ALTERATION HISTORY OF CR2 CHONDRITE GRA 06100: FE-EPMA AND TEM ANALYSYS. N. M. Abreu[1] and S. Singletary[2], [1]Earth Science Program, Pennsylvania State University - Du Bois Campus, Du Bois, PA 15801, USA (nma12@psu.edu), [2]Dept. of Natural Science, Fayetteville State University, Fayetteville, NC 28301, USA (ssingletary@uncfsu.edu).

Introduction: CR chondrites Renazzo-like (CR) chondrites are the only group of carbonaceous chondrites that exhibits the full range of aqueous alteration [e.g. 1-5]. One of the features of CR chondrites is abundant kamacite grains (~7 vol% - [6]). Alteration of these Fe-Ni alloys would affect composition of altering fluids and eventually precipitate siderophile-enriched secondary minerals. These interactions are particularly critical to understand alteration of extensively aqueously altered CR chondrites [e.g. 1,4,7]. In these chondrites, the formation of layers of pentlandite and oxides and complex opaque assemblages has been attributed to oxidation and sulfidization of precursor metal [4,7,8]. The effects of the introduction of Fe into secondary minerals in chondrule glass and matrix regions during aqueous alteration have only been evaluated for moderately altered CR2 chondrites that show limited evidence of replacement of kamacite [e.g. 9].The specifics of kamacite oxidation, subsequent elemental mobility and these alteration events need to be studied in more detail. Here, we use FE-EMPA and FIB/TEM observations of GRA 06100 as part of a continued effort to explore the effect that advanced stages of metal alteration have on matrix materials.

Results: Quantitative X-ray maps of 14 elements (Na, Mg, Al, Si, P, S, K, Ca, Fe, Ni, and Co) were obtained from a thin section of GRA 06100,6 by FE-EPMA for using 0.26 and 0.5 μm-beam diameters.

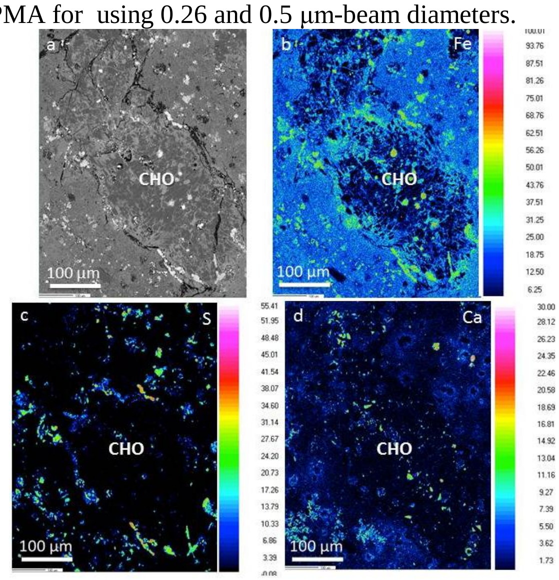

Fig. 1. BSE and X-ray maps of an altered, type I chondrule. (a) BSE of irregular partially integrated chondrule. (b) Fe map showing compositional integration between chondrule, metal, and matrix. (c) S-map showing sulfide veining. (d) Ca-map.

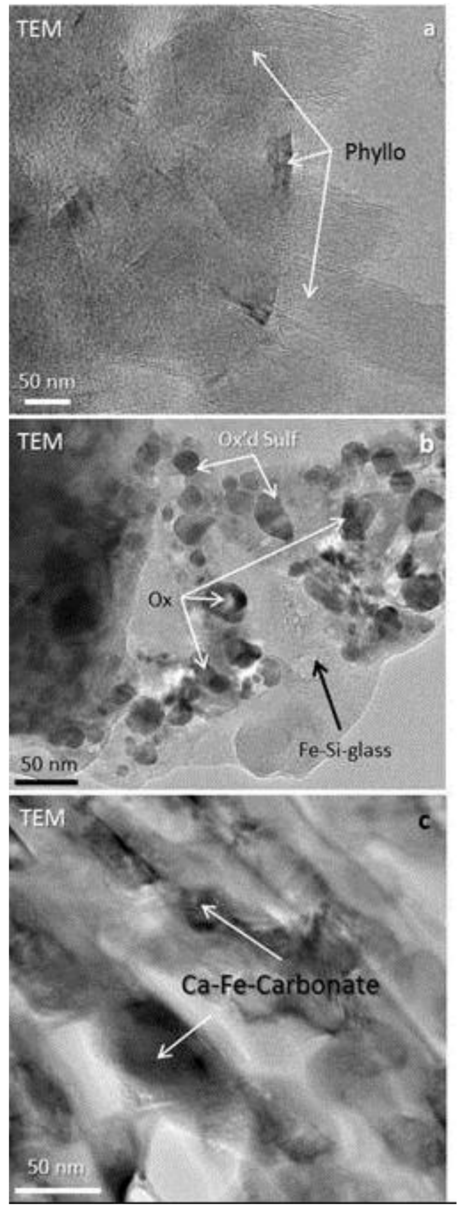

Fig. 2. TEM images of secondary assemblages in GRA 06100 matrix.(a) Tangle of phyllosilicates in matrix. (b) Typical regions of Fe-Si glass with oxidized Fe-Ni sulfide (Ox'd Sulf). (c) Elongate Ca-Fe-carbonates.

