MINERALOGY AND TEXTURAL CHARACTERISTICS OF FINE-GRAINED RIMS IN THE YAMATO 791198 CM2 CARBONACEOUS CHONDRITE: CONSTRAINTS ON THE LOCATION OF AQUEOUS ALTERATION. Lysa. J. Chizmadia and Adrian. J. Brearley, Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, USA (lchiz@unm.edu, brearley@unm.edu).

Introduction: Carbonaceous chondrites provide important clues into the nature of physical and chemical processes in the early solar system. A question of key importance concerns the role of water in solar nebular and asteroidal processes. The effects of water on primary mineral assemblages have been widely recognized in chondritic meteorites, especially the CI and CM carbonaceous chondrites [1]. These meteorites have undergone extensive aqueous alteration that occurred prior to their arrival on Earth. In the case of the CM chondrites, this alteration has resulted in the partial to complete replacement of the primary nebular phases with secondary alteration phases.

Considerable controversy exists as to the exact location where the alteration of the CM chondrites occurred. Several textural lines of evidence have been cited in support of aqueous alteration prior to the accretion of the final parent asteroid [2]. An important line of evidence to support this hypothesis is the disequilibrium nature of fine-grained rims and matrix materials. [2] also noted the juxtaposition of µm-sized Fe-Ni metal grains and apparently unaltered chondrule glass against hydrated rim silicates. Conversely, there is a large body of evidence in favor of parent body alteration [3-5] such as the occurrence of undisturbed Fe-rich aureoles [7] and the systematic redistribution of elemental components over millimeters, e.g., Mg^{2+} into the matrix and Fe^{2+} into chondrules etc. [6,8].

Most CM chondrites are breccias [2]. Therefore, in order to thoroughly evaluate the evidence for and against parent body alteration, it is important to minimize the complexities introduced by brecciation. For this reason, this study concentrates on the CM chondrite Yamato 791198, a weakly altered meteorite that has a primary accretionary texture [1,8]. Alteration in Y-791198 is confined to chondrule mesostasis and fine-grained rims: primary chondrule silicates show little or no evidence of alteration.

In this study, we have used SEM, electron microprobe and TEM techniques to examine the mineralogy of fine-grained rims in Y-791198, a meteorite whose fine-grained mineralogy has not been studied in detail. The objectives of this research are to: 1) examine the textural and mineralogical characteristics of fine-grained rim materials in a weakly altered CM chondrite for comparison with other CM chondrites, and 2) evaluate the origins of Fe-Ni metal grains in fine-grained rims. We are particularly interested in determining if these metal grains could have survived parent body alteration or if they were incorporated into the rims after the hydration of the bulk of the rim materials, i.e., preaccretionary alteration [1,9].

Results: Our preliminary TEM observations are from one fine-grained rim in Y-791198: studies of several additional fine-grained rims are currently in progress. These studies show that the rim is texturally and mineralogically relatively simple and differs from other more heavily altered CM chondrites in a number of important respects, as discussed below.

The fine-grained rim is dominated by extensive regions of amorphous material. Electron diffraction patterns of these regions are ring patterns with no distinct diffraction spots. HRTEM studies show, however, that in some areas, the amorphous material actually consists of a myriad of crystallites of nanophase phyllosilicates, with a basal spacing of ~0.7nm. These crystallites are rarely more than 2-3 unit cells in thickness and have curved and cylindrical morphologies. EDS analyses are consistent with serpentine with average Mg/(Mg+Fe) ratios of ~0.465. These regions are essentially devoid of any other phases. However they are juxtaposed and intermixed with regions of matrix that are characterized by the presence of fine-grained sulphide crystallites. These crystals are also embedded within amorphous to nanocrystalline material. The density of sulfides is extremely high in most areas and there are sometimes abrupt transitions between sulphide-free and sulphide-bearing regions. HRTEM, electron diffraction and EDS studies show that both pentlandite and Ni-bearing pyrrhotite are present. Most grains are $\leq$ 70 nm although rare grains up to 150 nm are present. The largest pentlandites can reach ~200 nm in size and sometimes occur as irregularly-shaped aggregates of several subrounded grains. Many of the pentlandites appear to be relatively poorly crystalline, with numerous crystal defects.

One of the remarkable features of this fine-grained rim is the absence of well-crystallized phyllosilicates. We have observed only one relatively well-ordered crystal of serpentine, 333 x 133 nm in size, embedded within micro-crystalline serpentine. Furthermore, no PCP or tochinilite have been found in any of the regions of the rim that have been studied. Unaltered primary phases are also present in the fine-grained rim, although their abundance is low. Coarse-grained forsteritic olivine grains (2-3 µm) are relatively common, and typically have subhedral morphologies and are defect free. One FeO-bearing olivine grain has also been observed (~2 µm). None of these grains show any clear evidence of alteration. We have also found one relatively large metal grain *in situ* (2-3µm). This grain has a composition consistent with kamacite and shows no obvious evidence of alteration. However, it has not, however, been possible to examine the interface between the metal grain and the surrounding material because the region was too thick.

