PETROLOGIC AND CHEMICAL EFFECTS OF THE ONSET OF AQUEOUS ALTERATION ON THE MATRICES OF CR CHONDRITES: GRA 95229. N. M. Abreu[1] and A. J. Brearley[2], [1]Earth Science Program, Pennsylvania State University - Du Bois Campus, Du Bois, PA 15801, USA, nma12@psu.edu, [2]Department of Earth and Planetary Sciences, MSC03-2040, University of New Mexico, Albuquerque, NM 87131-1000, USA, brearley@unm.edu.

Introduction: The details of the low temperature alteration of CR chondrites, as represented in the fine-grained matrix, are largely unexplored. Mineralogical and chemical studies of CR matrices are limited [e.g. 1,2]. As a consequence, there is little agreement on the characteristics of matrices in this group or the conditions of aqueous alteration [3]. Here, we use SEM, and EPMA to study fine-grained materials in GRA 95229, to shed light on the alteration history of the CR group. Although chondrules [3,4] and organic residues [e.g. 5] from GRA 95229 have been studied previously, the present work is the first to focus on the petrology and chemistry of its fine-grained materials.

Results: *Matrix.* The distribution of matrix is heterogeneous from one region to another in terms of abundance. Typical regions of matrix (Fig. 1) contain fine-grained silicate-rich material with platelet and framboidal magnetites and rare Fe,Ni sulfides, mixed with with mineral and chondrule fragments. In some regions, magnetite is as abundant as in Renazzo matrix [1]. Two regions of matrix were analyzed by EPMA for 13 elements (Na, Mg, Al, Si, P, S, K, Ca, Fe, and Ni) using a 10 µm-beam (average total = 85.9 wt% oxide). GRA 95229 matrix (Fig. 2) is significantly more Fe-rich than the matrices of CR chondrites Renazzo and Al Rais [1] and less Fe-rich than MET 00426 (CR3) matrix. Aluminum, Si, Cr, and Fe averages are moderately enriched compared to matrix abundances in Renazzo [1] and significant variability in the Na and K abundances is observed. There is no correlation between Al and Ca. Refractory lithophile element depletions are less pronounced than in MET 00426 matrix [6].

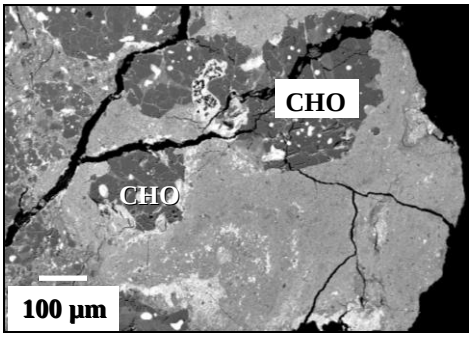

Fig. 1: BSE image of chondrules (CHO) and matrix in GRA 95229.

Clasts. GRA 95229 contains abundant and diverse clasts. Clasts are small (<100 µm), texturally distinct units that are often surrounded by areas with mineral and chondrule fragments. Some clasts are separated from adjacent material by a layer of opaques (Fig. 3). Six clasts were studied using EPMA. The average total for clasts is lower (72.15 wt% oxide) than for matrix. Although analyses from the clasts overlap with the matrix in the Fe-Si-Mg diagram (Fig. 2), they show more variability in Mg. Elemental abundance patterns show the same trends as in the matrix, albeit with more variabilty.

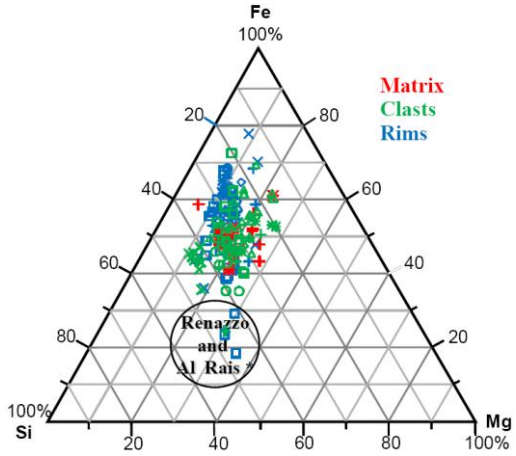

Fig. 2: Ternary Fe-Si-Mg (element wt%) diagrams of fine-grained regions in GRA 95229.

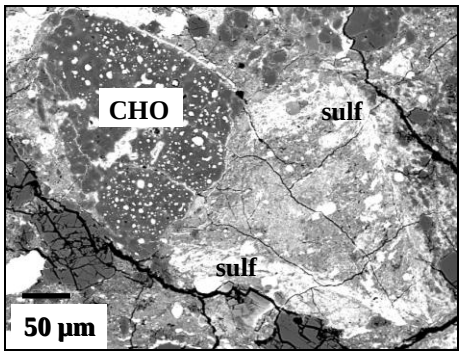

Fig. 3: BSE image of a clast with fine-grained material surrounded by wispy Fe,Ni-sulfides (sulf).

Rims. Fine-grained rims are rare and often discontinous, poorly defined, ~50-100 µm thick, texturally and mineralogically homogeneous (Fig. 4). They contain Fe-sulfides and scarce magnetite embedded in a sub-µm, silicate-rich groundmass. In addition, coarser-grained rims have been identified. These rims are sulfide-rich and <50 µm thick. They contain large crystals (>1 µm), mainly wispy, anhedral Fe,Ni-sulfides. Major

element compositions and elemental abundances of the fine-grained rims are similar to the matrix (Fig. 2). However, rims show more variability in Fe-content. Iron contents are lower than in MET 00426 matrix [6] and there is no correlation between Al and Ca.

