EARLY SOLAR SYSTEM PROCESSES RECORDED IN THE MATRICES OF CR2 CHONDRITES MET 00426 AND QUE 99177. Neyda M. Abreu and Adrian J. Brearley, Department of Earth and Planetary Sciences, MSC03-2040, University of New Mexico, Albuquerque, NM87131-1000, USA (abreu@unm.edu, brearley@unm.edu).

Introduction: Over the past few years, CR chondrites have received particular attention due to their primitive characteristics. Notably, the organic matter located in CR chondrite matrices contains extreme isotopic enrichments, which were potentially acquired in the interstellar medium [1]. However, CR chondrites also record moderate secondary aqueous alteration, which overprints primordial features [2]. In an effort to understand the alteration history of the CRs in more detail, we have carried out TEM studies of the matrices of the CR chondrites MET 00426 and QUE 99177, that have not examined in detail. Preliminary studies [3] of the matrices of these meteorites showed that MET 00426 and QUE 99177 are breccias, whose matrices are composed of dark inclusions (DIs), as well as distinctive rims surrounding type I chondrules and interchondrule matrix present in lesser proportions. These meteorites show significant variability in elemental abundances. Given the fine-grained nature of their matrices, TEM observations are necessary in order to describe their mineralogy, as well as the distribution and mineral associations of the carbonaceous matter.

Results: At the micron to sub-micron scale the matrices of MET 00426 and QUE 99177 exhibit a number of similarities. Broad beam electron microprobe (10 µm) analyses indicate that major element abundances are more akin to those of CM matrices than to other CR chondrites, showing consistently elevated Fe-contents throughout all areas of matrix. SEM observations indicate that their matrices, specially the interchondrule component, are hosts of numerous, distinct clasts.

TEM observations show abundant, amorphous to poorly crystalline Fe-Mg-Si-O material in the DIs and host meteorite. Ferrihydrite is less abundant. Crystalline phases are less common than amorphous material. They include phyllosilicates, sulfides, rare magnetite, carbide, and olivine. Phyllosilicates consist of Fe-rich serpentine-saponite intergrowths. Texturally, they are wispy and only a few unit cells in thickness. Using energy filtered TEM (EFTEM), we identified small amounts of carbonaceous material occurring in association with the phyllosilicates using EFTEM.

Sulfides are common in all the regions studied, but are heterogeneously distributed, particularly in QUE 99177. Fine-grained rims in QUE 99177 contain highly variable sulfide abundances from region to region. Elevated concentrations of rounded to well-facetted sulfides with grains sizes from > 5 nm to < 50 µm, are found in discrete regions of rims (Fig. 1a, b). The sulfide phases are exlusively pyrrhotite and pentlandite, both with variable Ni contents. Sulfides are generally associated N-bearing, amorphous to very poorly crystalline carbonaceous matter that loosely outline the periphery of the crystals. We observed no obvious systematic differences in the sulfide population in terms of size and composition from one region to another or between the two meteorites.

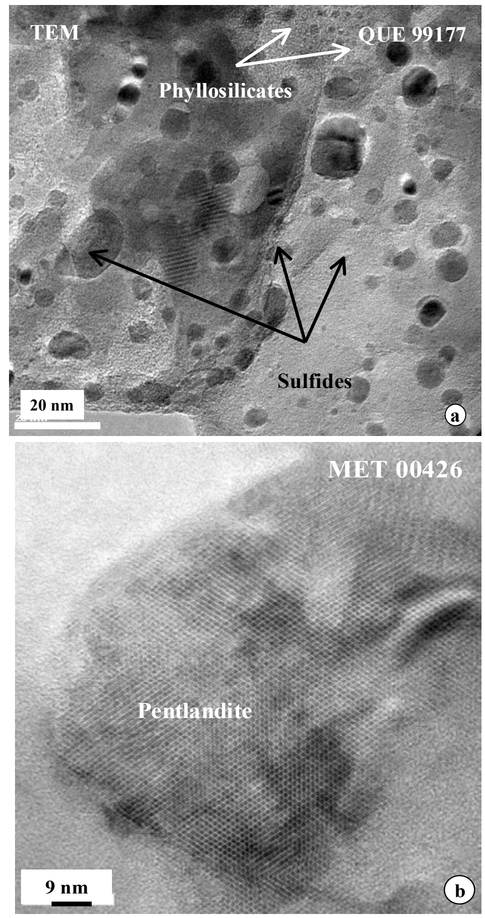

Fig. 1. (a) TEM image of a high sulfide abundance pocket in a rim in QUE 99177. (b) TEM image of a typical sulfide located in an MET 00426 rim.

Nanocrystalline magnetite occurs as haloes surrounding nanophase carbide grains (~ 10s of nm in diameter) in both meteorites. Between the carbide and the magnetite rim lies a thin layer of amorphous to poorly graphitized carbonaceous matter (PGC), which occurs at the interface between the carbide core and the magnetite rim. These composite core-shell carbide-magnetite particles are themselves rimmed by a thin layer of PGC, which is otherwise nearly absent in these meteorites. Olivine is extremely rare in both fine-grained rims and matrix. It occurs as individual crystals normally < 50 nm. More detail characterization is limited by its rarity.

