ORIGIN OF HYDROGEN CONTENT IN CHONDRULES OF CM CHONDRITES.
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Introduction: Due to their diversity of texture and mineralogy, the origin of chondrules remains poorly understood[1]. The chondrules were formed in different environments (e.g., reducing for type I FeO-poor chondrules and oxidizing for type II FeO-rich chondrules) in contact with H2 of the protoplanetary disk. Stephant et al.[2] reported large hydrogen content in olivine (up to 1,000 ppm) in chondrules of carbonaceous chondrites, whereas Shimizu et al.[3] detected only few ppm of hydrogen in silicate minerals (<15 ppm). All this observation remains debated. The aim of this study is to constrain the origin of hydrogen contained in chondrule olivines of CM chondrites and to assess the influence of aqueous alteration on hydrogen content and isotopic signature in these emblematic constituents of chondrites.

Two main reservoirs of hydrogen, with distinct isotopic compositions, could likely contribute to chondrule minerals: the molecular gas of the protosolar nebula with a low D/H[4] and water ice. The D/H ratio of water presents variations related to the distance to the star. A part of the water can thus have a presolar origin (high D/H ratio) and another part can result from re-equilibration with the H2 of the disk[5]. Water ice was likely accreted on the parent body of hydrated meteorites like carbonaceous chondrites. Due to asteroid internal heating, ice melted and water percolated into the parent body resulting in the aqueous alteration of its components. Moreover, this aqueous alteration could have affected mineral components of both matrices and chondrules. To what extend chondrules in CM chondrites have preserved their pre-accretionary H content and isotope signature?

Sample and Methods: Three carbonaceous chondrules showing different alteration degrees were investigated: Paris (CM2.7 to CM2.9), Aguas Zarcas (CM2) and Mukundpura (CM2). Three polished sections were prepared in epoxy and carbon coated. Hydrogen content and isotopic composition of olivines in type I (FeO-poor) and type II (FeO-rich) chondrules were analyzed by Cameca SIMS 1280 HR2 (CRPG, Nancy) and by Cameca NanoSIMS 50 (IMPMC, Paris) with a Hyperion radio-frequency plasma source in both cases[6]. The vacuum in the analytical chambers never exceeded 2.10^-8 mbar for the SIMS and 2.10^-9 for the NanoSIMS.

Results and Discussion: The hydrogen concentration, expressed as water concentration, in olivine of the CM chondrites varies between 0.02 and 0.53 wt% (Paris: 0.17 < [H2O] (wt%) < 0.53; Aguas Zarcas: 0.02 <[H2O] (wt%) < 0.32; Mukundpura: 0.15 < [H2O] (wt%) < 0.49), whereas the D/H ratio in olivine of the chondrules ranges between 53 and 247 ppm (Paris: 98 < D/H (ppm) < 164; Aguas Zarcas: 53 < D/H (ppm) < 247, Mukundpura: 80 < D/H (ppm) < 168). Moreover, there is a clear correlation between the iron-content of these olivines, the water concentration and the D/H ratio especially in Mukundpura (R² = 0.83 for [H2O] and 0.90 for D/H) and in some chondrules of Aguas Zarcas. When the D/H ratio and Mg# decrease, the water concentration increases. Moreover, this D-poor signature is also present at the edge of some zoned olivines in Aguas Zarcas and Mukundpura, where some MgO-rich olivines are surrounded by more FeO-rich and hydrated olivines.

The aqueous alteration and the chondrule-matrix interaction could explain this correlation. According to Piani et al.[7] the matrix of CM chondrites was altered by D-poor water and then records this D-poor signature. Thus, the signature at the mineral edge could be interpreted as a chondrule-fluid interaction during aqueous alteration, by isotope exchange or diffusion. However, there is no correlation between the degree of alteration of the chondrites and the water concentration of the olivines. The three meteorites exhibit the same range of water concentrations. Moreover, some petrological evidences (e.g. high hydrogen content in the less altered type II chondrules) suggest that the hydrogen composition of these olivine reflects a preaccretional origin even if the effect of aqueous alteration on the composition of iron-rich olivines cannot be excluded. The high hydrogen content may be explained partially by hydrated precursors.

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