

LOCALIZED CHEMICAL REDISTRIBUTION DURING AQUEOUS ALTERATION IN CR2 CARBONACEOUS CHONDRITES EET 87770 AND EET 92105 Paul V. Burger and Adrian J. Brearley, Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, USA (pvburger@unm.edu, brearley@unm.edu).

Introduction: Carbonaceous chondrites are primitive meteorites that are valuable because they preserve evidence of processes that occurred in the solar nebula and on asteroidal parent bodies. Among the carbonaceous chondrite groups, the CR group appears to contain a particularly pristine record of early solar system processes. Distinguishing characteristics of CR2 chondrites include a high abundance of chondrules (50-60 vol. %) and Fe, Ni metal (5-8 vol. %) [1]. These meteorites preserve evidence for varying degrees of aqueous alteration [2], manifested by progressive replacement of chondrule mesostasis by phyllosilicates. Recent studies have suggested that even in weakly altered chondrites, mass transfer occurred between chondrules and fine-grained matrices, implying that aqueous alteration must have followed lithification of the final meteorite parent body [3]. Although petrographic characteristics of alteration in CR chondrites have been documented [2], mechanisms of alteration are still only poorly understood. For example, the relative rates and scales of elemental mobility as well as the sources and sinks for key elements are currently not constrained. An improved knowledge of these issues will contribute to an increased understanding of aqueous alteration reactions on meteorite parent bodies.

This study expands on research conducted on Type IIA chondrules and chondrule fragments from two CR2 chondrites, EET 87770 and EET 92105. These chondrites have been weakly altered; chondrule mesostases show incipient alteration primarily where they are in direct contact with fine-grained matrices.

Petrographic Observations: Three Type IIA chondrules were studied: a main chondrule and nearby chondrule fragment from EET 92105 and an additional chondrule in EET 87770. We have described the petrographic characteristics of the chondrules previously [3]. Chondrules from EET 92105 have a porphyritic texture (PO) while the chondrule in EET 87770 is half barred olivine (BO) and half porphyritic olivine (PO). Alteration zones occur primarily where mesostasis is in direct contact with fine-grained matrix material in both chondrites. These zones are better developed in EET 87770, where they can be up to 107 μm in thickness, compared with ~ 50 μm in EET 92105. Observations were conducted in this study using optical microscopy, SEM and EPMA.

Compositional Data: Electron microprobe traverses were measured from the chondrule glass through the alteration zone into the matrix. Among the chondrules, Si shows the most predictable behavior from chondrule

glass through alteration zones (Figure 1); chondrule glass compositions range from 52.9-61.4 avg. wt.% SiO_2 in the three chondrules, while alteration zones range from 33.8-35.7 avg. wt.% in chondrules in EET 92105 to 44.2 avg. wt.% in EET 87770.

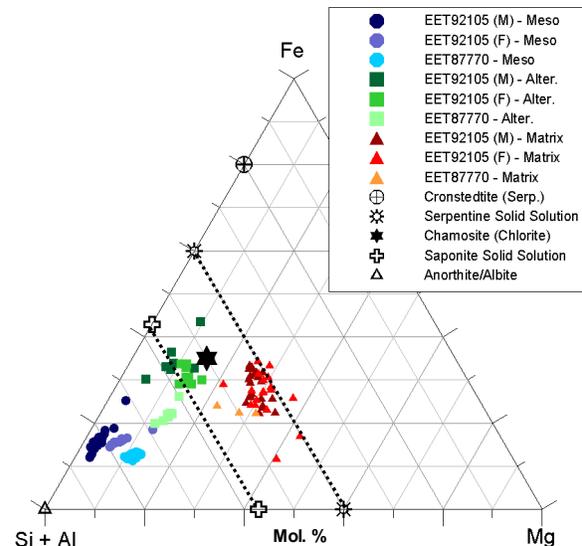


Figure 1. CR2 EET 87770 and EET 92105 Type IIA chondrite phase compositions plotted on an Fe-(Si + Al)-Mg Mol.% ternary diagram.

Fe and Mg show enrichments in the alteration zones (Figure 1). MgO concentrations range from 1.6-6.0 avg. wt.% in mesostasis to 4.3-7.3 avg. wt.% in alteration zones. FeO has similar distributions; mesostasis concentrations range from 15.5-15.8 avg. wt.% in EET 92105 to 11.7 avg. wt.% in EET 87770 (Figure 1). Concentrations of FeO in alteration zones are uniformly enriched, ranging from 27.8 to 29.7 avg. wt.% in EET 92105 to 21.3 avg. wt.% in EET 87770. These values are similar to values in adjacent fine-grained matrix where FeO varies from 23.2-27.6 avg. wt.% in EET 92105 to 21.5 avg. wt.% in EET 87770. These zones are also remarkably similar in area. Although Mg is enriched in alteration zones relative to chondrule mesostasis, concentrations are not as high as those in fine-grained matrices outside of the chondrule (Figure 1). This is in contrast to Fe, whose concentrations in altered glass is equivalent to, if not slightly higher, than in adjacent fine-grained matrix (Figure 1).

