COSMIC RAY EXPOSURE AGES, BULK AND ISOTOPIC H, C, AND N COMPOSITIONS OF DOMINION RANGE (DOM) CO3 CARBONACEOUS CHONDRITES AND IMPLICATIONS FOR PAIRING. K. Righter[1], H. Busemann[2], L. M. Eckart[2], C. Alexander[3], D. Foustoukos[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: Over 20 CO3 chondrites have been recovered in the Dominion Range (DOM) dense collection area (DCA) of the Transantarctic Mountains by ANSMET (Antarctic Search for Meteorites) across 6 field seasons (e.g., [1,2]). Because of the significant masses involved and huge community interest in the most primitive samples of all carbonaceous chondrite classes such as the CO3s, we have undertaken a detailed assessment of the pairings and petrologic types using field relations, macroscopic observations, petrography, olivine compositions, and bulk and isotopic H, C, N compositions, and noble gas abundances and isotopes for cosmic ray exposure (CRE) ages, for all specimens (e.g., [3,4]). Most recently, teams during the 2018-19 and 2019-20 seasons recovered 10 new CO3 samples [5] (**Figure 1**). Here we report new H, C, and N bulk and isotopic data, as well as CRE ages, for these 10 samples and DOM 10900 (which has some unique properties and may not be a CO chondrite). This completes the characterization of all known CO3s from DOM, allowing a thorough assessment of possible pairing relations.

Samples and approach: We studied small aliquots of DOM samples 10900, 18019, 18069, 18070, 18286, 19034, 19049, 19068, 19099, 19170, and 19179. Subsplits of each meteorite were derived for each technique as described below. Using the approach of [6], and thin sections available at NASA-JSC, we previously measured the Cr contents of olivine in type II FeO-rich chondrules [4,5] to help estimate the petrologic type. In addition to the geochemical and olivine analyses, we examined the field and lab photos for macroscopic appearance. DOM CO3s have been recovered from both blue ice and moraine settings and exhibit a wide range of appearances. Samples recovered in moraines are typically more battered and worn, with less fusion crust preserved (e.g., DOM 14359) and more interior showing, resulting in more of the CO3s from moraines being identified in the field as "carbonaceous". In comparison, many blue ice CO3 recoveries were not identified as "carbonaceous" and instead were noted as "OC" because the extensively fusion-crusted and weathered stones looked more similar to ordinary chondrites. There are exceptions to the above observations, such as DOM 10900 which was recovered from blue ice and most of its fusion crust is gone. This distinct appearance may be an indicator of uniqueness, also supported by its compositional and isotopic composition (see below).

Experimental methods: Noble gas measurements were conducted at ETH Zurich on aliquots of ~20-25 mg from the 11 samples. The gas extraction occurred in one temperature step at ~1700 °C, followed by cryogenic separation into three fractions, He-Ne, Ar, and Kr-Xe, measured successively in a custom-built mass spectrometer. For some samples, complete gas extraction was verified by a re-extraction step at ~1750 °C. Details on the sample preparation and measurement protocols can be found in [7], and data reduction and age determinations followed the approaches of [8,9].

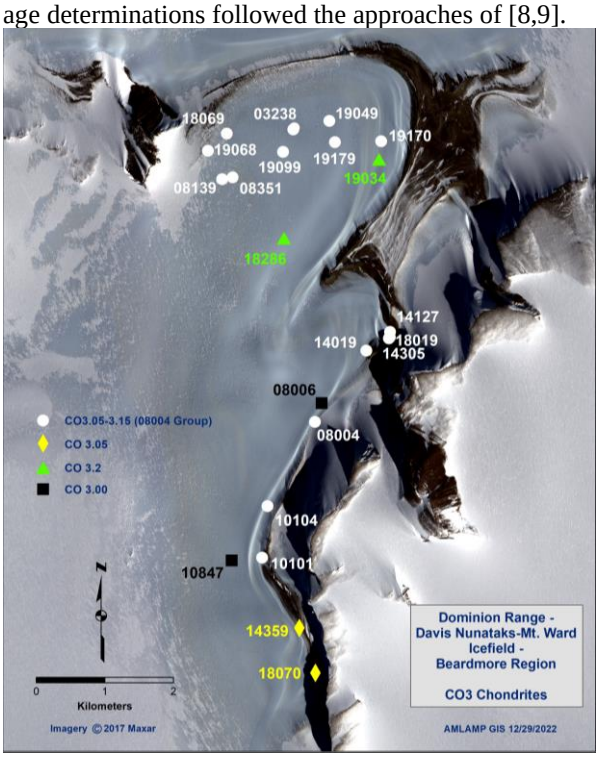

Figure 1: *Map of CO3s from the DOM DCA showing the pairing groups. Worldview 2 image – 19 January 2017 (Copyright 2017 Maxar). All Maxar Worldview satellite imagery was acquired through Polar Geospatial Center. Support for this work was provided by the Polar Geospatial Center under NSF-OPP awards 1043681 and 1559691).*

The T21 age refers to the cosmic ray exposure (CRE) age determined using cosmogenic ^{21}Ne. Bulk H, C and

N abundances were determined by elemental analyzer-isotopic ratio mass spectrometer (EA-IRMS) [10].

