

CHEMICAL CLASSIFICATION AND EXAMINATION OF METAMORPHIC PROCESSES IN FIVE ANTARCTIC CARBONACEOUS CHONDRITES. G. M. Moriarty^{1,2}, D. Rumble III³, and J. M. Friedrich^{2,4}, ¹Queens College, The City University of New York, 65-30 Kissena Boulevard, Flushing, NY 11367, ²Department of Earth and Planetary Sciences, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024, ³Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road NW, Washington DC 20015 (e-mail: rumble@gl.ciw.edu), ⁴Department of Chemistry, Fordham University, Bronx, NY 10458 (e-mail: friedrich@fordham.edu).

Introduction: There are distinctive chemical differences that delineate groups of carbonaceous chondrites. Trace elemental analysis is a useful tool for identifying chemical affinities and results can be used to draw inferences about post-accretionary parent body processes, such as the thermal metamorphism and aqueous alteration chondrites may have experienced. In this study, we used Inductively Coupled Plasma Mass Spectrometry (ICPMS) to perform trace elemental analysis of five Antarctic carbonaceous chondrites: Wisconsin Range (WIS) 91600, LaPaz Icefield (LAP) 02206, Elephant Moraine (EET) 96010, Meteorite Hills (MET) 01070 and LAP 02277 to examine the processes which may have altered these materials. We compare our data to previously analyzed samples [1].

Oxygen isotope data can also be used to identify chemical group affinities and can reveal valuable information on the evolutionary histories of chondrites. To further help classify three of our samples, we collected oxygen isotope data on aliquots of LAP 02206, MET 01070 and LAP 02206. We compare our data with that from [2,3].

Materials and Methods: We obtained the five Antarctic carbonaceous chondrites WIS 91600, LAP 02206, EET 96010, MET 01070 and LAP 02277 from the NASA JSC Meteorite Working Group. We completely dissolved the samples with established techniques so as to ensure chemically representative analyses and quantified 41 trace elements by ICPMS using a VG PQ2+ instrument at the Lamont Doherty Earth Observatory, Columbia University, using the methods outlined in [1 and 4]. We performed two replicate digestions and at least two duplicate measurements for each sample, standard and blank aliquot. We used the established oxygen isotope procedure of [5].

Results and Discussion:

LAP 02206. On both trace element (Fig. 1) and oxygen isotope (Fig. 2) basis LAP 02206 proves to be a CV chondrite. A CI normalized plot of LAP 02206 exhibits a hint of Group II REE pattern [6] coupled with a slight Y-poor nature. This indicates an inhomogeneous and refractory-rich bias in our allotted sample and accounts for the slight offset from the other CV in our comparison suite (Fig. 1).

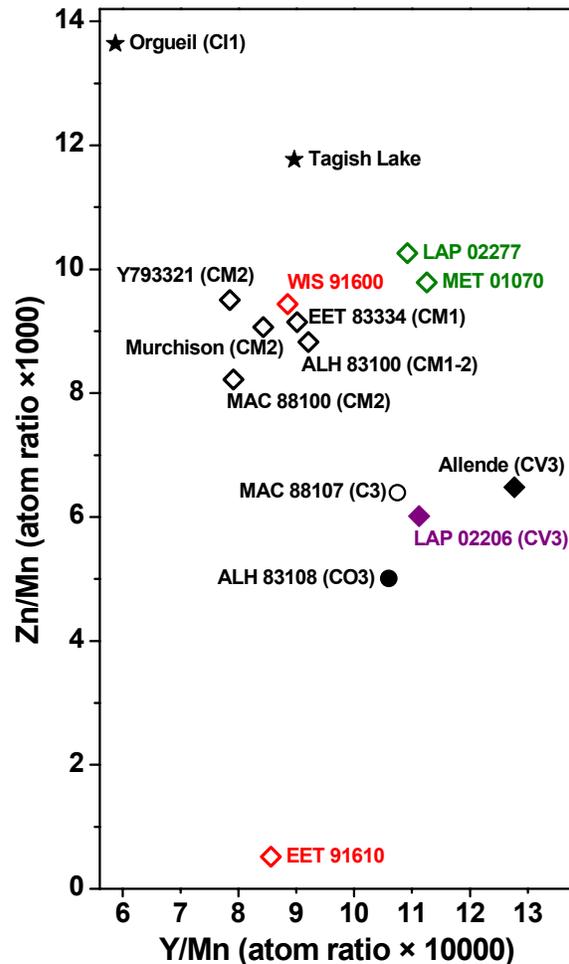


Figure 1. Zn/Mn vs. Y/Mn atomic-basis ratios for carbonaceous chondrites in this study compared with previous data [1]. LAP 02206 shows a clear affiliation with the CV chemical class. Hydrated and heated (B-7904 like) WIS 91600 and EET 91610 reveal a CM chemical relationship notwithstanding their unusual thermal histories. The location of EET 91610 is due to the open-system thermally labile element (e.g. Zn) loss, but refractory/moderately volatile (Y/Mn) ratios remain firmly within the CM range. Aqueously-altered [14-16] LAP 02277 and MET 01070 seem at least CM-related, but are outliers from the main group of previously analyzed CM chondrites.

