THREE PHASES OF CARBONATE MINERALS AND TWO DEGREES OF ALTERATION IN THE NOGOYA CM2 CARBONACEOUS CHONDRITE

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Introduction: The Nogoya CM carbonaceous chondrite has been described as highly altered by [1], classified as a CM2.2 by [2], and found to be more highly altered than Mighei (CM2.3) yet less altered than Cold Bokkeveld (CM2.2) [3]. The present study indicates that Nogoya can in fact be divided into two contrasting lithologies that differ in degree of alteration and carbonate mineralogy; one is a CM2.2 and the other a CM2.3. Here we have sought to understand the alteration conditions that produced the two Nogoya lithologies.

Methods: BSE imaging and EDX-ray analyses of a polished and carbon coated thin section of Nogoya were undertaken in a field emission Zeiss Sigma SEM operated at 20 kV. TEM analyses were performed on three FIB liftouts of dolomite and intergrown minerals as well as Mg-rich serpentine after calcite. Diffraction contrast images and diffraction patterns were acquired using a FEI T20 TEM operated at 20 kV. Raman spectroscopy and EPMA were also used in this study for mineral identification and quantitative chemical analysis respectively.

Results and discussion: Petrographic observations indicate that in the more highly altered of the two lithologies the majority of Mg-rich olivine grains have been replaced by serpentine, and Fe-Ni metal is near absent from mafic silicates. Therefore, this lithology has been classified as CM2.2. The less highly altered lithology is a breccia, and texturally analogous to the matrix of Mighei. Most of Mg-rich olivine grains are well preserved. In some cases their margins are etched, and have been replaced by calcite or phyllosilicates. The abundance of Fe-Ni metal in this lithology is less than 0.2 vol. %, although rare intact metal grains were observed inside olivine grains. Thus, these observations suggest that the less altered Nogoya lithology is a CM2.3. The matrix of the CM2.3 lithology has higher concentrations of Mg than the CM2.2 region, which is consistent with the fact that the matrix of CM chondrites becomes enriched in Mg with progressive aqueous alteration [4]. Nogoya contains several distinct generations of carbonate minerals; the CM2.3 lithology hosts aragonite, calcite and dolomite, whereas the CM2.2 has only calcite. This is the first time that aragonite has been found in close association with dolomite in a CM meteorite, and the first description of dolomite within a CM2.3. The presence of two differently altered lithologies within Nogoya can be explained either by fine-scale contrasts in alteration conditions (i.e. ice content, porosity) or by mixing of clasts from different parent body regions. We favour the former possibility; that the parent body contained small isolated regions (a few hundred microns) of contrasting porosity and water content, producing matrices with different Mg concentrations and carbonate mineralogies.

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References: [1] McSween H. Y. 1979. *Geochimica et Cosmochimica Acta* 43: 1761-1770**.** [2] Rubin A. E. et al. 2007. *Geochimica et Cosmochimica Acta* 71: 2361-2382. [3] Howard K. T. et al. 2011. *Geochimica et Cosmochimica Acta* 75: 2735-2751. [4] Zolensky, M. et al. 1993. *Geochimica et Cosmochimica Acta* 57: 3123-3148.