Ca and P mobility is highly coupled among both chondrites. In EET 87770, the chondrule fragment in EET 92105, CaO drops from chondrule mesostasis

to the alteration zone, from 2.8 avg. wt.% to 0.6 avg. wt.% and from 1.6 avg. wt.% to 0.2 avg. wt.%, respectively. P_2O_5 behaves similarly, dropping from 5.8 to 3.0 avg. wt.% and 1.0 to 0.6 avg. wt.% in EET 87770 and the EET 92105 fragment, respectively. However, in the fine-grained matrices immediately adjacent to these chondrules, Ca and P jump to higher concentrations. X-ray maps of Ca and P in fine-grained matrices indicate that these elements are precipitating in discrete, coherent regions. In the main chondrule in EET 92105, higher Ca and P concentrations occur in alteration zones in the main chondrule, as opposed to fine-grained matrices, suggesting Ca and P were not mobilized outside of the chondrule in this case.

Of all the elements, the alkalis are the most heavily leached during alteration. Na_2O ranges from 4.9-7.2 avg. wt.% in mesostasis in EET 92105 chondrules, but drops to < 1.3 avg. wt.% in the alteration zones. An even more drastic depletion is seen in EET 87770, where mesostasis is depleted from 10.3 to 0.4 avg. wt.% Na_2O during alteration. K shows similar behavior although K_2O concentrations are lower in chondrule mesostasis.

Discussion: Isocon diagrams illustrate relative mobility for each of the oxides (Figure 2). The line which connects the origin and TiO_2 is considered immobile; oxides which plot above the line are enriched within alteration zones relative to chondrule mesostasis (FeO, MgO), whereas those that plot below have been leached from chondrule glass (Na_2O , K_2O , SiO_2). Alkali elements show the highest degrees of depletion. Although slight increases in Na concentration were observed corresponding to areas of Ca and P precipitation, no sink for Na and K has been identified immediately outside of chondrules. This suggests that Na and K mobility extends beyond the range seen for other elements and that they are most likely redistributed through the chondrite and incorporated into secondary phases at low levels during aqueous alteration. Recent investigations of altered medieval stained glasses [4] confirm that alkali elements are among the first elements to be leached during aqueous alteration.

Ca and P mobilization begins early during aqueous alteration as well; correlation of X-ray maps indicate that these elements are co-precipitating as Ca-phosphate, possibly apatite, in the alteration zone in the main chondrule in EET 92105, and outside of chondrules in adjacent fine-grained matrices in EET 87770 and the chondrule fragment in EET 92105. Ca and P mobilization from chondrule mesostasis and precipitation as Ca-phosphate in matrix requires parent-body alteration, and it may be inferred that alteration has progressed further in EET 87770 and the chondrule fragment in EET 92105, where Ca and P have precipitated outside chondrules. This is consistent with petro-

graphic observations; alteration zones are much thicker in EET 87770 (107 μm) as opposed to the main chondrule in EET 92105 (~50 μm), suggesting more advanced alteration in EET 87770. As alteration progresses, it is likely that phases such as apatite undergo cycles of dissolution and subsequent reprecipitation, slowly migrating out of the chondrule.

Finally, Fe and Mg enrichment in alteration zones (Figure 1, Figure 2), and depletion of Fe from adjacent fine-grained matrix material, seems to be the result of the mobilization of these elements into the chondrule during alteration. Zones of Fe depletion in fine-grained matrix material, similar in area to adjacent alteration zones, suggest that Fe is more mobile than Mg. Ternary diagrams illustrate this point (Figure 1); Fe in alteration zones is nearly equivalent in concentration to fine-grained matrices in both chondrites, while Mg, though enriched relative to mesostasis, is still at a lower concentration in alteration zones than in fine-grained matrix material. Patterns of elemental redistribution in EET 87770 and EET 92105 are entirely consistent with parent-body alteration. Elements leached from mesostasis during alteration (Na, K) have been redistributed outside of the chondrules, while elements enriched in alteration zones (Fe, Mg) are being introduced into chondrules from adjacent matrix material. Ca and P, which have their source in chondrule mesostasis, mobilize outward, eventually precipitating outside of the chondrule with progressive alteration.

References: [1] Brearley A. J. and Jones R. H. (1998) In 'Planetary Materials, Reviews in Mineralogy' **36**, 3/01-3/398. MSA. [2] Weisberg M. K. et al. (1993) *GCA* **57**, 1567-1586. [3] Burger P. V. and Brearley A. J. (2004) *LPS XXXV*, Abs CDRom #1966. [4] Sterpenich J., and Libourel G. (2001) *Chemical Geology* **174**, 181-193. **Acknowledgements:** Supported by NASA Origins of Solar Systems grant NAG5-11862 to A.J. Brearley (PI).

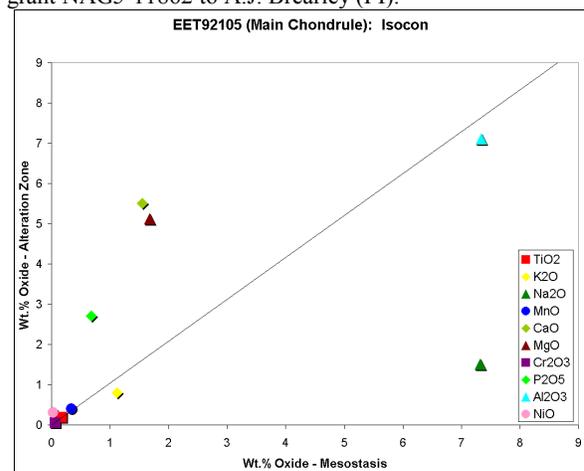


Figure 2. CR2 EET 92105 isocon diagram illustrating chemical mobility.