"PRIMITIVE" AND IGNEOUS ACHONDRITES RELATED TO THE LARGE AND DIFFERENTIATED CR PARENT BODY.

T. E. Bunch[1], A. J. Irving[2], T. E. Larson[3], F. J. Longstaffe[3], D. Rumble, III[4] and J. H. Wittke[1], [1]Dept. of Geology, Northern Arizona University, Flagstaff, AZ 86011 (tbear1@cableone.net), [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195, [3]Dept. of Earth Sciences, University of Western Ontario, London, ON N6A 5B7, [4]Geophysical Laboratory, Carnegie Institution, Washington, DC 20015.

Introduction: One of the more daunting tasks in meteoritics is to attempt the reconstruction of now disaggregated, potentially large planetary bodies that may have populated the early solar system. The remnants of these bodies, which may have been numerous [1], now consist of the present asteroids plus fragments that fall to Earth as meteorites. The increased bounty of research material, especially from Northwest Africa and Antarctica, has led to new hypotheses concerning the constitution, size and thermal regimes on these former objects. One recent proposal [2] addresses the recognition of candidate core, mantle and regolith materials from the CV parent body. Here we apply the same forensic principles to the putative CR parent body, and suggest that it may have been even larger and experienced igneous activity in a similar manner to proto-Vesta.

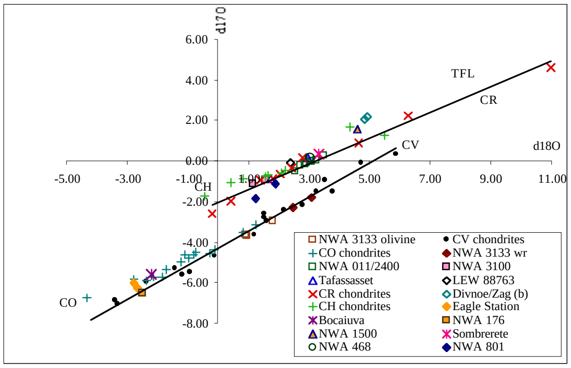
Petrology of "Primitive" Achondrite NWA 3100: This 136 gram slightly weathered stone purchased in Morocco in 2003 was initially considered to be an L7 chondrite, but the elevated Fe/Mn ratios of the mafic silicates and the relatively calcic composition of plagioclase suggested that it may not have affinities with ordinary chondrites. One thin section shows this sample to be quite fine grained and relatively equigranular (0.03 to 0.7 mm, mean 0.155 mm) with a metamorphic texture and ~120 triple junctions among constitutent grains (Figure 1). In a second thin section, two very small relict chondrules were observed. The major minerals are 78% olivine ($Fa_{28.7}$, FeO/MnO = 65.6), 10% orthopyroxene ($Fs_{23.5}Wo_{0.8}$, FeO/MnO = 48.8) and 5% plagioclase ($An_{34.1}Or_{3.1}$), with accessory diopside ($Fs_{12.8}Wo_{41}$, FeO/MnO = 29.2), troilite (4.2 wt.% Ni), metal (20.1 wt.% Ni), chromite (Cr/(Cr+Al) = 0.80, Mg/(Mg+Fe) = 0.21) and merrillite. Because carbonaceous chondrites have bulk ratios of Fe/Mn and Ca/Na considerably higher than for ordinary chondrites, this sample seemed like a candidate for further testing.

Oxygen Isotope Data: As part of an ongoing assessment of primitive achondrite specimens, the oxygen isotopic composition of NWA 3100 was measured in duplicate by laser fluorination at the

Figure 1. Plane-polarized light image of NWA 3100 showing the very fine grained, polygonal-granular texture (width of field = 5 mm).

University of Western Ontario ($\delta^{17}O$ = -0.92, -1.07; $\delta^{18}O$ = 1.54, 1.15; $\Delta^{17}O$ = -1.72, -1.66, per mil, respectively). Data were obtained also at the Geophysical Laboratory for CR2 chondrite NWA 801 ($\delta^{17}O$ = -1.84, -1.11; $\delta^{18}O$ = 1.24, 1.88; $\Delta^{17}O$ = -2.50, -2.10 per mil, respectively), and for igneous achondrite NWA 2400 ($\delta^{17}O$ = 0.30, 0.00; $\delta^{18}O$ = 3.48, 3.05; $\Delta^{17}O$ = -1.52, -1.61 per mil, respectively), a new 137 gram specimen paired with NWA 011.

