Mg ISOTOPIC AND TRACE ELEMENT COMPOSITIONS OF SPINEL-PYROXENE INCLUSIONS IN THE MIGHEI C2 METEORITE; Glenn J. MacPherson[1] and Andrew M. Davis[2], [1]Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, D. C. 20560; [2]Enrico Fermi Institute, Univ. of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637

Isotopic and trace element studies of refractory inclusions in C2 meteorites have concentrated on the hibonite-rich varieties, believed to be the most primitive inclusions and where large isotopic anomalies have been found [1,2]. However, the most abundant inclusions in Mighei are 100-500 μm spinel-rich with subordinate pyroxene and perovskite [3]; hibonite-rich inclusions (spheroidal and irregular) are less abundant. Like the ones in Murchison [e.g., 4], the Mighei spinel-rich inclusions range from "nodular" (or botryoidal) inclusions with a compact internal structure to chain-like "banded" morphologies in which the individual parts are separated from one another by meteorite matrix. These inclusions have been variously interpreted as condensates [4] and residues from evaporation/ablation of partial melts [5]. A lack of isotopic and trace element data has until now prevented evaluation of these hypotheses.

We have analyzed spinel in six Mighei inclusions for magnesium isotopes by ion microprobe. Three chain-like banded inclusions, one nodular inclusion, one fragment of a larger inclusion and one unique inclusion were analyzed. The latter inclusion, 3483-3-8, is an irregular cluster of independent spinel-perovskite nodules, all having identical textures and mineralogy but separated from one another by an accretionary mantle-like structure that encases all of the parts into a single whole. Because the inclusions are so small, only two spots were analyzed on each inclusion. All have magnesium isotopic fractionation of less than ~6‰/amu (Table 1).

Three of the inclusions were analyzed for major and trace elements by ion microprobe. Ion microprobe analysis is the only practical way of obtaining trace element analyses of this type of inclusion. Although some inclusions are massive enough for INAA, they lack the distinctive blue color (caused by hibonite) necessary for recognition in density separates from C2 chondrites. Mighei 3483-3-3 is a banded inclusion with a spinel-perovskite core and a diopside rim. The spinel-perovskite region has a gently sloping REE pattern with a negative Eu anomaly (Eu/Eu* of 0.30). REE enrichment factors drop from 75 to 50 × C1 chondrites from La to Lu. The diopside rim has a gently sloping REE pattern with REE increasing from 18 to 30 × C1 and Eu/Eu* = 0.44 (Fig. 1). 3483-3-4 is a compact nodular inclusion with a spinel core and a thin diopside rim. Analyses of the spinel-rich area gave a group III pattern with enrichment factors of 3 to 8 × C1 for most REE and Y, Eu/Eu* = 0.07 and Yb/Yb* = 0.34 (Fig. 1). Analysis of one spinel-perovskite nodule in the unique inclusion 3483-3-8 gave a group I REE pattern uniformly enriched in all REE, while analysis of a second, texturally indistinguishable, nodule gave a modified group II REE pattern (Fig. 1). In contrast to normal group II REE patterns in which Eu and Yb are similarly depleted relative to light REE, the area in 3483-3-8 has Yb enriched to the same level as the light REE. 3483-3-8 is the first reported occurrence of fractionated and unfractionated REE patterns within a single refractory inclusion.

INAA of a suite of hibonite-bearing refractory inclusions from Murchison showed a variety of REE patterns, with average C1 chondrite-normalized enrichment factors of 30 to 100 [6]. Although the spinel-pyroxene inclusions analyzed in this work are of different mineralogical composition, the perovksite-bearing inclusions lie in the same general REE concentration range. It has been suggested that most spinel-rich inclusions in C2 chondrites have group II REE patterns [5], because these inclusions are small and less likely to incorporate enough refractory element-rich grains to give a homogeneous, unfractionated bulk REE pattern. Although the statistics are poor so far, we have found that only one-half inclusion (3483-3-8) out of three spinel-rich inclusions has a group II REE pattern.

These preliminary data place strong constraints on the origins of the inclusions. First, the absence of any large degree of mass-dependent isotopic fractionation of Mg rules out volatilization as the primary process by which the refractory characters of these inclusions were established. Davis *et al.* [7] have shown that residues from evaporation of liquid Mg_2SiO_4 are strongly enriched in the heavy isotopes of Mg, Si and O. The isotopic data do not by themselves rule out the model of [5] in which the spinels (and perovskites) were unmelted solid grains within a partial silicate melt that underwent ablation and/or distillation to leave only the solid residue. However, the side-by-side occurrence of two fundamentally different REE patterns within two parts of a single inclusion rules out the possibility that the two parts were ever in equilibrium with one another, which they presumably would be if they were formed out of the same melt. Moreover, group II REE patterns can only be explained by a condensation process. This one inclusion, at the least, cannot have formed by the volatilization/ablation model of [5]. It seems more likely that the spinel-rich inclusions in C2 chondrites are aggregates of condensate grains. It remains unclear why spinel and perovskite are so often found together without melilite, as the solar nebular condensation temperature is ~100°

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higher than that of spinel [8]. It is hoped that further isotopic and trace element analyses of spinel-rich inclusions will improve understanding of their formation.

