SURVEY OF DOMINION RANGE (DOM) AND MILLER RANGE (MIL) CO3 CARBONACEOUS CHONDRITES: MAGNETIC SUSCEPTIBILITY AND TYPE II CHONDRULE OLIVINE Cr_2O_3 CONTENTS AND THEIR IMPLICATIONS FOR PAIRING. K. Righter[1], H. Busemann[2], L. M. Eckart[2], C. Alexander[3], J. Schutt[4], R. Harvey[4], and J. Karner[5], [1]Mailcode XI2, NASA Johnson Space Center, 2101 NASA Pkwy, Houston, TX, 77058, USA, [2]ETH Zürich, Inst. Geochem. Petrol, Clausiusstrasse 25, 8092 Zürich, Switzerland; [3]Earth and Planets Laboratory, Carnegie Institution for Science, 5241 Broad Branch Road, NW, Washington, DC 20015-1305; [4] EEPS, Case Western Reserve University, Cleveland, OH 44106; [5]Geology & Geophysics, University of Utah, Salt Lake City UT 84112.

Introduction: Primitive carbonaceous chondrites contain the oldest solids known in the solar system, ancient chondrules and metal grains, organic compounds that may have contributed to the origin of life, and presolar grains that inform nucleosynthetic processes. Identification of primitive materials is thus of broad interest to the science community. Ten CO3 chondrites have been recovered in the Dominion Range (DOM) dense collection area (DCA) of the Transantarctic Mountains by ANSMET (Antarctic Search for Meteorites) teams during the 2018-19 and 2019-20 seasons [1-2], and may be paired with 14 others previously recognized as part of a DOM CO3 pairing group [3]. In addition, >200 CO3 chondrites have been recovered in the Miller Range (MIL) DCA of the Transantarctic Mountains by ANSMET teams in 2005-06, 2007-08, 2009-10, 2011-12, 2013-14, 2015-16 field seasons (e.g., [4,5]). Both areas have yielded very primitive CO3 meteorites (e.g., [6,7]), yet the pairing within the two DCAs, and thus the total amount of primitive materials, remains uncertain. Because of the significant masses involved and huge community interest in the most primitive samples of all carbonaceous chondrite classes such as the CO3, we have undertaken a detailed assessment of the pairing and petrologic type using field relations, macroscopic observations, petrography, olivine compositions, and bulk H, C, N and noble gas abundances and isotopes.

Samples and approach: We examined NASA-JSC library thin sections of DOM samples 18019, 18069, 18070, 18286, 19034, 19049, 19068, 19099, 19170, 19179, and MIL samples 07182, 07193, 090038, 090073, and 090785. Using the approach of [8], we measured the Cr contents of olivine in type II FeO-rich chondrules. In addition to the olivine analyses, we also examined the field photos, labs photos for macroscopic appearance, and modal mineralogy in thin section.

Experimental methods: Large sample splits (>5 g) were measured for magnetic susceptibility using a H Instruments SM30 magnetic susceptibility meter. Electron microprobe analyses were obtained using the Cameca SX100 electron microprobe at NASA Johnson Space Center. Standards employed were Marjalahti pallasite olivine (Mg, Si), chromite (Cr), rhodonite (Mn), K411 natural glass (Ca, Fe), and albite (Al). Analytical conditions include 15 kV accelerating voltage and 20 nA sample current. Because Type II chondrules are relatively rare in CO3 chondrites, we examined both full chondrules and individual olivine grains or fragments that are related to the FeO-rich chondrules, to increase the number of sample analyzed and thus the population statistics for the measurements. Standard deviations in Cr contents were calculated and used to assess the petrologic type (3.0-3.2) for each DOM sample [8].

The bulk H, C and N abundances were determined by elemental analyzer-isotopic ratio mass spectrometer (EA-IRMS) as described in [9]. Noble gas analyses were performed at ETH Zurich following the procedures described by [10] and data reduction and age determinations following approaches of [11, 12]. T21 age refers to cosmic ray exposure (CRE) age determined using ^{21}Ne.

