TRACE ELEMENT ANALYSES OF SILICATES AND GLASS IN RENAZZO (CR2) CHONDRULES. E. Jacquet[1,2], O. Alard[3], M. Gounelle[2] [1]Ecole Normale Supérieure de Paris, 45 rue d'Ulm, 75005 Paris, France (e-mail: ejacquet@mnhn.fr) [2]LMCM, UMR 7202, CNRS & MNHN, CP52, 57 rue Cuvier, 75005 Paris, France. [3]Géosciences Montpellier, UMR 5243, Université de Montpellier II, Montpellier, France.

Introduction: Trace element geochemistry might help to constrain the genesis of chondrules and their precursors (e.g. [1],[2]). Following our work on Vigarano (reduced CV3.3) ([3]), we report preliminary observations on trace element analyses of individual silicate crystals and melt patches in seven chondrules of the Renazzo (CR2) meteorite. Special emphasis is put on incompatible-poor mineral olivine. We shall largely focus here on Rare Earth Elements (REE).

Methods: Chondrules were documented using scanning electron microscopy and electron microprobe (Cameca SX100 at Paris VI university). Trace element LA ICPMS analyses were performed in Montpellier II university, with a fluence of 15 J/cm^2 and a pulse frequency of 5 Hz. Spot size for olivine ranged from 26 to 102 µm, an aperture of 51 µm being a typical value. The relevant signal was selected using the GLITTER software, inspection of major element signal such as Al and Ca enabling one to avoid incompatible-enriched phases encountered by the laser. Pyroxene, clinopyroxene and mesostasis, if present, were then also analyzed.

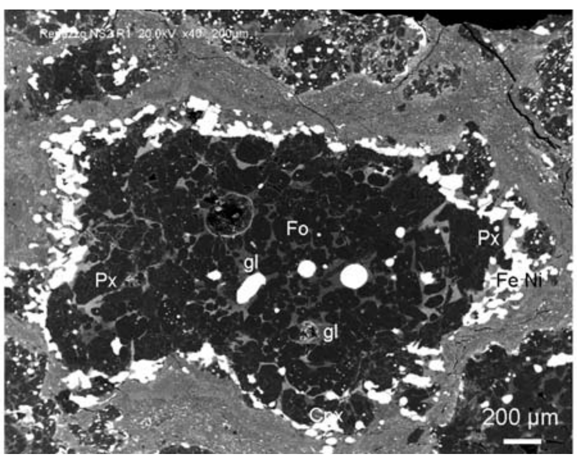

Figure 1: BSE image of the largest analyzed POP type I chondrule (~3 mm across). Nodules and rim are iron-nickel (FeNi). Large low-Ca pyroxene slabs (Px) are seen in the periphery, sometimes with a clinopyroxene (Cpx) overgrowth, while olivine (Fo) occurs as mostly angular equant grains. The latter are set in a devitrified mesostasis (gl) partly replaced by whitish phyllosilicates.

Results:

Petrography, major and minor elements. The analyzed chondrules have been selected to span a wide range of textures: 2 Porphyritic Olivine Pyroxene (POP) (one shown on fig. 1), 1 Porphyritic Pyroxene (PP) fragment, 1 Porphyritic Olivine (PO), 1 Barred Olivine (BO), 1 GLassy (GL), 1 lithic fragment with large olivine. Granoblastic textures are uncommon in Renazzo. But for the PO chondrule (shown in fig. 2), all are type I, with a mean Fa = 2 mol % for olivine. Minor element correlations in olivine are similar to those described by [2] for Unequilibrated Ordinary Chondrites (UOCs), with e.g. volatile Mn being anti-correlated with refractory Ti. Siderophile concentrations (Co, P, Ni) are one order of magnitude lower than in UOCs. Cr content correlates rather tightly with Fa for type I chondrules.

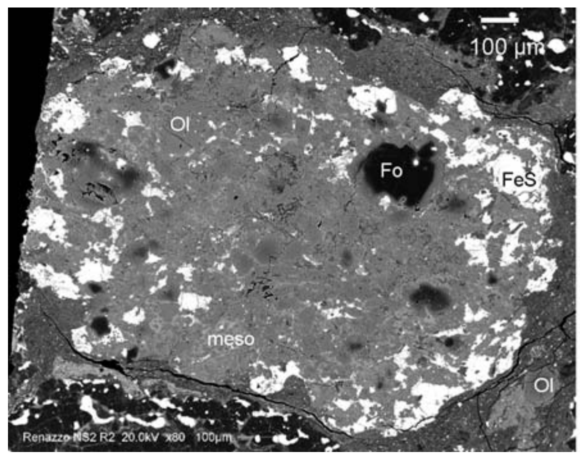

Figure 2: BSE image of the only type II chondrule analyzed, a PO 1.3 mm across. Sulfides (FeS) occur mainly at the edge. Relict forsterites (Fo) are distributed among more ferroan olivines (Ol) (Fa = 25-35 mol%), with intersticial altered mesostasis (meso).

Rare Earth Elements. Fig. 3 displays typical REE patterns of the different phases analyzed. No relationship with textural type, presence of metal or location within a given chondrule has been evidenced yet.

Glassy mesostasis has a generally flat, if slightly decreasing, pattern at ~10 x CI. Clinopyroxenes exhibit a concave Light Rare Earth Element (LREE) pattern rising from (sub)chondritic levels to a plateau for the Heavy Rare Earth Elements (HREE) at 5-10 x CI, with a negative Eu anomaly (Eu/Eu* ranges from 0.07 to 0.3) indicative of equilibrium with feldspathic mesostasis. Low-Ca pyroxene's pattern rise steadily from ~ 10^{-1} x CI to near chondritic values. Many low-

Ca pyroxene exhibit instead a flat REE patterns at a few times CI but insofar as they parallel that of glass, melt impregnation might be suspected.