Discussion: Several studies of fine-grained rims in CM chondrites show that they are mineralogically

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complex and show considerable texturally variability. In comparison, one of the remarkable features of this Y-791198 fine-grained rim is its relative simplicity and textural homogeneity. Three major mineralogical components are present: 1) amorphous to nano-crystalline material that is compositionally consistent with serpentine, 2) nanophase sulfides (pentlandite and pyrrhotite) and 3) coarser grained, unaltered primary phases (olivines and Fe, Ni -metal). The major textural heterogeneity within the matrix is the presence of two distinct regions of amorphous or nanocrystalline material; sulfide-free and sulfide-bearing. However, the textures within these two different regions are identical throughout the rim. The alteration phases are uniformly very fine-grained, evidence indicating that alteration was extremely limited compared with other CM chondrites. This low degree of alteration may be the result hydration at lower temperatures than other CM chondrites, lower water:rock ratios or for a limited period of time. The effects of more extensive reaction are to drive recrystallization of fine-grained phases, resulting in the formation of coarser-grained phyllosilicates. These textures are commonly found in rims in more altered CM chondrites, such ALH81002 [10] and Murchison [11-12], but are absent in Y-791198. The fine-grained rims in Y-791198 may be the most weakly altered CM material that has been studied to date.

[2-3,9] have argued that the disequilibrium nature of the mineral assemblage present in rims in Y-791198 supports preaccretionary alteration. However, it is clear from our preliminary studies that at the submicron scale, the rims show no evidence of textural or compositional disequilibrium that would support this argument. On the contrary, the evidence strongly argues against preaccretionary alteration. Our TEM observations show that the only unaltered phases are relatively coarse-grained minerals with grain sizes >1μm. We have found no evidence of primary, unaltered phases (olivines, low-Ca pyroxenes, Fe,Ni metal etc), with grain sizes <1 μm. These fine-grained phases are common components of nebular dust, based on TEM studies of the matrices of highly unequilibrated chondrites [13]. Their absence in this rim argues strongly against mixing of altered and unaltered nebular dust prior to accretion.

Further, preaccretionary alteration would produce a spectrum of alteration products that would have been mixed with unaltered dust before the rims accreted. If such material were represented in fine-grained rims then considerable compositional and textural heterogeneity in terms of the alteration phases is expected. The absence of such heterogeneity provides further evidence that a preaccretionary origin for this fine-grained rim is untenable.

To emphasize this conclusion, we note the absence of PCP of any kind in the rim material. PCP is a common component of altered CM chondrites and would be expected to be present in fine-grained rims, if they sampled partially altered CM material, prior to accretion. Instead, we propose that the absence of PCP is a consequence of extremely mild parent body alteration. In this model, the earliest stages of alteration result in the formation of very poorly crystalline phyllosilicates and very high abundances of nanophase Fe-sulfides. However, with more advance alteration, these fine-grained sulfides are progressively consumed by a reaction which forms PCP. This is supported by two lines of evidence: 1) nanophase sulfides are much rarer in fine-grained rims in more heavily altered CM chondrites such as Murchison and ALH81002 and 2) more altered chondrites contain PCP in their fine-grained rims.

The rim materials of Y-791198 are clearly not a complex, disequilibrium mixture of unaltered materials on all scales. The only phases that are out of equilibrium with the alteration assemblage are olivine and Fe,Ni metal grains. The absence of evidence for reaction of olivine can be explained by their forsteritic compositions, which are known to be resistant to alteration [14]. Since there is no other evidence to support preaccretionary alteration in the rims, it seems likely that the persistence of metal can be simply explained by consideration of the geochemistry of the altering fluids. Alteration of metal proceeds rapidly under acidic conditions and is inhibited in alkaline solutions. It is well known that during the early stages of hydrolysis of silicates [15], hydrogen ions in solution are rapidly consumed resulting in progressively more alkaline solutions. We, therefore, propose that alteration of metal grains in Y791198 was inhibited by the high pH of the solution during the earliest stages of alteration. However, as alteration proceeds the pH of the fluid will drop allowing alteration of metal to proceed as has occurred in more altered CM chondrites.

An additional important feature of this rim is the absence of any evidence of pseudomorphic replacement of preexisting phases. It is possible that this reflects the fact that the the precursor material of the rim was not crystalline, but amorphous material, such as that present in the CO3 chondrite ALH 77307 (CO3) [13].

References [1] Zolensky & McSween, (1988) In Meteorites and the Early Solar System 114; [2] Metzler *et al.* (1992) *GCA* **56** 2873; [3] Tomeoka & Buseck (1985) *GCA* **49** 2149; [4] Browning *et al.* (1996) *GCA* **60** 2621; [5] McSween (1987) *GCA* **43** 1761; [6] McSween (1979) *GCA* **43** 1761-1770; [7] Hanowski & Brearley (2001) *GCA* **65** 495-518; [8] Hanowski & Brearley (2000) *MAPS* **35** 1291-1308; [9] Lauretta *et al.* (2000) *GCA* **64** 3263; [10] Brearley, A.J. *et al*. (1999) LPSC 1460; [11] Zolensky, M.E. *et al*. (1990) LPSC 1383; [12] Brearley & Geiger (1991) *Meteoritics* **26**, 323 [13] Brearley, A.J. (1993) *GCA* **57**, 1521. [14] Zolensky *et al*. (1993) *GCA* **57**, 3123. [15] Drever (1997) In The Geochemistry of Natural Waters 129. **Acknowledgements:** This research was supported by NASA grant NAG5-9798 to A. J. Brearley (PI).