Results: DOM 18070 and 18019 both have high average Cr contents (0.36 wt%) and relatively low σ-Cr_2O_3 (0.08–0.11 wt%) (**Figure 1)**. On the other hand, DOM 18069, 19049, 19068, 19099, 19170, and 19179 all have intermediate Cr_2O_3 contents and higher σ-Cr_2O_3. DOM 18286 and 19034 have relatively low Cr_2O_3 contents (<0.10 wt%). Among the MIL samples analyzed, MIL 07182, 07193, 090038, and 090785 all have Cr_2O_3 contents of 0.25 to 0.29 wt%, similar to many other MIL CO3 samples [3]. MIL 090073 on the other hand, has higher Cr_2O_3 contents of 0.36 wt% (and relatively low σ-Cr_2O_3 of 0.10).

The magnetic susceptibilities for all DOM CO3 samples analyzed here correlate with their type II olivine Cr contents, with the most primitive CO3s (3.00) having values near 5 (**Figure 2**).

Bulk H and N contents and isotopic values for the DOM and MIL fields overlap significantly with H ranging from 0.25 to 0.5 wt%, δD from 0 to -130 per mil, N from 0.01 to 0.10 wt%, $\delta^{15}N$ from -15 to +10 per mil. Bulk C contents range from 0.3 to 1.2 wt%, and $\delta^{13}C$ from -13 to -4; however, the MIL and DOM samples do not overlap and instead form distinct groupings (**Figure 3**).

Discussion: DOM 18286 and 19034 both exhibit low Cr_2O_3 contents, suggestive of petrologic grades >3.2. The high Cr_2O_3 contents of Type II olivine in DOM 18070 and 18019 indicate that they might be as

primitive as DOM 08006 (CO3.00). All other DOM18 and DOM19 CO3s are consistent with petrologic type 3.10 or 3.15. MIL 090073 might be more primitive than other MIL samples, has a younger CRE age [3] (**Figure 4**), low natural TL values [13], and has been suggested to be a CM [9]. MIL 090785 has similar olivine compositions to the main group of MIL CO3s but has a very young CRE age [3] that may be attributed to its highly weathered nature [9]. All other MIL CO3 samples analyzed here are consistent with petrologic types 3.10 or 3.15.

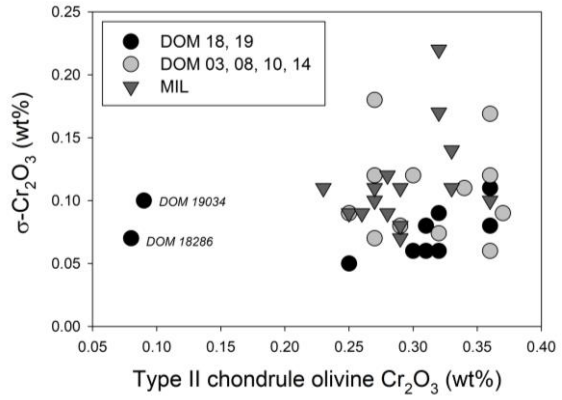

Figure 1: Summary of Cr_2O_3 analyses and σCr_2O_3 values for olivine in Type II chondrules in DOM and MIL CO3 chondrites from this work and from [3].

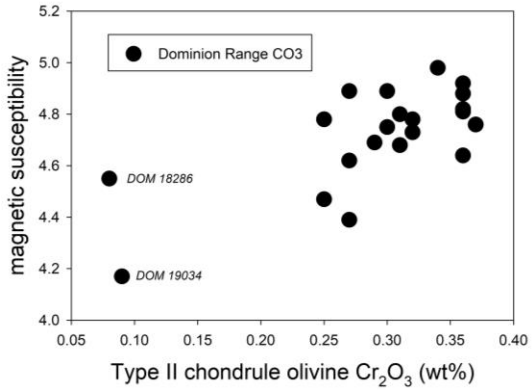

Figure 2: Magnetic susceptibility versus olivine Cr content for all DOM CO3 samples (2003, 2008, 2010, 2014, 2018, 2019 seasons).