Figure 2 shows that the oxygen isotopic composition of NWA 3100 falls very close to the best fit line for bulk CR chondrites (data mostly from [3]), as do the several measured isotopic compositions for NWA 011 and NWA 2400. The new data for NWA 801 also plot within the CR field, which probably is broadened by variable contributions from CAI. As previously noted by a number of workers [4], other meteorites with oxygen isotopic compositions plotting within the field for CR chondrites include the primitive achondrite LEW 88763, the equilibrated achondrite Tafassasset (which does contain relict chondrules), and the ungrouped silicated irons Sombrerete and NWA 468. The heterogeneous primitive achondrite NWA 1500 [5] also has an oxygen isotopic composition close to but distinctly above the CR trend, towards those of the ungrouped primitive achondrites Divnoe and Zag(b), and in fact within the field for winonaites.



CR Parent Body Building: In our previous work [2], we sought to assemble the CV parent body from materials including the silicated irons Bocaiuva and NWA 176, Eagle Station pallasite, primitive achondrite NWA 3133, and a CV3 chondrite regolith. Here we make the case for a CR parent body consisting of a silicated iron core (like Sombrerete and/or NWA 468), a mantle composed of material like LEW 88763, NWA 3100 and Tafassasset, and a partially hydrated CR2 to CR1 chondrite regolith. In addition (and perhaps in contrast to the CV parent body), the crust may have contained igneous differentiate masses composed of "gabbroic" rocks like NWA 011/2400. It should be emphasized that Sombrerete and NWA 468 are petrologically and geochemically different [6], despite their nearly identical oxygen isotopic compositions. Although LEW 88763 is very similar to CR chondrites in bulk composition [7], Zipfel et al. [4] have shown that Tafassasset is fractionated relative to CR chondrites. Among other samples that may be genetically related to these, we note that Yamato 74160 [8] has the same textural and mineral chemical traits.

The hydration evident in CR chondrites may have been a feature of the entire CR body, and perhaps may explain the existence of mafic igneous bodies produced by melting of hydrated mantle at cooler temperatures. Alternatively, the CR body may have been sufficiently large that radiogenic heating of even an anhydrous mantle could produce mafic magmas. Other evidence for a large body includes the relatively young ^{39}Ar-^{40}Ar age for Sombrerete (4.54 Ga), and the much younger, possibly impact-reset age for NWA 011 (3.15 Ga), despite its 4.46 Ga Sm-Nd formation age [9].

Concluding Remark: We suspect that there may be many "primitive" achondrites yet to be found with petrological attributes similar to known meteorite classes, but which have oxygen isotopic compositions that preclude their genetic connection with those classes. These specimens may well represent the remnants of now-disaggregated, differentiated planetary bodies from the early solar system that we may be able to at least partially reconstruct from fragmentary evidence.

Acknowledgement: We are very grateful to Adam and Greg Hupé for providing small samples of NWA 801, Tafassasset and Zag(b) for our studies.

References: [1] Wetherill G. W. (1992) *Icarus, 100*, 307; Chambers J. E. and Wetherill G. W. (2001) *MAPS, 36*, 381. [2] Irving A. J. et al. (2004) *EOS, 85*, #P31C-02. [3] Clayton R. N. and Mayeda T. K. (1999) *GCA 63*, 2089. [4] Clayton R. N. and Mayeda T. K. (1996) *GCA 60*, 1999; Swindle T. D. et al. (1998) *MAPS, 33*, 31-48; Bourot-Denise M. et al. (2002) *LPS XXXII*, #1611; Zipfel J. et al. (2002) *MAPS, 37*, A155; Nehru C. E. et al. (2003) *LPS XXXIV*, #1370; Promprated P. et al. (2003) *LPS XXXIV*, #1757. [5] Bartoschewitz R. et al. (2003) *MAPS, 38*, A64; Mittlefehldt D. W. and Hudon P. (2004) *MAPS, 39*, A69. [6] Grossman J. N. and Zipfel J. (2001) *Met. Bull. 85*, A268; Ruzicka A. and Hutson M. (2003) *MAPS, 38*, A129. [7] Kallemeyn G. W et al. (1994), *GCA, 58*, 2873. [8] Takeda H. et al. (1984) *EPSL, 71*, 329. [9] Bogard D. D. and Garrison D. H. (2000) *MAPS, 35*, A30; Korochantseva E. V. et al. (2003) *LPS XXXIV*, #1575; Nyquist L. E. et al. (2003) *MAPS, 38*, A59; Bogard D. D. and Garrison D. H. (2004) *LPS XXXV*, #1094.