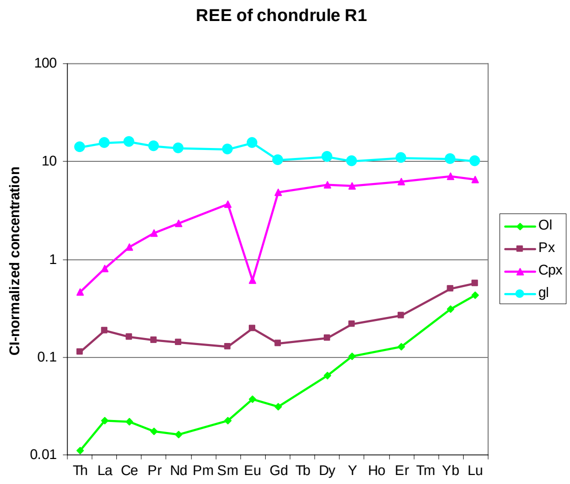

Figure 3: CI-normalized REE patterns of chondrule R1 (pictured on fig. 1). Each curve represents average of analyses of the same phase. From top to bottom: glassy mesostasis (gl), calcic clinopyroxene (Cpx), low-Ca pyroxene (Px) and olivine (Ol – *geometrical* average).

Olivine is somewhat fractionated in terms of REE, with LREE typically at a few 10^{-2} x CI and Lu at some fraction of the chondritic value. Negative Eu anomalies sometimes occur. La/Yb ranges from 0.02 to 0.4 (a larger depletion is measured for a coarse forsteritic relict in a type II chondrule, with La below detection limit and Ce, Pr, Nd concentration reaching a few 10^{-3} x CI). The pattern flattens toward the LREE.

One could argue that olivines are more fractionated than measured (say, LREE < ~10^{-3} x CI) but that melt contamination buffers LREE contents at higher levels. This is especially true for the BO chondrule, whose *least* contaminated olivine analysis has REE content > 10^{-1} x CI and this certainly prompts one to prefer in general the most REE-depleted olivine analyses. This is why we favour a geometrical averaging over an arithmetical one when we provide a representative olivine analysis for a given chondrule. However, the analytical methods provide some constraints on the allowable heterogeneity. While the LA ICPMS cannot pinpoint heterogeneities exactly lying in the transverse direction — unless abnormally high count rates in Al or Ca are involved —, depth profiling can in principle resolve heterogeneity on the scale ablated during one mass scan which is of the order of ~1 µm. As shown in fig. 4, the selected olivine analyses display no correlation between La/Yb and Al (a potential proxy for melt/pyroxene contamination). This appears to suggest that our analyses faithfully (within error) represent the olivines down to the micrometer scale, that is, with the possibility of smaller inclusions. Such melt entrapment was indeed explicitly considered by [4] for their rapid-cooling experiments. They therefore deemed their olivine/melt partition coefficients to be “effective” in the sense that the analyzed crystals might not be pure olivine. Insofar as these experiments probe the same scale than our measurements, partitioning behaviors may be compared.

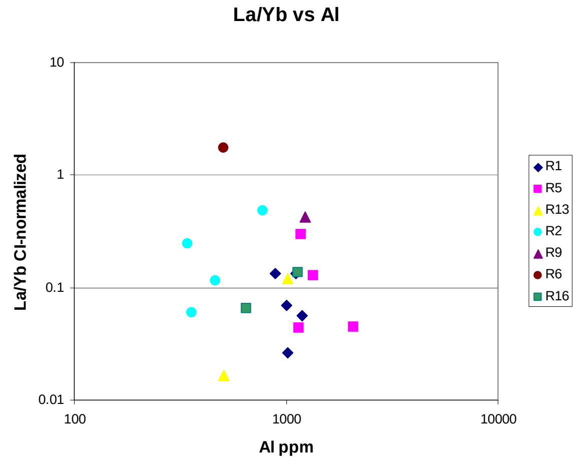

Figure 4: CI-normalized La/Yb in olivine versus Al content. Points are keyed by chondrule

Discussion: If correct, the above analyses suggest that chondrule olivines genuinely differ in REE content from those in olivine-bearing differentiated meteorites such as ureilites or pallasites, whose LREE content might be < 10^{-3} x CI ([5], [6]). Moreover, an equilibrium partitioning between olivine and liquid might be difficult to envision according to experimental data of [4], as this would imply LREE enrichments three orders of magnitudes above chondritic values for the parent liquid, whereas rapid cooling (2193 K/h) partition coefficients of [4] would result in REE contents of a few times CI up to one order of magnitude above CI. Unless some factors pertaining to chondrule formation conditions can account for different equilibrium partitioning behaviors, it thus would seem that REE retain a rapid cooling signature (a conclusion similar to those drawn by [1] and [2]).

References: [1] Alexander C.M.O’D. (1994), *GCA, 58*, 3451-3467. [2] Ruzicka et al. (2008), *GCA, 72*, 5530-5557. [3] Jacquet et al. (2009), *Meteoritics & Planet. Sci. Supplement*, 5354. [4] Kennedy et al. (1993), *EPSL, 115*, 177-195. [5] Guan Y. & Crozaz G. (2000), *Meteoritics & Planet. Sci., 35,* 131-144. [6] Minowa H. & Ebihara M. (2002), LPS XXXIII, abstract #1386.