



A mutli-technique search for the most primitive CO chondrites

C.M.O'D. Alexander^{a,*}, R.C. Greenwood^b, R. Bowden^c, J.M. Gibson^b,
K.T. Howard^d, I.A. Franchi^b

^a Dept. Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington DC 20015, USA

^b Planetary and Space Sciences, Department of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK

^c Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, NW, Washington DC 20015, USA

^d Physical Sciences Department, Kingsborough Community College, City University of New York, 2001 Oriental Blvd., Brooklyn, New York, NY 11235, USA

Received 9 December 2016; accepted in revised form 14 April 2017; available online xxxx

Abstract

As part of a study to identify the most primitive COs and to look for weakly altered CMs amongst the COs, we have conducted a multi-technique study of 16 Antarctic meteorites that had been classified as primitive COs. For this study, we have determined: (1) the bulk H, C and N abundances and isotopes, (2) bulk O isotopic compositions, (3) bulk modal mineralogies, and (4) for some selected samples the abundances and compositions of their insoluble organic matter (IOM). Two of the 16 meteorites do appear to be CMs – BUC 10943 seems to be a fairly typical CM, while MIL 090073 has probably been heated. Of the COs, DOM 08006 appears to be the most primitive CO identified to date and is quite distinct from the other members of its pairing group. The other COs fall into two groups that are less primitive than DOM 08006 and ALH 77307, the previously most primitive CO. The first group is composed of members of the DOM 08004 pairing group, except DOM 08006. The second group is composed of meteorites belonging to the MIL 03377 and MIL 07099 pairing groups. These two pairing groups should probably be combined. There is a dichotomy in the bulk O isotopes between the primitive (all Antarctic finds) and the more metamorphosed COs (mostly falls). This dichotomy can only partly be explained by the terrestrial weathering experienced by the primitive Antarctic samples. It seems that the more equilibrated samples interacted to a greater extent with ¹⁶O-poor material, probably water, than the more primitive meteorites.

© 2017 Elsevier Ltd. All rights reserved.

Keywords: Chondrites; Oxygen isotopes; Carbon isotopes; Hydrogen isotopes

1. INTRODUCTION

Primitive COs are of considerable interest for a number of reasons. For instance, they can preserve in their matrices some of the highest abundances of presolar silicates observed in any chondrites (Nguyen et al., 2007, 2010). This is presumably because they experienced low degrees of both metamorphism and aqueous alteration. The study of the

most primitive matrices in chondrites, including in COs, will help determine how variable matrix is between chondrite groups, and how closely related it is to IDPs and cometary material, such as that from comet Wild 2. Metamorphism and aqueous alteration may have modified chondrule components, particularly glass compositions, complicating the interpretation of the apparent Al-Mg chondrule ages (Alexander, 2005; Alexander and Ebel, 2012). Identification of the most primitive COs will minimize the possibility that the internal isotope systematics of chondrules have been disturbed, although care will still have to be taken to only select the most pristine chondrules

* Corresponding author.

E-mail address: calexander@carnegiescience.edu (C.M.O'D. Alexander).

<http://dx.doi.org/10.1016/j.gca.2017.04.021>

0016-7037/© 2017 Elsevier Ltd. All rights reserved.

(e.g., Ushikubo et al., 2013). Ungrouped meteorites, such as Acfer 094, that have many affinities to the COs, also contain high abundances of presolar grains (Nguyen and Zinner, 2004; Vollmer et al., 2009), as well as unusual components, such as the so-called cosmic symplectite (Sakamoto et al., 2007; Seto et al., 2008) that may hold clues to the origin of water and non-solar O isotopes in the inner Solar System. The discovery of very primitive COs would also help to determine whether the COs and other chondrite groups accreted insoluble organic matter (IOM) that was similar to the IOM in CRs (Alexander et al., 2007), or whether the IOM accreted by each chondrite group varied as a result of changing nebular conditions. Finally, it is possible that relatively unaltered CMs like Paris (Hewins et al., 2014) that contain abundant metal could have been misclassified as COs.