X-ray maps show extensive compositional overlap among the chondrules, metal, and matrix. Figure 1 shows a chondrule surrounded by vein and bleb-shaped opaque assemblages and matrix. The Fe map in Fig. 1b shows that the boundaries between these components are very diffuse. Calcium's concentration increases on the periphery of oxidized metal grains and sulfides (Fig. 1c-d).

We have also prepared several TEM sections from typical regions of matrix by ion milling and a FIB section by cutting through an alteration embayment in a kamacite grain. These regions contain abundant opaque phases, hydrous and anhydrous silicates, and carbonates. Primary Fe-Ni metal was completely replaced by complex opaque nodules [7]. These grains have wavy surfaces with numerous embayments, containing Ni-bearing Fe-oxyhydrates, Fe-sulfides, and partially oxidized Fe-sulfides (Figs. 1, 2b). Sub-micron chromite and apatite are found on the surface and cracks of relic kamacite.

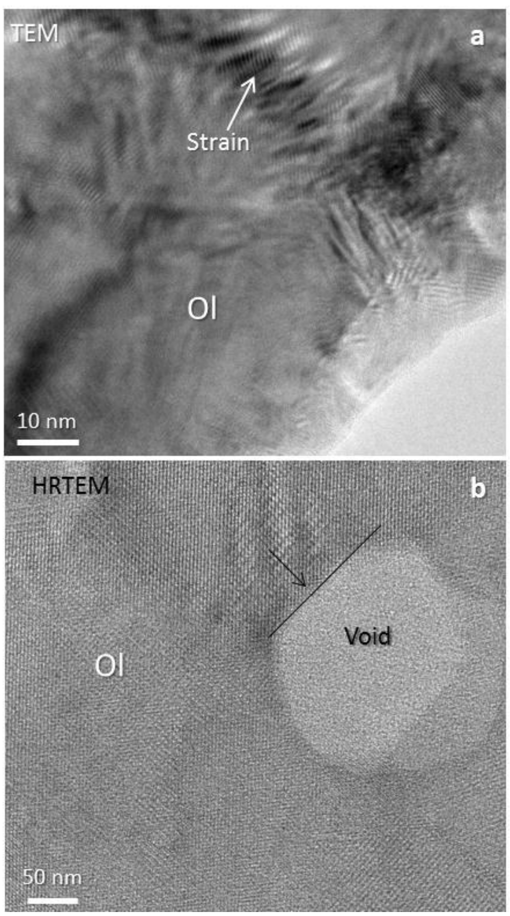

Fig. 3. TEM images of GRA 06100 matrix olivines. (a) Strained olivine (Ol). (b) Detail on strain olivine. (b) Voids common in olivines.

TEM observations reveal that the fine-grained silicates are highly porous. In contrast with weakly altered CR2 chondrites where phyllosilicates are relatively rare, GRA 06100 matrix is dominated by phyllosilicates with basal spacings ranging from 14-17Å in association with rounded Fe-oxides, up to 100s of nm in diameter (Fig. 2a). In addition to phyllosilicates, rare micron and sub-micron Fe-rich olivines were observed. These olivines are irregularly shaped, often strained (Fig. 3a) and containging crystallographically controlled voids (Fig. 3b). Finally, we identified rare elongate Ca-Fe carbonates, showing bead-like features that are particularly Fe-rich.

Discussion: GRA 06100 contains a complex assemblage of materials that may have formed by the combined action of aqueous alteration and thermal metamorphism.

Aqueous Alteration. Evidence of aqueous alteration includes the presence of phyllosilicates, oxidation of metal, and carbonates. Presence of Fe-oxides, chromite and apatite is consistent with pitting corrosion and progressive mobilization of Fe and other siderophile elements into the fine-grained matrix.

Evidence of Thermal Metamorphism. While most CR chondrites show little evidence of thermal metamorphism, [7] have suggested that some characteristics of GRA 06100 formed by hydration followed by heating, based on similarities between GRA 06100 and ungrouped carbonaceous chondrites B-7904, Y-86720, Y-82162, and Y-79332 [10, 11]. Similarities include textural integration of the different components. Here, we present further evidence of high porosity and straining of matrix olivines that is consistent with volumetric changes (Fig. 3). The heat source driving metamorphism has not been identified. However, irregular chondrule shapes, thin S-bearing veins, and highly strained matrix olivines are suggestive of impact metamorphism.

Conclusions: The presence of opaque assemblages and Fe-rich matrix olivines suggest that at least some regions of the CR parent body experience significant thermal metamorphism and the relationship between heating and hydration needs to be carefully evaluated.

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