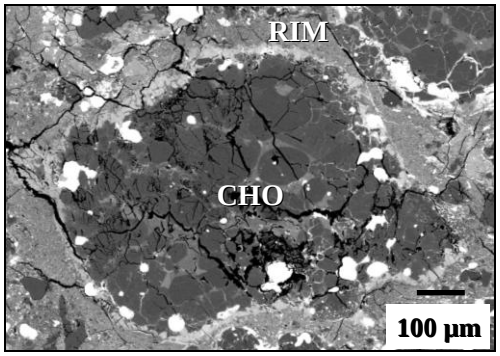

Fig. 4: BSE images of a chondrule (CHO) surrounded by a fine-grained rim.

Discussion: Although GRA 95229 exhibits variable matrix textures, EPMA data indicate that all fine-grained regions have very similar major and minor element trends. Iron/Si contents are intermediate between those in the pristine CR3 MET 00426 [7] and CR2 Renazzo [1]. Refractory lithophile contents are not as depleted as in the pristine CR3 chondrites. The average Fe/Si ratios for CR matrices are inversely, correlated with both Al/Si and Mg/Si ratios (Fig. 5). On these plots, GRA 95229 fine-grained material falls between the CR3 matrices, which have high Fe/Si ratios and CR2 matrices, with low Fe/Si ratios. These trends may be explained by progressive removal of Fe from the fine-grained silicate-rich materials, as Fe is fractionated into magnetite during aqueous alteration. As magnetite forms, Al and Mg remain in the silicate phases. Thus, these elements are effectively enriched in the fine-grained portion of extensively altered CR chondrites, Finally, although Ca is generally considered to be mobile during aqueous alteration, there is no clear correlation between the Al/Si and Ca/Si ratios of CR matrices (Fig. 5), indicating that matrix Ca contents are not particular useful indicators of alteration.

Petrography. The presence of magnetite throughout all regions of fine-grained materials indicates that GRA 95229 has undergone mild aqueous alteration. However, GRA 95229 shares some characteristics with pristine CR3 chondrites [6], including the presence of unaltered mesostasis in some chondrules [3] and absence of calcite. GRA 95229 contains abundant clasts that mineralogically and compositionally diverse. These clasts may record more extensive aqueous alteration, as they have lower oxide totals, which is consistent with the presence of phyllosilicates and contain more bundant magnetite. The presence of clasts recording potentially different degrees of aqueous alteration from the matrix suggests that brecciation occurred before final lithification of the meteorite.

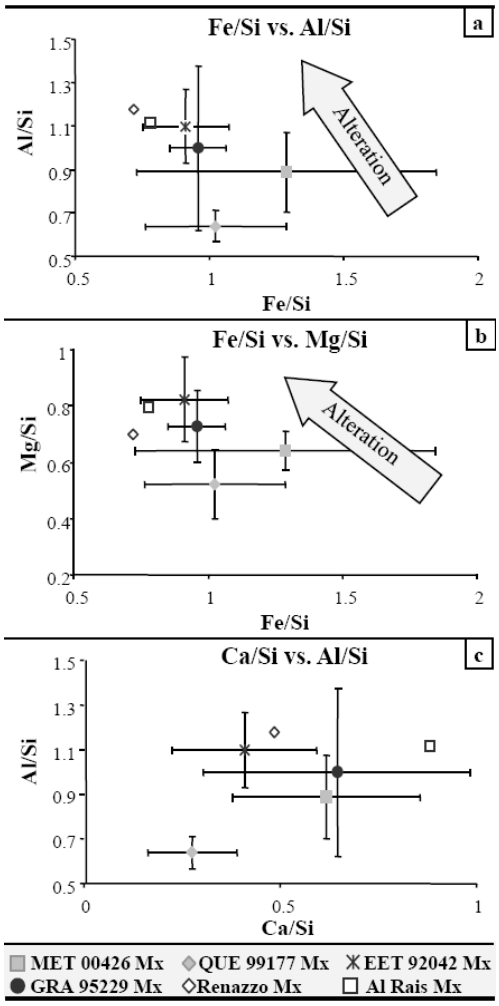

Fig. 5: Element/Si ratios for CR matrices normalized to CI chondrites. Similar trends are observed in rims.

Conclusions: Fine-grained materials in GRA 95229 record aqueous alteration intermediate between pristine CR3 (e.g. MET 00426 - [6]) and altered CR2 chondrites (e.g. Renazzo [1]). Aqueous alteration is reflected by a progressive decrease in the Fe content of the matrix as a result of the progressive formation of magnetite. We propose that the Fe content of the matrix can be used to assess aqueous alteration . In addition, the modal abundance of magnetite may also increase as aqueous alteration advances. However, quantitative data is necessary to confirm this suggestion.

References: [1] Zolensky *et al.* (1993) *GCA*, 57, 3123-3148. [2] Endreß *et al.* (1994) *Meteoritics* 29, 26-40. [3] Krot *et al.* (2002) *MAPS, 37*, 1451-1490. [4] Krot *et al.* (2005) *Ap. J., 622*, 1333-1342. [5] Cody & Alexander (2004) *MAPS., 33*, 1085-1097. [6] Abreu N. M. & Brearley A. J. (2006) *LPS XXXVII*, Abstract # 2395. [7] Kallemeyn *et al.* (1994) *GCA, 58*, 2873-2888.

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