OXYGEN ISOTOPE EVIDENCE FOR THE RELATIONSHIP BETWEEN CM AND CO CHONDRITES: COULD THEY BOTH COEXIST ON A SINGLE ASTEROID? R. C. Greenwood[1], K. T. Howard[2], I.A. Franchi[1] , M. E. Zolensky[3], P. C. Buchanan[4] and J. M. Gibson[1], [1]Planetary and Space Sciences, The Open University, Milton Keynes MK7 6AA, UK (r.c.greenwood@open.ac.uk). [2]American Museum of Natural History, [3]ARES, Johnson Space Center, Houston TX, USA.[4]Kilgore College, Kilgore, Texas 75662 USA.

Introduction: Water played a critical role in the early evolution of asteroids and planets, as well as being an essential ingredient for life on Earth. However, despite its importance, the source of water in the inner solar system remains controversial. Delivery of water to Earth via comets is inconsistent with their relatively elevated D/H ratios, whereas carbonaceous chondrites (CCs) have more terrestrial-like D/H ratios [1].

Of the eight groups into which the CCs are divided, only three (CI, CM, CR) show evidence of extensive aqueous alteration. Of these, the CMs form the single most important group, representing 34% of all CC falls and a similar percentage of finds (Met. Bull. Database). CM material also dominates the population of CC clasts in extraterrestrial samples [2, 3]. The Antarctic micrometeorites population is also dominated by CM and CI-like material and similar particles may have transported water and volatiles to the early Earth [4].

CCs, and CMs in particular, offer the best opportunity for investigating the evolution of water reservoirs in the early solar system. An important aspect of this problem involves identifying the anhydrous silicate component which co-accreted with ice in the CM parent body. A genetic relationship between the essentially anhydrous CO group and the CMs was proposed on the basis of oxygen isotope evidence [5]. However, previous CM whole-rock oxygen isotope data scattered about a line of approximately 0.5 that did not intersect the field of CO chondrites [5]. Here we discuss new oxygen isotope data which provides additional constraints on the relationship between CO and CM chondrites.

Analytical methods: Oxygen isotope analysis was performed by infrared laser-assisted fluorination [6]. All analyses were obtained on untreated whole rock samples (0.5-2 mg). A minimum of two replicates were analyzed per sample. System precision, as determined on an internal obsidian standard is: ±0.05‰ for $\delta^{17}O$; ±0.09‰ for $\delta^{18}O$; ±0.02‰ for $\Delta^{17}O$ (2σ).

Fluorination of CM samples: CM chondrites can be challenging samples to analyze by laser fluorination, as they consist of a mixture of phyllosilicates and anhydrous minerals. The main problem is that the hydrated minerals react with BrF_5 at room temperature. As a result, once an aliquot of BrF_5 is introduced into the fluorination chamber a proportion of the ^{18}O-rich component within the CM sample is removed. Our normal procedure for running samples is to load a tray containing 22 wells with 16 samples and 6 standards [6]. However, at an early stage in this project it was discovered that there was a tendancy for successive CM samples in a tray to become progressively ^{16}O-enriched as each fresh aliquot of BrF_5 effectively leached out more of the ^{18}O-rich phyllosilicate component. In order to overcome this problem later CM samples were run as "single shots" with just one CM aliquot and one standard per tray. A second problem with running hydrated samples is that rapid release of gas during laser heating can cause material to be partially ejected from the sample well. This results in a deceased yield and hence fractionated results. To overcome this problem a modified sample tray was designed with an internal BaF_2 window placed over the well with the CM sample.

Results: Analyses for 17 CM chondrites are plotted in Fig.1. The points plotted are whenever possible those that were run as "single shots" and analyses with low yields have been excluded. The CM analyses in Fig. 1 define a linear trend with a slope of 0.70 and a y axis intersection of -3.69 (R^2=0.87). This regression line intersects the field occupied by analyses of CO3 chondrites [7]. A possible genetic relationship between the CO and CM group was proposed by Clayton and Mayeda [5] despite the fact that their CM data scattered about a line of slope 0.5 that did not intersect the CO field. Their CM data contained a large number of Antarctic finds which may have been subject to terrestrial alteration. Further support for a link between the COs and CMs comes from the fact that anhydrous mineral separates from Murchison plot close to the CO3 field (Fig. 1) [5].