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Table 1. Mg isotopic compositions ($\pm 2\sigma$) of spinel in Mighei refractory inclusions.

	$\delta^{25}Mg$	$\delta^{26}Mg$
3483-3-1	2.5 ± 1.3	4.7 ± 2.4
banded	1.8 ± 3.3	0.9 ± 5.5
3483-3-3	3.5 ± 2.9	2.2 ± 3.7
banded	5.7 ± 3.9	5.7 ± 5.3
3483-3-4	0.9 ± 1.3	2.0 ± 2.6
nodular	1.6 ± 1.6	0.7 ± 2.7
3483-3-5	6.2 ± 1.6	7.3 ± 2.5
banded	4.5 ± 1.3	6.8 ± 2.6
3483-3-8	1.1 ± 1.6	1.6 ± 2.7
unique	3.9 ± 1.2	6.7 ± 2.4
3483-3-10	3.3 ± 1.5	5.8 ± 2.5
fragment	4.2 ± 1.2	6.9 ± 2.6

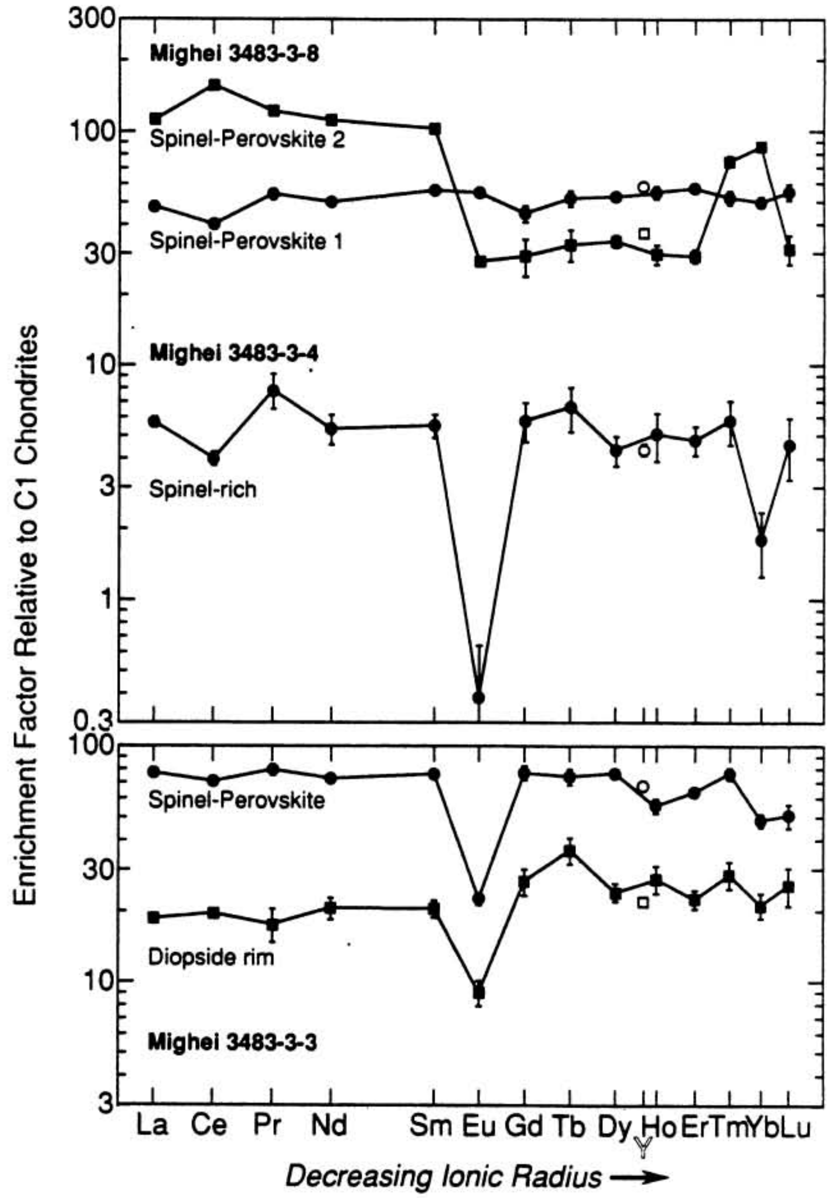

Figure 1. REE patterns of spinel-rich inclusions in the Mighei C2 chondrite.