BULK OXYGEN ISOTOPIC COMPOSITION OF ANTARCTIC MICROMETEORITES : EFFECT OF ATMOSPHERIC ENTRY. C. Engrand[1] and E. Dobrică[2], [1]CSNSM Univ. Paris Sud-CNRS/IN2P3 (Bat 104, 91405 Orsay Campus, France, cecile.engrand@csnsm.in2p3.fr, [2]Department of Earth and Planetary Sciences MSC03-2040, University of New Mexico, Albuquerque, NM 87131-0001, USA.

Introduction: The distribution of O isotopes in the protoplanetary disk is heterogeneous on a small scale defining localized O isotope reservoirs, as evidenced by analyses of different classes of meteorites [1]. The processes leading to this distribution of O isotopes in meteorites and rocky planets are not clearly established yet [2-5]. The oxygen isotopes being characteristic of meteorite classes and of mineral phases (e.g. refractory phases), deviations from the usual values can give insights into the evolution of these phases. For instance, some calcium-aluminum-rich inclusions (CAIs) could have sampled more than one O isotopic reservoir, thus recording a circulation in the early solar nebula (e.g. [6]). However, primitive bodies of apparently diverse origins such as carbonaceous chondrites, comet 81P/Wild2, stratospheric Interplanetary Dust Particles (IDPs) and Antarctic Micrometeorites (AMMs), share striking similarities of their oxygen isotopic compositions [7-11].

Micrometeorites in the size range of 20 µm – 1 mm constitute the dominant extraterrestrial matter accreted by the Earth [12]. Previous mineralogical, chemical and isotopic studies, together with independent dynamical modeling suggest that most of them could have a cometary origin [13-16]. Knowing their bulk oxygen isotopic composition and deciphering the effects of atmospheric entry heating is thus an issue that we address in this work.

Samples and Methods: Fragments of 27 Antarctic micrometeorites from the Concordia collection were crushed on a gold foil for bulk O isotopic measurements. These micrometeorites cover textures ranging from unmelted particles that were not significantly altered by heating during atmospheric entry (14 AMMs, including one containing a spinel inclusion) to partially melted (scoriaceous) particles (9 AMMs), according to the textural classification defined by [17]. One additional AMM with a large surface of exposed magnetite shell (Fig. 1) and three additional micrometeorites containing refractory minerals (diopside, spinel, anorthite) were analyzed in polished sections. The oxygen isotopic compositions were measured by secondary ion mass spectrometry (SIMS) using the IMS 1270 at CRPG Nancy, with a primary current of 1nA for a beam diameter of ~ 10 µm. The three oxygen isotopes were measured using multicollection detection, with ^{16}O on a faraday cup and ^{17}O and ^{18}O on electron multipliers (EM). One to three spots were analyzed in each AMM. Instrumental mass fractionation and occasional EM drift corrections were corrected using San Carlos olivine and central Africa magnetite (CAF, from CRPG-Nancy), depending on the average composition of the analyzed spot (silicates or magnetite, respectively). The reported analytical uncertainties are 2σ.

Results and discussion: The bulk oxygen isotopic compositions of unmelted AMMs crushed on gold foils range from $\delta^{18}O = -5.1 \pm 0.8‰$ to $\delta^{18}O = 15.5 \pm 0.8‰$ and $\delta^{17}O = -7.0 \pm 1.4‰$ to $\delta^{17}O = 7.7 \pm 1.0‰$ (blue squares in Fig. 2). This range does not take into account the ^{16}O-rich value of $\delta^{18;17}O = (-23.6 \pm 0.9; -24.5 \pm 1.1)‰$ corresponding to the analysis of mixed spinel-matrix phases in one crushed AMM (03-32-G). The corresponding average values for this population are $\delta^{18}O = 3.5‰$ and $\delta^{17}O = 0.4‰$.

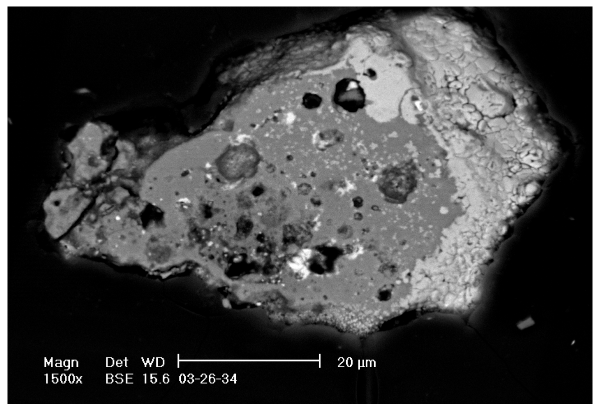

Fig. 1. Backscattered electron image of scoriaceous AMM 03-26-34 mounted in polished section. The outer magnetite shell was not fully embedded in epoxy and thus was available for O isotope analyses (high Z contrast phase on the right: only a portion of the magnetite shell was polished).

