Macromolecular Organic Material in the CR2 Chondrite Grove Mountain 021710 and the Ungrouped Carbonaceous Chondrite Ningqiang: Organic Bearing Fluids on Early Planetesimals

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Introduction: A precise history of the formation and evolution of organic material (OM) from early planetesimals is enigmatic. Organic material (OM) is ubiquitous in the cosmos. This can range from circumstellar envelopes, the interstellar medium to dense molecular clouds and solar nebulae (Kerridge, 1993). Such astrophysical environments seeded the organic inventory in early planestimals such as asteroids but in non-mutually exclusive ways. Different chondrite petrologic types record varying degrees of parent body processing. The most primitive type 3 chondrites have also experienced some degree of processing of primary materials (e.g. Changela et al., 2017). Parent body effects such as aqueous alteration and mild thermal metamorphism (Brearley, 2006) in primitive chondrites must therefore be considered when elucidating the formation and evolutionary history of chondritic OM. The properties of chondritic solid OM are sensitive to such processes. For instance, different carbonaceous chondrite (CC) groups recording varying thermal histories also contain a record of structural variation of OM (Quirico et al., 2009). In an attempt to unravel this complex evolutionary history of chondritic OM, we have been characterising the organic chemistry, morphology, isotopic composition and microscopic setting of solid OM *in situ* in an Antarctic CR2 GRV 021710 CC find and an unclassified CC fall from Ningqiang, China. We are coordinating Raman-SEM-NanoSIMS-STXM-TEM on meteorite chips and polished thin sections on both meteorites in order to shed more light on the evolutionary history of OM across different CCs groups.

Samples & Methods: Grove Mountain (GRV) 021710 is an Antarctic meteorite from the Chinese Antarctic Research Expedition (CHINARE), 2002. A traditional polished thin section was prepared embedded in epoxy. Ningqiang is an anomalous CC with CV and CK affinities. A thin section was embedded under vacuum conditions where epoxy was confined to only a few mm along the boundary of the section. Raman Spectroscopy was performed on the thin sections at Guilin University of Technology, China with a Renishaw *Invia* 514 nm laser source. Electron microscopy and isotopic imaging was performed at IGGCAS with a Zeiss *Auriga* Dual Beam FIB-SEM and a Cameca NanoSIMS 50L respectively. In order to eliminate any potential contamination by EPOXY, some fresh chips of Ningqiang were hand polished, wrapped in Cu tape and Au coated for SEM and FIB. Scanning transmission X-ray microscopy (STXM) was performed at the Canadian Light Source, Beamline 10 ID-1 on 100-150 nm FIB sections of both meteorites.

Results & Discussion: Raman mapping shows OM ubiquitously distributed across the matrices of both GRV 012710 and Ningqiang. This is observed by the presence of a G and D band at ~1600 cm-1 and 1350 cm-1 respectively. The larger D band in the Ningqiang Raman spectra is consistent with the elevated thermal histories of e.g. CV chondrites than in more primitive CCs such as the CRs (Quirico et al., 2009). Raman spectra of epoxy on the side of the thin section and within veins in GRV 021710 exhibit a positive shift in the G band position at ~1610 cm-1 and a narrower FWHM which is distinguishable from chondritic OM. Ningqiang displays a more homogenous Raman signal interstitial to distinctive chondrules. Coordination of SEM with Raman mapping identified organic particles in GRV 021710. Their morphologies are consistent with CC insoluble organic matter (IOM) (Fig. 1b,c) e.g. Changela (2015). Some of these particles display vein-like matrix filling textures (Fig 1a,b). Such singular organic particle morphologies have yet to be identified in Ningqiang. In Ningqiang, OM occurs as a lining of material around fine grained fayalite which dominates the matrix (Fig. 1c). Thus the role of fluids seem have led to the occurrence of these phases in both meteorites. Carbon XANES measured by STXM (Fig 1d) shows the characteristic 3-band aromatic/olefinic (C=C) – carbonyl/phenol (C=O) – carboxyl (COOH) functional chemistry of IOM. However, Ningqiang displays much stronger absorption due to carboxyl functional chemistry than the organic particles in GRV 021710 (Fig 1d). Elevated carboxyl fractions are also characteristic of a ubiquitous organic component associated with amorphous silicates and phyllosilicates in the CR chondrites. This carboxylic-rich 'diffuse OM' has been interpreted as the result of the redistribution of organic compounds by aqueous fluids (Le Guillou et al., 2014; Changela et al., 2017). Oxidation of some organic moieties may have elevated carboxyl fractions under higher temperatures experienced in Ningqiang when compared with GRV 021710 (Yabuta et al., 2007). Such parent body effects have obscured the possible pre accretionary organic precursors although formose based reactions have been described to interpret the organic morphologies found in primitive chondrites (Kebukawa et al., 2013). The glue-like lining of oxidized OM around fine scaled fayalite grains lacking the distinctive OM morphology found in the more primitive CCs is both a unique OM morphology and distribution amongst CCs.

