A COMPLEX INTERPLAY OF HEAT AND AQUEOUS ALTERATION EXPERIENCED BY THE PARIS CM CHONDRITE

L. Bonal[1], P. Beck[1], T. Nakamura[2], Y. Enokido[2], J. Gattacceca[3], J. Eschrig[1] [1]Institut de Planétologie et d'Astrophysique de Grenoble – Université Grenoble Alpes, CNRS (Grenoble - France) (lydie.bonal@univ-grenoble-alpes.fr), [2]Laboratory for Early Solar System Evolution, Tohoku University (Japan), [3]CNRS, Aix Marseille Univ, IRD, Coll France, INRA, CEREGE (Aix-en-Provence, France).

Introduction: The Paris meteorite is a CM chondrite [1] that has been thoroughly studied to assess its parent body history. Paris was classified as type 2.7 [2] on the alteration scale defined by [3]. Paris is brecciated and petrographically heterogeneous, with distinct lithologies (typically metal-rich and metal-poor, [4]) having experienced various degrees of alteration [4, 5]. In particular, it is suggested that the least aqueously altered parts are type 2.9 [4, 5], resulting in Paris to be considered as among the most pristine meteorites. Paris being a CM chondrite, its aqueous alteration is the main secondary process that has been considered, while its thermal history has been mostly overlooked. In the present work, by combining several analytical techniques on sub-samples of Paris, our objectives are twofold: *(i)* assess, through independent tracers, aqueous and thermal alteration of the Paris meteorite at the millimeter scale; and *(ii)* further refine our understanding of reflectance spectra of such materials. Reflectance spectroscopy is one of the main tool to characterize asteroids and to establish genetic links with meteorites. However, the interpretation of some spectral bands in terms of composition is not necessarily straightforward. We are here particularly interested in the mineralogical control of the so-called 0.7-micron band used as a proxy for hydrated minerals on asteroids [e.g., 6] and that is sometimes observed and sometimes not on Ryugu [e.g., 7], the asteroidal target of Hayabusa-2.

Methods: Eleven raw sub-samples with mass in the 50-100 mg range were obtained from a slice of Paris. The magnetic properties of these sub-samples have been previously characterized [4]. Each of these sub-samples are several millimeter apart and were subsequently characterized through the following analytical sequence: *(i)* magnetic hysteresis measurements of bulk sub-samples to quantify the abundance of ferromagnetic minerals; *(ii)* Raman spectroscopy of matrix grains to characterized the structural order of the polyaromatic carbonaceous matter to assess their thermal history [e.g. 8]; *(iii)* IR measurements of matrix grains in transmission, under vacuum and a low temperature, to assess the extent of aqueous alteration [9]; *(iv)* reflectance spectroscopy in ambiant conditions, and under vacuum with the SHADOWS instrument [10]; *(v)* synchrotron X-ray diffraction (Beam line 3A in KEK, Tsukuba, Japan) to identify and quantify the mineralogy.

Results and discussion: The combination of the above-mentioned analytical techniques reveals a high variability of hydration and thermal history among the considered sub-samples of Paris. In particular, some samples are characterized by *(i)* a variable hydration and absence of significant heating (group A, 7/11 samples), and *(ii)* a limited hydration, but clear evidence of heating (group B, 4/11 samples). Raman data will be further investigated to understand whether the thermal history is due to short-time heating related to e.g., shock, as commonly observed among CM chondrites [8, 11], or to radiogenic long-term thermal metamorphism. In comparison to non-heated samples, heated samples are characterized by higher abundances of magnetite, serpentine in decomposition, absence of tochilinite, very shallow 3-microns band, and reflectance spectra clearly distinct from typical CM chondrites and other heated CM chondrites [e.g., 12]. Hydrated and non-heated samples (group A) are characterized by a clear dominance of metal over magnetite, a variable 3 microns bands, presence of tochilinite and serpentine, and most likely presence of amorphous silicates. These sub-samples experienced aqueous alteration, but to an extent clearly lower than in most CM chondrites. They most likely correspond to the "pristine" lithology as described in the literature [4, 5]. The presence of a significant abundance of magnetite in the very poorly hydrated but heated samples (group B), and the presence of metal dominating over magnetite in poorly hydrated but non-heated samples of Paris could be explained by hydration (leading to the formation of magnetite) followed by dehydration (explaining serpentine decomposition) through the heating process. Interestingly, the reflectance spectra of the hydrated samples all exhibit the 3 micron band, but not systematically the 0.7 micron band, only visible on the most aqueously altered samples. We will further investigate its mineralogical carrier through comparison of spectral and diffraction data. The present study also clearly underlines the mm-scale variability of this meteorite. Such variability is often overlooked when tentatively establishing genetic link between meteorites and asteroids.

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