The oxygen isotopic numbers for AMMs that were partially melted during atmospheric entry range from $\delta^{18}O = 6.4 \pm 0.9‰$ to $\delta^{18}O = 32.0 \pm 1.0‰$ and $\delta^{17}O = 1.6 \pm 1.2‰$ $\delta^{17}O = 15.3 \pm 1.1‰$ (red diamonds in Fig. 2). The corresponding average values are $\delta^{18}O = 19.8‰$ and $\delta^{17}O = 8.5‰$.

Partially melted micrometeorites are usually covered by a magnetite shell that forms during atmospheric entry heating [18]. The isotopic composition of this magnetite was determined for AMM 03-26-34 (Fig. 1) and shows heavy O isotope enriched values on the terrestrial fractionation line: $\delta^{18}O \sim 42‰$ and $\delta^{17}O \sim 23‰$ (light blue squares in Fig. 2). The oxygen isotopic composition of the matrix in the center of this AMM plots in the range observed for the other crushed scoriaceous AMMs ($\delta^{18}O = 11.8 \pm 1.2‰$ and $\delta^{17}O = 3.6 \pm 0.9‰$).

The heavy isotope enriched value for the magnetite formed during atmospheric entry can be explained by mixing with heavy atmospheric oxygen ($\delta^{18}O$ = 23.5‰, $\delta^{17}O$ =11.8‰ [19]) followed by mass-dependent fractionation due to the evaporation of a large fraction (> 50% in this case) of the newly formed magnetite. As the magnetite shells are usually only a few micrometre thick, such large evaporative losses should not be an issue. Larger heavy isotope enrichments have also been observed in type I spherules that form by the oxidation of chondritic metal during atmospheric entry [20, 21], as well as in stony cosmic spherules [22].

The AMMs containing refractory minerals show ^{16}O enriched values along the slope 1 CAI line, as observed in carbonaceous chondrites, IDPs, AMMs and Wild 2 samples [7, 8, 11, 23, 24]. These data are in agreement with previous O isotopic analyses of refractory minerals in AMMs [11, 25].

The range of observed isotopic composition for unmelted micrometeorites is broadly compatible with that of components of carbonaceous chondrites. No exotic population of particles like the one proposed by [26] was found. We propose that the systematic enrichment in heavy oxygen isotopes of partially melted AMMs compared to the unmelted ones is due to analyses of mixed phases (silicate and heavy O isotope magnetite) in the ion microprobe spot. This proposition is supported by the fact that magnetite preferentially develops on particles that are strongly heated during atmospheric entry.

Conclusions: The bulk O isotopic composition of Antarctic micrometeorites is broadly compatible with that of carbonaceous chondrites, as previously proposed by analyses of individual minerals [11]. Systematic heavy O isotope enrichment is due to atmospheric entry heating. No exotic population of cosmic dust particles was found.

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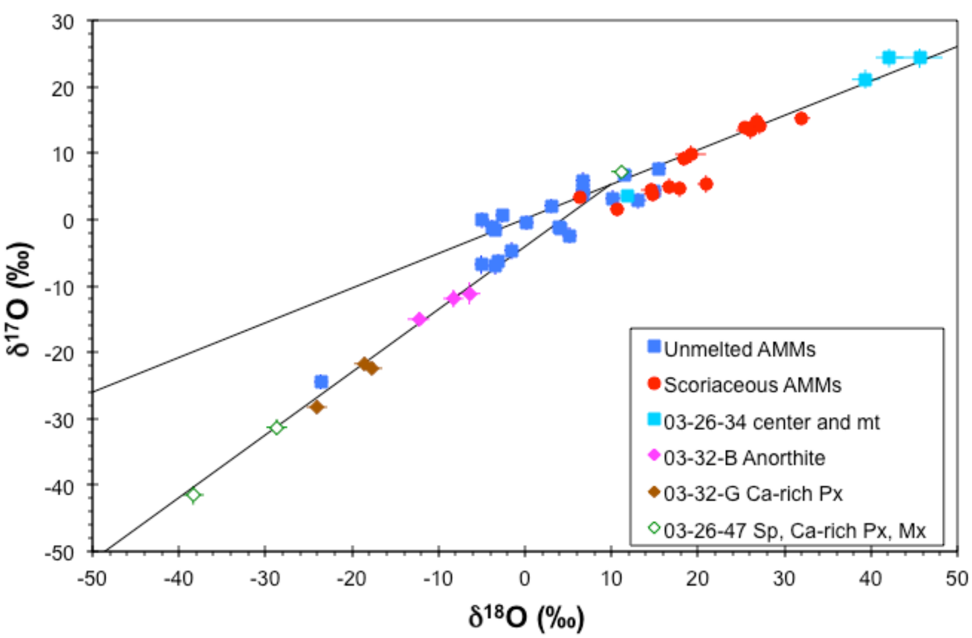

Fig. 2. Oxygen three isotope diagram showing the bulk oxygen isotopic composition of Antarctic micrometeorites (AMMs) with increasing degree of heating during atmospheric entry. The isotopic composition of the magnetite shell formed during atmospheric entry is shown in light blue. Three additional micrometeorites containing refractory minerals were analyzed (03-32-B, -G and 03-26-47).