Discussion: Our observations indicate that crystalline phases in MET 00426 and QUE 99177 represent only a modest percentage of the fine-grained material. This is a departure from previous CR chondrite studies, which have described the matrices as phyllosilicate-calcite-magnetite-sulfide assemblages [i.e. 2,4]. In fact, MET 00426 and QUE 99177 present a much simpler mineralogical assemblage, dominated by Fe-rich phyllosilicates and sulfides. These differences are probably due to the methods utilized, previous studies were largely limited to SEM observation and TEM studies of CR matrix remain very limited [2].

Secondary Alteration: In general, matrix mineralogy these meteorites is rather homoheneous, which suggests that alteration took place in the parent body. Perhaps the most surprising observation of this study is the fact that the abundance of phyllosilicates in these two meteorites is quite low and that the dominant silicate material is amorphous in character. We observe essentially no evidence of the replacement of crystalline precursor phases by phyllosilicate phases. Amorphous material has also been observed in a number of other primitive chondrites such as Acfer 094 (unique), ALH 77307 (CO3) and Y791198 (CM) [see 5 for review]. For these meteorites the amorphous material has been interpreted as either amorphous nebular condensate material or possibly amorphous presolar dust [5]. For the case of Y791198 [use Lysa's thesis as the reference], it has been suggested that the amorphous material represents the precursor phase from which the phyllosilicates formed during aqueous alteration.

We propose a similar origin for the phyllosilicates we observe in the matrices of MET 00426 and QUE 99177, that are intimately associated with the amorphous material. The presence of a large fraction of amorphous material indicates these meteorites either underwent only partial hydration, insufficient to drive full crystallization the amorphous component or that alteration occurred at temperatures too low to cause extensive recrystallization.

Carbonaceous Matter: The carbonaceous material in MET 00426 and QUE 99177 exhibits a very low degree of crystallinity and contains detectable concentrations of N. In most cases, graphitization of carbonaceous matter is caused by moderate to high temperature processing over extended periods of time. This process induces the loss of elements previously present in the organic material (e.g. N, O, S, etc.). Thus, the characteristics of the carbonaceous material associated with sulfides and carbides in MET 00426 and QUE 99177 strongly suggest that the carbonaceous matter is very primitive. Our observations are consistent with the presence of exotic, potentially interstellar isotopic signatures, characteristic of the CR group [1].

The presence of N in measurable concentrations is also an indicator of the organic nature of these C-compounds. Despite the clear differences in the alteration styles, the carbonaceous occurrences are similar to those observed in the matrices of CM chondrites [7], where a significant component of organic material is located on the periphery of sulfides, and Fe,Ni carbides, and more limited quantities of C are associated with phyllosilicates. Although both sulfides and phyllosilicates have been largely produced during by aqueous alteration, the sulfides have probably kept the nebular distribution, shape and grain size of their precursors during the alteration process. Hence it seems probable that sulfides and their associated organic-rich rinds provide a record of a nebular rather than asteroidal process. The close association of organic material with sulfides provides strong evidence that there is a genetic relationship between these two types of material. Synthesis of organic compounds both within the solar nebular and on asteroidal parent bodies could have involved a catalytic process, such as Fischer-Tropsch type synthesis. There has been extensive discussion in the literature as to whether FTT reactions were important in the synthesis of the carbonaceous material in carbonaceous chondrites and exactly what type of mineral catalysts were involved. [8] have suggested that under nebular conditions, sulfides have been effective catalysts for organic synthesis. Our observational data appear to be in accord with this conclusion, and suggests that some component of the organic material in CR chondrites formed by FTT-type reactions. The rinds of carbonaceous material represent a residue of high molecular weight material that ultimately probably poisoned the catalytic activity of the sulfide particles. The catalytic properties of phyllosilicates have been extensively documented [i.e. 9] and tt seems probable that catalytic activity began in the solar nebula and continued within asteroidal parent bodies.

Conclusion: Despite the fact that the matrices of MET 00426 and QUE 99177 have experienced aqueous alteration they still record processes that occurred prior to accretion. The abundant amorphous material that constitutes the bulk of the silicate material in the matrices of these meteorites may represent nebular condensate material that has undergone only partial hydration and recrystallization to form phyllosilicates. Further the relationships between sulfides and carbides and carbonaceous material provide strong evidence for the importance of catalysis reactions in organic synthesis in the solar nebula and possible within asteroidal parent bodies.

References: [1] Cody *et al*. (2004) *MAPS* 33 (Suppl.): A23. [2] Weisberg *et al.* (1995) *Proc. NIPR Symp. Antarct. Meteorites* 8:11-32 [3] Abreu and Brearley (2005) *MAPS* 40 (Suppl.): 5332. [4] Krot *et al.* (2003) *MAPS* 37:1451-1490. [5] Nuth *et al.* (2005) In *Chondrites and the Protoplanetary Disk* p.675. [6] Chizmadia (2004) In *Petrographic comparison of the fine-grained rims and chondrule mesostasis in the unbrecciated CM2 chondrites Y-791198 and ALH81002 (Ph.D. dissertation).* [7] Brearley (2004) LPSC XXXV: 1896. [8] Llorca and Casanova (2000) *MAPS* 35: 841-848. [9] Orgel (1998) *Origins of Life and Evolution of the Biosphere* 28: 227-234.

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