OLIVINE OF CARBONACEOUS CHONDRITES AND RESERVOIR OF NEBULAR HYDROGEN.

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Introduction: Olivine is a nominally anhydrous mineral usually depleted in water unless formed in a high pressure and temperature environment[1]. Several studies have found 10 to 100 times more water in olivine of carbonaceous and ordinary chondrites than on Earth[2,3]. In the meantime, Shimizu et al.[4] detected less than 15 ppm of hydrogen in silicate minerals in chondrules of Semarkona (LL3), QUE 97008 (L3.05) and DOM 08006 (CO3).

Two main reservoirs of hydrogen, with distinct isotopic compositions, could likely contribute to chondrule mineral hydrogen content: the molecular gas of the protosolar nebula with a low D/H[5] and water ice. The D/H ratio of water in solar system objects exhibit variations related to the distance to the star. Part of the water can thus have a presolar origin (high D/H ratio) and another part can result from re-equilibration with the H_2 of the disk[6]. Water ice accreted on the parent body of hydrated meteorites like carbonaceous chondrites. Due to asteroid internal heating, , ice melted and water percolated leading to aqueous alteration of its components. Both matrices and chondrules were affected. As a consequence, aqueous alteration could have contributed to the water budget of chondrules' olivine as well, therefore making the deconvolution of pre-accretionnary and post-accretionnary contributions difficult.

Samples and Methods: Three carbonaceous chondrites 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 olivine in type I (FeO-poor) and type II (Feo-rich) chondrules and isolated olivine were analyzed by Cameca SIMS IMS 1280 HR2 (CRPG, Nancy) and by Cameca NanoSIMS 50 (MNHN, Paris) using an O- primary beam from a Hyperion radio-frequency plasma source in both cases. Olivine crystals isolated in the matrix are thought to be fragments of chondrules ejected during their formation. Thus, like the chondrule olivine, they have crystallized in the protoplanetary disc a few million years after the Solar System formation.

4 tips were prepared by focused ion beam (FIB) milling using a Thermofisher Helios G4 UXe DualBeam Xenon plasma FIB, and analysed by atom probe tomography (APT) using a Cameca LEAP 4000XHR instrument. The hydrogen contents (concentration, spaciation) were compared with those of anhydrous San Carlos olivine prepared and analysed in the same conditions with the same instruments.

Results: Olivine of carbonaceous chondrites contain large and variable amounts of non-labile hydrogen as attested by SIMS and atom probe tomography. The isotopic composition of this hydrogen varies between the signature of H_2 in the disk (D/H ~ $26 \pm 7\times10^{-6}$ [5]) and water ices (D/H > 156×10^{-6} [7]). The D/H ratios of Paris olivine cover a wide range of values (99 to 151×10^{-6}) and are not correlated to Mg#. Mg-rich olivine of Aguas Zarcas also show this large variability (77 to 151×10^{-6}). However, the D/H ratios is more homogeneuous around $115 \pm 10\times10^{-6}$ when the iron content is above 40%. The olivine of Mukunpura, the most altered chondrite, have homogeneous isotopic compositions around $134 \pm 7\times10^{-6}$.

Discussion: With increasing degree of aqueous alteration on the parent body, the hydrogen content and D/H of olivine tends to be more homogeneous; D/H ratio of hydrogen in olivine tends to become isotopically akin to terrestrial mantle water[11]. Despite the marks of some aqueous activity in these chondrites, the isotopic variabilities measured in Paris and Mg-rich Aguas Zarcas olivine might be an heritage of the different sources (ice or hydrogen of the protoplanetary disk) of hydrogen that embedded solid precursors during olivine formation.

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References: [1] Mackwell, S.J. and Kohlstedt, D.L. (1990) *Journal of Geophysical Research* 95:5079-5088. [2] Deloule, E. et al. (1998) *GCA* 62 :3367-3378. [3] Stephant, A. et al. (2017) *GCA* 199 :75-90. [4] Shimizu, K. et al. (2021) *GCA* 301 :230-258. [5] Mahaffy, P.R. et al. (1998) *Space Science Reviews* 84:251-263. [6] Jacquet, E. and Robert, F. (2013) *Icarus* 223 :722-732. [7] Hartogh, P. et al. (2011) *Nature* 478 :218-220. [11] Hallis, L.J. et al. (2015) *Science* 350 :795-797.