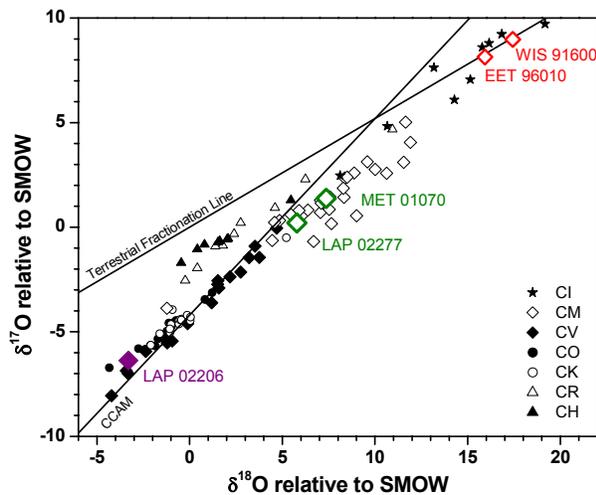


Figure 2. LAP 02206, LAP 02277, and MET 01070 bulk oxygen isotope results (this work) compared with previous data [2,3]. The CV classification of LAP 02206 is confirmed. LAP 02277 and MET 01070 show a clear relationship with the CM group with respect to their oxygen isotope abundances, with no evidence of extensive hydration or thermal metamorphism. WIS 91600 and EET 96010 data [3] show the oxygen isotope signatures indicative of extensive hydration.

EET 96010. EET 96010 was previously shown to have been thermally metamorphosed [7,8,9]. Petrographic evidence of heating lies in the fusion of chondrule and matrix and the presence of recrystallized olivine grains [9]. Previous investigations of the trace element chemistry of this sample suggests that it experienced open-system heating reaching 600-700°C because of loss of the thermally labile elements Cd, Tl, Bi, In and Zn [7]. Our data confirms this as we see that EET 96010 has been noticeably depleted in the most volatile elements in our analytical suite (Zn, Sn, and Bi). Oxygen isotopes of EET 96010 [3] do not place it with CV chondrites, but suggest extensive hydration and subsequent heating [3,9]. Much like B-7904, the EET 96010 precursor seems to be chemically related to the CM chondrites [10].

WIS 91600. Like EET 96010, WIS 91600 was previously shown to have been thermally metamorphosed [7,8,11,12]. While EET 96010 was depleted in many thermally labile elements, WIS 91600 was only depleted in most labile Cd, suggesting it was only heated to 400-500°C [7]. Our data again confirms a milder heating as it is more volatile-rich than EET 96010. Fig. 1 shows WIS 91600's CM chondrite chemical affinity and Fig. 2 shows its relation to the B-7904 group.

LAP 02277 and MET 01070. The CM chondrites are known to exhibit a range of aqueous alteration [13]. The mineralogy and petrology of LAP 02277 and MET 01070 strongly suggest that they experienced extreme episodes of aqueous alteration: [14-16] demonstrated that LAP 02277 is likely among the most extensively hydrated CM chondrites known. MET 01070 was shown to contain a lens of poorly characterized mineral phases thought to have formed by the precipitation of minerals from a water rich fluid [16]. Our trace element data strongly suggest that these two chondrites are genetically related. In Fig. 1 we note that LAP 02277 and MET 01070 lie in a distinct region slightly removed from other CM chondrites. The elements in Fig. 1 illustrate the slight differences of LAP 02277 and MET 01070 from the main CM chondrite group: on average, LAP 02277 and MET 01070 have slightly lower lithophile abundances, as well as a more significant depletion in the moderately volatile elements as compared to previously studied CM chondrites [e.g. 1]. This suggests that their depletion (or degree of enrichment) of volatiles was different than CM chondrites and that they are genetically dissimilar from the CM chondrites. Oxygen isotope data places these samples among other CM-chondrites, as seen in Fig. 2. Taken together, our results suggest that the chemical diversity of CM-like material throughout the solar system is broader than previously anticipated.

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