; $\delta^{18}O$ = 0.341, 0.372; $\Delta^{17}O$ = -1.778, -1.747 per mil. These results lie on the CR oxygen isotope trend, but ^{54}Cr values [2] ***are inconsistent with*** CR chondrites, implying derivation from a different (and new) parent body.

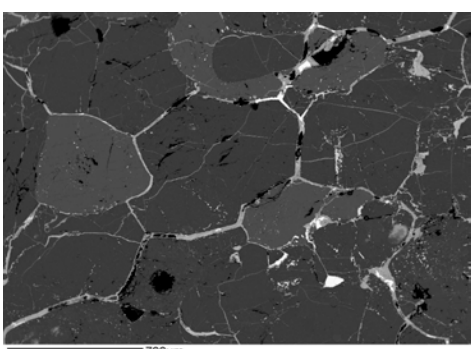

Figure 4. *BSE image of NWA 8054, showing its protogranular texture and grain-boundary metal.*

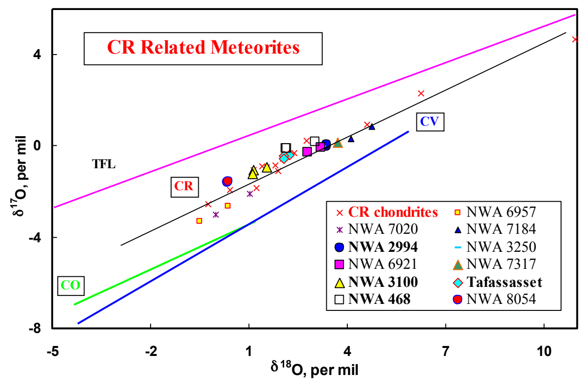

Figure 5. *Oxygen isotope plot for specimens with CR chondritic affinities and NWA 8054*

Collisional Disruption Model: The hypothesis that at least some carbonaceous chondrite parent bodies were much more heterogeneous than once supposed (first suggested by [7] with reference to the CV parent body) has been reinforced by discovery of additional achondritic lithologies (e.g., NWA 7822 [8]) plausibly related to CV chondrites, by the evidence for a core dynamo based on magnetic properties of Allende [9], and by thermal modeling studies [10]. Here we conclude that the CR parent body also was internally heterogeneous, and that portions of it included metasomatized chondrite protoliths, igneous intrusive plutons and even potentially a metallic core region.

A corollary of such a hypothesis is that the differentiated bodies probably are no longer intact, and likely have been disrupted by large collisions early in the history of the Solar System. The surviving fragments may now reside within the main asteroid belt, where they can more recently yield samples of diverse meteorites found on Earth, allowing us to perform the forensic analysis necessary to reconstruct the original parent bodies.

References: [1] Bunch T. et al. 2005 *Lunar Planet. Sci.* **XXXVI**, #2308; Bunch T. et al. 2008 *Lunar Planet. Sci.* **XXXIX**, #1391 [2] Sanborn M. et al. 2014 *This conference* [3] *Meteorit. Bulletin* **102** [4] Yamaguchi A. et al. 2002 *Science* **296**, 334-336; Floss C. et al. 2005 *MAPS* **40**, 343-360 [5] Schiller M. et al. 2010 *Geochim. Cosmochim. Acta* **74**, 4844-4864; Bouvier A. et al. 2011 *Geochim. Cosmochim. Acta* **75**, 5310-5323 [6] Rubin A. et al. 2002 *Geochim. Cosmochim. Acta* **66**, 3657-3671 [7] Irving A. et al. 2004 Abstract #P31C-02. *EOS, Trans. AGU* [8] Irving A. et al. 2013 *75th Meteorit. Soc. Mtg.*, #5269 [9] Carporzen L. et al. 2011 *PNAS* 108, 6386-6389 [10] Elkins-Tanton L. et al. 2011 *Earth Planet. Sci. Lett.* **305**, 1-10; Weiss B. and Elkins-Tanton L. 2013 *Ann. Rev. Earth Planet. Sci.* **41**, 21.1-21.32.