Experimental study of laboratory-heated CM2 chondrites Mighei and Murchison

Conference or Workshop Item

EXPERIMENTAL STUDY OF LABORATORY-HEATED CM2 CHONDRITES MIGHEI AND MURCHISON. M. A. Ivanova[1], C. A. Lorenz[1], R. C. Greenwood[2], I. A. Franchi[2], M. A. Nazarov[1], A. A. Morris[2], L. Baker[2], and F. Brandstaetter[3]. [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Kosygin St. 19, Moscow 119991, Russia (venus2@online.ru). [2]Planetary and Space Sciences Research Institute, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK. [3]Naturhistorisches Museum, Burgring 7, A-1010, Vienna, Austria.

Introduction: Metamorphosed carbonaceous chondrites (MCCs) of the Belgica-7904 group from Antarctica [1] and two non-Antarctic MCCs from the desert of Oman, Dhofar 225 and Dhofar 735 [2] – are very different in oxygen isotopic compositions from normal CMs (Fig. 1). They are characterized by $\delta^{18}O$ 21.07-22.29 ‰, $\delta^{17}O$ 9.22-11.59 ‰, and $\Delta^{17}O$ –0.06+0.38 [3]. MCCs are also different from CMs in mineralogy and chemistry [2]. Unlike normal CMs, all MCCs have low H_2O content, their phyllosilicates are dehydrated and they lack tochilinite and P-rich sulfides [2]. We conducted experimental heating of two CM2 chondrites, Murchison and Mighei, to study changes in their oxygen isotopic compositions and mineralogy and explore possible genetic relationships between MCCs and normal CMs.

Experimental: The heating experiment was conducted in the Laboratory of Meteoritics of the Vernadsky Institute in Russia. Chips of Murchison and Mighei were powdered, homogenized and split into several aliquots. The aliquots were placed into copper crucibles and heated under vacuum for one hour. The Murchison aliquots were heated to temperatures of 450°, 600° and 930°C. The Mighei aliquots were heated to 400°, 600° and 800°C. The hottest temperatures (800°-930°C) correspond to the temperatures at which olivine and enstatite form by complete dehydration of serpentite and saponite [4]. The samples were weighed before and after heating. Oxygen isotopic compositions of heated and unheated samples of Murchison and Mighei were determined by laser fluorination [5] at the Open University (UK), with changes measured by Thermo-Gravimetric/Evolved Gas Analyser (TGA-EGA).

Two chips of each meteorite, Murchison and Mighei, were also heated under vacuum for two hours at temperatures of 500° and 700°C, respectively. Polished sections were prepared from these chips and the sections were studied by optical microscopy, SEM, and microprobe analyses at the Vernadsky Institute and the Natural History Museum and the University of Vienna (Austria).

Results and discussion: Most CM2s fall on a mixing line with slope ≈0.6 and display $\delta^{18}O$ of over 8‰ [3]. The unheated samples of Mighei and Murchison plot at the low ^{18}O end of this trend. The unheated and 450°C samples of Murchison are not distinguished (Fig. 1, 2). The unheated Mighei sample is poorer in ^{18}O than all the heated samples and is very similar to published data [3]. The unheated Murchison sample lies at the low end of the CM2 range in both $\Delta^{17}O$ and $\delta^{18}O$ – quite distinct from previous data [3,6], which also displayed some variation. Given the isotopic heterogeneity within CM2s, considerable variation in whole-rock measurements is to be expected.

For both Mighei and Murchison, the heated samples become more ^{18}O rich with increasing temperature (Fig. 1). $\delta^{18}O$ values vary from 5.92 to 9.69 ‰, in the range of CM2 chondrites. $\Delta^{17}O$ falls from ~ -2.99-3.20 to lower values with increasing temperature (Fig. 2), away from the less negative MCCs and towards the level of partially dehydrated CMs (A881334, Y793321, Y82098, Y86695) [3]. The heated Murchison samples display larger isotopic shifts than the Murchison samples studied in [6], because they were heated in closed tubes which could permit isotopic equilibration at temperature above 500°C (Fig. 3).

Significant variations in oxygen isotopic composition result from dehydration of phyllosilicates, tochilinite and decomposition of carbonates. Mineralogical study of polished sections of the Murchison and Mighei heated samples showed that carbonates survived heating to 500°C and 700°C in both meteorites, as well as in all MCCs [1], although they should decompose between 400-700°C [7]. The TGA analyses of all Murchison samples showed a peak of CO_2 at 600-700°C, indicating the presence of carbonates; however the extent of their decomposition during heating is poorly quantified. Tochilinite-bearing objects in the matrices of the heated samples have different compositions than in typical CMs. Usually tochilinite occurs in assemblages with phyllosilicates in different abundances, displaying negatively-correlated variation in S and Si contents [8]. Tochilinite should decompose at 245°C [8], but we observed it in the 500°C heated samples of both meteorites and traces of it in the 700°C heated samples of Mighei. Probably the decomposition rates of tochilinite and carbonates were not enough to form final products during our short experiments. The abundance of tochilinite and carbonates in Murchison is notably less than phyllosilicates.