Conclusion: If the main DOM CO3 chondrite pairing group members are from the same fall, which seems likely based on CRE age between 10-12 Ma, recovery location, field appearance, and petrography, there is a range of metamorphic grade represented within the members of the group from 3.05 to 3.15. Additionally, the similarity of CRE ages among the MIL and DOM groups suggests that they are derived from the same CO3 parent body impact but fell at distinct times and locations. However, their distinct C and d13C values would have to be caused by terrestrial weathering. Assessment of terrestrial ages and isotopic effects of weathering would add to this story!

References: [1] Satterwhite, C. and Righter, K. (2009) Antarctic Meteorite Newsletter (AMN), https://curator.jsc.nasa.gov/antmet/amn/amn.cfm#n322 , 32, no. 2; [2] Satterwhite, C. and Righter, K. (2011) AMN 34, no. 2; [3] Righter, K., et al. (2021) 84th *Ann. Met. Soc.*, abstr. #6191; [4] Satterwhite, C. and Righter, K. (2011) AMN 33, no. 1; [5] Satterwhite, C. and Righter, K. (2009) AMN 34, no. 1; [6] Davidson, J., et al. (2019) *GCA* 265, 259-278; [7] Simon, J.I. et al. (2019) *Astro. Jour. Lett.* 884, L29; [8] Grossman, J.N., Brearley, A.J. (2005) *MaPS* 40, 87-122; [9] Alexander, C. et al. (2018) GCA 221, 406-420; [10] Riebe M.E.I., et al. (2017) *MaPS* 52, 2353–2374 [11] Krietsch, D., et al. (2021) GCA, 310, 240-280; [12] Mertens, C.A.K., et al. (2021) 52nd LPSC, abstr. #2098; [13] Sears, D.W. (2016) GCA 188, 106-124.

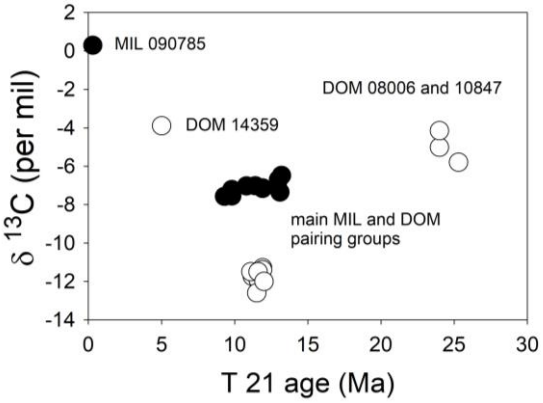

Figure 3: $\delta^{13}C$ and T21 ages for DOM and MIL CO3, showing distinct C bulk and isotopic groupings of MIL and DOM, while H and N bulk and isotopic overlap.

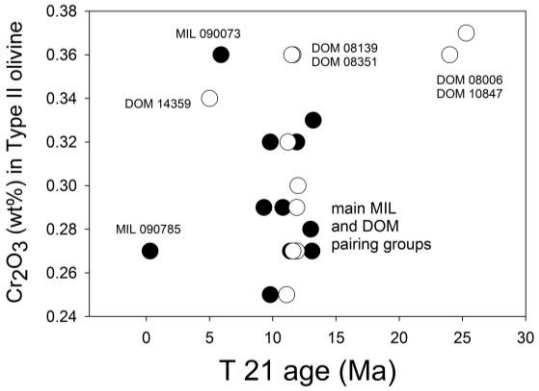

Figure 4: Olivine Cr_2O_3 and T21 CRE age for MIL (solid circles) and DOM (open circles) CO3s. Six samples have high Cr_2O_3 contents and also exhibit a range of ages: DOM 08006/10847 at ~25 Ma, DOM 08139/08351 at ~11 Ma, DOM 14359 at ~5 Ma, and MIL 090073 at ~6 Ma. The main MIL and DOM groups have similar ages of 10-12 Ma. MIL 090785 has a very low CRE of 0.3 Ma.