Results: Most of the DOM 18 and DOM 19 CO3s have H, C, N bulk compositions and isotopic values and CRE ages that are the same or similar to the large DOM 08004 pairing group (**Figures 2 and 3**). This large group – now totaling 16 samples - also has type II chondrule olivines with relatively high Cr contents representing a range of metamorphic grades from 3.05 to 3.15 (**Figure 3**). There are several other samples that are exceptional. DOM 18070 has an exposure age near 7 Ma; despite similarity in CRE age, H, C, N values, find location (Fig. 1) and petrologic type, the noble gas composition of DOM 14359 is distinct suggesting they are not paired. DOM 19034 has a CRE age of ~3 Ma, much lower H, C, and N than other CO3s, and type II chondrule olivine with very low Cr contents (< 0.1) consistent with petrologic types ≥ 3.2. DOM 18286 has a very large CRE age of ~82 Ma (not shown in Fig. 3), that may be the highest CRE age ever reported for carbonaceous chondrites. Like DOM 19034, it also has much lower H, C, and N than other CO3s, and type II chondrule olivine with very low Cr contents (< 0.1) consistent with petrologic types ≥ 3.2.

Discussion: Altogether there appear to be at least five distinct groups of CO3s recovered at the Dominion Range: (a) the main DOM 08004 pairing group (16 specimens with a CRE age near 12 Ma), (b) the DOM 08006 group (2 specimens incl. DOM 10847 near 25 Ma), (c) DOM 14359 and DOM 18070 with CRE ages of 5 and 7 Ma, (d) DOM 18286 (CRE age ~82 Ma), and (e) DOM 19034 (CRE age ~ 3 Ma). Magnetic susceptibilities for all DOM CO3 samples correlate with their type II olivine Cr contents, with the most primitive CO3s (3.00) having logχ values near 5, while the higher grade CO3s having logχ values as low as 4.17.

DOM 10900 has anomalous properties for a CO, and it might instead be a CM. Its CRE age of 2.7 Ma is similar to two other DOM CM samples originally classified as CO3s – DOM 10299 and DOM 10121 (2.5 Ma; [3]). It also has a distinct appearance with little fusion crust and a greater friability that is not observed in other DOM CO3s. DOM 10900 has higher but somewhat variable bulk H and C contents and distinct isotopic values from the DOM CO3 samples. Finally, the thermoluminescence data [11] show that DOM 10121, 10299 and 10900 have young terrestrial ages of ~100 ka, also consistent with these three being CMs.

Interestingly, the CRE ages for the large DOM 08004 pairing group and many Miller Range (MIL, a DCA ~200 km to the north) CO3 chondrites are all near 10-12 Ma. Furthermore, thermoluminescence data [11] concluded that 29 MIL CO3 samples have the same terrestrial age as DOM 10104 and DOM 08139 of ~300-600 ka. Although these two areas seem distant to be part of a single fall (e.g., [12]), they are still shorter than the largest strewnfield found to date (400 km; [13]). If they are part of the same fall their distinct C and $\delta^{13}C$ values would have to be caused by terrestrial weathering. Alternatively, the similarity of CRE ages between the MIL and DOM CO3 groups could indicate they were derived from the same impact but delivered to Earth at distinct times and locations.

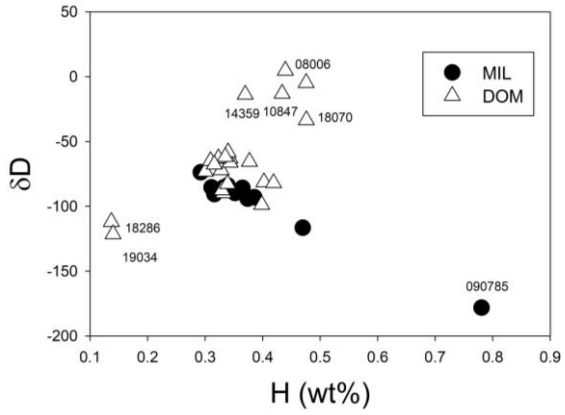

Figure 2: *Hydrogen and δD values for the DOM and MIL CO3 chondrites.*

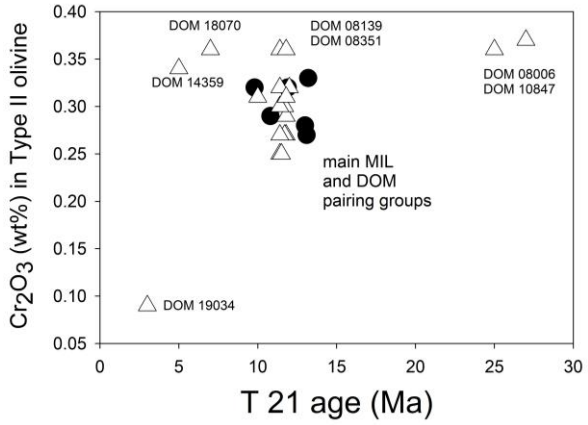

Figure 3: *Cr_2O_3 (wt%) in type II chondrule olivine versus T21 ages for DOM and MIL CO3 chondrites.*

References: [1] Satterwhite, C. and Righter, K. (2009) *Antarctic Meteorite Newsletter (AMN)* 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] Righter, K. et al. (2019) *82nd Ann. Met. Soc.*, abstr.#6423. [5] Righter, K. et al. (2022) 53rd *LPSC*, abstr.#2414. [6] Grossman, J.N., Brearley, A.J. (2005) *MaPS* 40, 87-122; [7] Riebe M.E.I., et al. (2017) *MaPS* 52, 2353–2374 [8] Krietsch, D., et al. (2021) *GCA*, 310, 240-280; [9] Mertens, C.A.K., et al. (2021) *52nd LPSC*, abstr.#2098; [10] Alexander, C. et al. (2018) *GCA* 221, 406-420; [11] Sears, D.W. (2016) *GCA* 188, 106-124.; [12] Righter, K. et al. (2021) *MaPS* 56, 1556-1573; [13] Li, Y. (2022) Sci. Adv. 8, eabm8890.