References

Brearley, A. J. The action of water. In Meteorites and the early solar system II, edited by Lauretta D. and McSween H. The University of Arizona Press: The Arizona board of Regents pp. 587- 624, 2006.

Changela, H. G. Geochimica et Cosmochimica Acta 159, 285-297, 2015.

Changela, H. G., Le Guillou, C., Bernard, S., and A. J. Brearley. Hydrothermal evolution of the morphology, molecularcomposition and distribution of organic matter in CR chondrites, Meteoritics and Planetary Science, in review, 2017.

Kebukawa, Y., Kilcoyne, A.L.D. and Cody, G. D. Exploring the potential formation of organic solids in chondrites and comets through polymerization of interstellar formaldehyde. The Astrophysical Journal 771, 19 -31, 2013.

Kerridge, J. F. Origins of organic matter in meteorites. Proceedings NIPR Symposium on Antarctic meteorites 6, 293-303, 1993.

Le Guillou C., Bernard, S., Brearley, A. J and Remusat, L. Evolution of organic matter in Orgueil, Murchison and Renazzo during parent body aqueous alteration: in situ investigations. Geochimica et Cosmochimica Acta 159, 285-297, 131, 368-392, 2014.

Quirico, E., Montagnac, G., Rouzaud, J. N., Bonal, L., Bourot-Denise, M., Duber, S. and Reynard, B. Precursor and metamorphic condition effects on Raman spectra of poorly ordered carbonaceous matter in chondrites and coals. Earth and Planetary Science Letters 287(1), 185-193, 2009.

Yabuta H., Naraoka, H., Sakanishi, K., and Kawashima, H. Solid-state ^{13}C NMR characterization of insoluble organic matter from Antarctic CM2 chondrites: Evaluation of the meteoritic alteration level. Meteoritics and Planetary Science 40, 779, 2007.

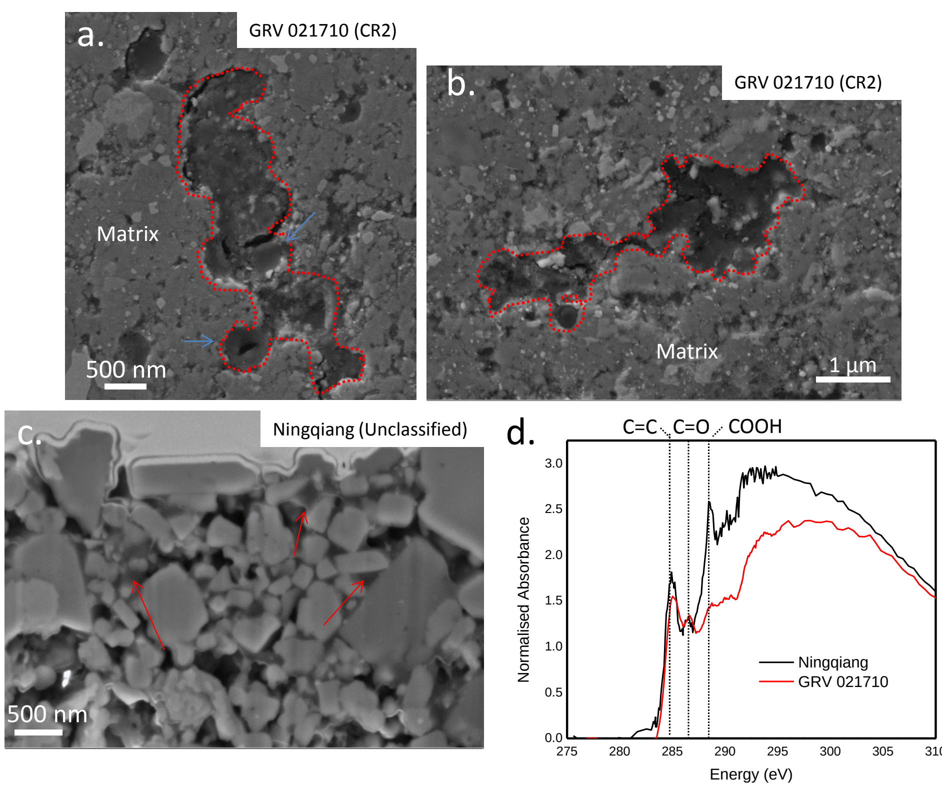

Figure 1. (a-b) SEM images of organic particles (dashed boundary) with vein-like morphologies in GRV 021710. (c) SEM image of a FIB section of Ningqiang showing the dark grey organic material (e.g. arrowed) lining fine fayalite grains. (d) C XANES of representative organic particles in GRV 021710 Vs OM in Ningqiang.