As well as being of interest in its own right, IOM is a sensitive indicator of metamorphism, with IOM becoming less abundant and more 'graphitic' with increasing metamorphism (Quirico et al., 2003; Alexander et al., 2007; Bonal et al., 2007; Busemann et al., 2007; Cody et al., 2008). Since IOM is the major C-bearing component of chondrites and the C isotopic composition of IOM tends to also change during metamorphism, bulk C abundances and isotopic compositions may be useful preliminary indicators of petrologic type. Similarly, bulk H abundances and isotopes can be useful indicators of the degree of aqueous alteration (Alexander et al., 2013). Bulk C and H abundances and isotopes in a suite of COs were used to identify DOM 08006 as a potentially very primitive CO3 (Alexander et al., 2014). A subsequent presolar grain search showed that it has the highest matrix-normalized presolar silicate abundance of any chondrite (Nittler et al., 2013). Position sensitive detector X-ray diffraction (PSD-XRD) has proven to be a very useful tool both for determining bulk mineral abundances and for classification (Bland et al., 2004; Menzies et al., 2005; Dunn et al., 2010; Howard et al., 2010, 2011, 2015). Lastly, bulk O isotopes are an indispensable tool for classifying meteorites and for providing constraints on the influence of fluids during parent body processing (e.g., Clayton and Mayeda, 1999; Young et al., 1999; Greenwood and Franchi, 2004; Schrader et al., 2011).

Here, we report the results of an initial search for very primitive COs and minimally altered CMs amongst 16 Antarctic meteorites whose preliminary classifications indicated that they were low petrologic type COs. This study uses bulk analytical methods (bulk H, C, N, and O isotopes), combined with bulk PSD-XRD and analyses of isolated IOM, both to classify these COs and to identify the most primitive ones amongst them.

2. METHODS

0.5–3 g samples were acquired of 16 relatively large Antarctic meteorites whose preliminary classifications suggested that they are primitive CO3s (Table 1). The samples were crushed to a grain size of <150 μm . Aliquots were then analyzed for their bulk H, C and N abundances and isotopic compositions (Table 1 and Fig. 1). Subsets of the samples were subsequently analyzed for the abundances and

isotopic compositions of H, C and N in their IOM (Table 2), for their bulk O isotopic compositions (Table 3) and for their bulk mineralogy by PSD-XRD (Table 4).

2.1. IOM isolation

The new IOM residues were prepared and analyzed using the same methods as described in Alexander et al. (2007). The new residues were prepared using the CsF-HF technique in which crushed samples (<106 μm) are first leached with 2 N HCl, followed by rinsing with milliQ water and dioxane, and then shaken in the presence of two immiscible liquids, a CsF-HF solution (1.6–1.7 g/cc) and dioxane. When liberated from the mineral matrix, the IOM collects at the interface of the CsF-HF solution and the dioxane, while the denser minerals sink to the bottom. After centrifugation, the IOM is pipetted off and rinsed with 2 N HCl, milliQ water and then dioxane, before being dried down at <30–50 $^{\circ}\text{C}$. There was no specific attempt to remove soluble organic material. However, the repeated washing with aqueous solutions and dioxane should have effectively removed most soluble organic compounds known to be present in chondrites.

2.2. H, C and N analyses

For the elemental/isotopic analyses, aliquots of the meteorite powders were weighed into foil capsules (Ag for H, Sn for C and N) and were stored in desiccators for days to weeks at room temperature to minimize adsorbed water contents. However, this process will not have removed all of the terrestrial water associated with weathering products. The samples were weighed prior to being placed in the desiccators and again several days later. Typical sample weights were 5–6 mg for bulk H measurements, 8–9 mg for bulk C and N measurements, and 0.3 mg of IOM for both the H and the C and N measurements. Weight losses after desiccation ranged from 0.3 wt.% to 3 wt.%. The highest weight losses were for Buckley Island (BUC) 10943 and Miller Range (MIL) 090073, both of which it turns out are probably CMs.

Elemental and isotopic analyses were made with: (1) a Thermo Scientific DeltaV^{plus} mass spectrometer connected to a Carlo Erba (NA 2500) elemental analyzer (CE/EA) via a ConFlo III interface for C and N analyses, and (2) a Thermo Finnigan Delta^{plus}XL mass spectrometer connected to a Thermo Finnigan Thermal Conversion elemental analyzer (TC/EA) via a ConFlo III interface for H analyses. The ConFlo III interface facilitates the introduction of the N₂ and CO₂ reference gases for the N and C isotope analyses, while a dual inlet system facilitates introduction of the D/H reference gas for the H isotope analyses. A H₃⁺ correction was determined and applied to the H measurements. We used in house standards to normalize and correct the data at regular intervals (e.g., every 10–12 samples) to monitor the accuracy and precision of the measured isotopic ratios and elemental compositions throughout the runs. These in house standards, which included both gases and solid materials, have been calibrated against international (SMOW, NBS-22, PDB and

Download English Version:

<https://daneshyari.com/en/article/8911009>

Download Persian Version:

<https://daneshyari.com/article/8911009>

[Daneshyari.com](https://daneshyari.com)