Unlike other CC groups the six known CO3 falls show extremely limited oxygen isotope variation (Fig. 3) [7]. The fact that the regression line for our new CM data intersects the field of CO3 chondrites appears to provide additional support for a close relationship between these two groups.

In course of refining our analytical protocols for CM-like material we undertook a large number of analyses of individual meteorites which have been excluded from the dataset plotted in Fig. 1 on the basis that they had experienced some "BrF_5 leaching". For individual meteorites used in these tests, the results plot along well definded mixing lines that intersect the

CO3 field. The well-defined linear regression lines that can be plotted through the data for individual CMs provides support for the view that theses meteorites can be modeled as a two component mixture of phyllo-sililicates and high-temperature phases [5]. A similar relationship was seen for the Paris meteorite [8].

A single CO-CM asteroid? It has long been known that the high temperature phases (chondrules, CAIs, AOAs, etc) in CO3 and CMs show many similarities in texture and composition, such that the two groups are often regarded as forming a clan [9]. However, the oxygen isotope data presented here suggests that the relationship between the two groups may be stronger than previously envisaged. In terms of their oxygen isotope composition our new data suggests that the CO3s are essentially identical to the anhydrous precursor material to CMs. If this is correct is it possible that both groups could coexist on a single asteroid or are they both derived from distinct parent bodies.

One argument against a single asteroid scenario is the fact that there is a clear compositional break between the two groups in Fig. 1. If both were from a single asteroidal source transitional material ought to be present and yet none seems to be sampled in the meteorite record.

However this evidence may be less persuasive than it appears at first sight. The gap in oxygen isotope compositions between COs and CMs may be telling us something fundamental about the structure of carbonaceous chondrite parent bodies. If the COs and CMs did co-accrete into a single parent body the precursor material to both presumably contained water. As the core of such an asteroid heated up fluid would have been expelled outwards rapidly leaving an essentially anhydrous and hydrothermally unaltered core [10]. The outer hydrous zone may have experienced prolonged aqueous alteration with the transition between the two zones being sharp, hence the lack of any intermediate material. In such a scenario the COs would sample the anhydrous core and the CMs the outer aqueous altered material. CM-like material appears to be rather ubiquitous in the early Solar System [2] and may be common end product for many parent bodies that accreted beyond the nominal snow line. While it maybe that most of the CM2 meteorites originate from a single parent body in near Earth orbit [11] it is likely that other sources of such typical material may also be contributing to the flux of CM2-like material that are difficult to identify within the CM2 population.

Conclusions: New oxygen isotope data provides additional evidence in favour of a genetic link between the CO and CM chondrites. The two groups are likely to have formed from essentially the same precursor material. They may then have evolved within distinct asteroids, either water-rich (CMs) or water-poor (COs). Alternatively, it is possible that both could co-exist within a single composite asteroid. This latter possibility needs to be evaluated further by modeling studies.

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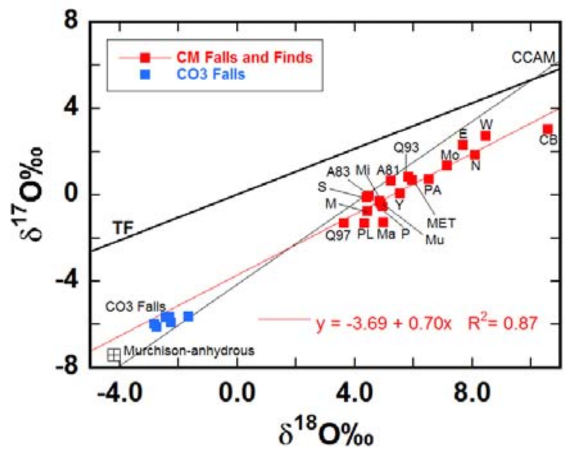

Fig. 1 Oxygen isotope composition of CM and CO chondrites. Symbols: A81:ALHA81002; A83:ALH 83100; CB:Cold Bokkeveld; E:Essebi; Ma: Maribo; MET: MET 01070; MI: Mighei; Mo: Moapa; M: Murchison; Mu: Murray; N: Nygoya; P: Paris (mean); PA: Paris altered; PL: Paris less atered; S: SCO 06043; Q93: QUE93005; Q97: QUE97990 Y: Y791198; W: WIS 91600. CO3 falls [7] plus Moss (unpublished data).