Therefore the oxygen isotopic system in our experiment was more affected by dehydration of phyllosilicates than by decomposition of carbonates and tochilinite.

We suggest that the observed effects of oxygen isotopic fractionation could take place during thermal metamorphism of carbonaceous chondrites. However, the shift in $\delta^{18}O$ of the heated samples is not out of the CM2 field (Fig. 1). Therefore, a genetic relationship between CM2s and MCCs could not be confirmed. Probably MCCs were affected by multiple processes of hydration-dehydration due to aqueous alteration and metamorphism, enriching the silicates in ^{18}O. Alternatively, MCCs could represent a separate group of chondrites whose primary material was different from typical CM2 chondrites and formed in a different oxygen reservoir.

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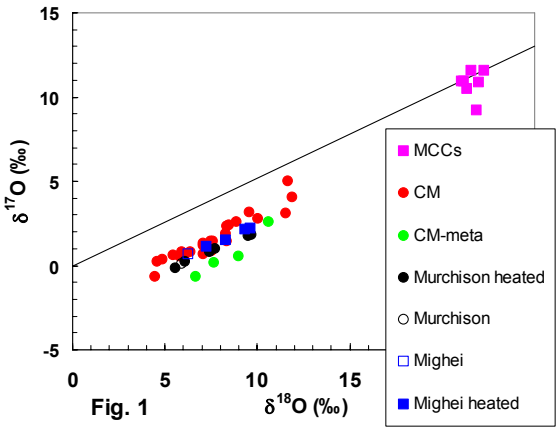

Fig. 1

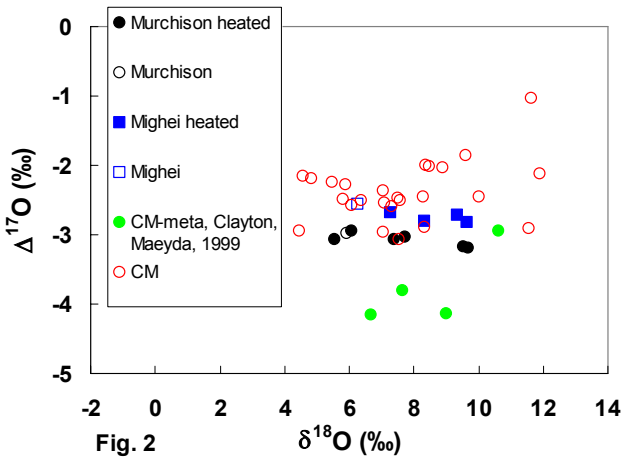

Fig. 2

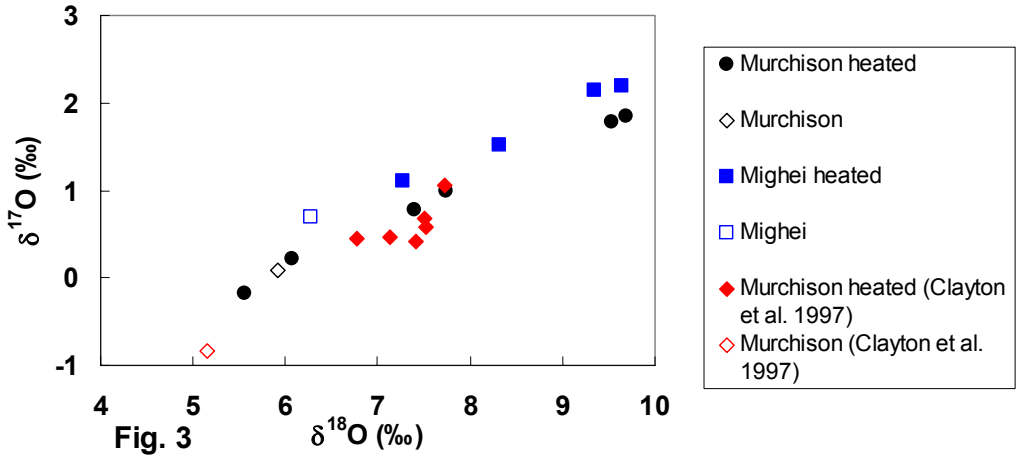

Fig. 3