DEVELOPMENT OF AN ADVANCED ELECTRON MICROSCOPY METHODOLOGY: COMPARISON OF THE MINERALOGY OF FINE-GRAINED RIMS AND ADJACENT MATRIX IN THE CM PARIS CHONDRITE. P-M. Zanetta[1], H. Leroux[1], C. Le Guillou[1], B. Zanda[2]. [1]UMET, Université de Lille & CNRS, F-59655 Villeneuve-d'Ascq, France. [2] IMPMC, Sorbonne Université, MNHN, UPMC Paris 06, UMR CNRS 7590, IRD UMR 206, 75005 Paris, France. Mail: pierre-marie.zanetta@ed.univ-lille1.fr

Introduction: Fine-grained rims (FGRs) are dust-sized material that surrounds chondrules and refractory inclusions in chondritic meteorites. As matrix, they consist of an unequilibrated mineral assemblage made of a groundmass of amorphous silicates and Mg-Fe rich phyllosilicates which embed numerous inclusions of anhydrous silicates, sulfides, metal and organic compounds [1]. The origin of FGRs is debated and formation in both nebular and parent body settings have been proposed [2-4]. Although FGRs certainly carry a diversity of information about processes which took place during accretion in the early solar system, scenarii of formation cannot be easily discriminated since investigations are limited by the spatial resolution of analyzes on a sufficiently large area to be representative of the whole rims. So far, no clear compositional or mineralogical differences between FGRs and matrix could be evidenced.

In this study, to differentiate matrices and chondrule rims, and eventually place constraints on the nature of the dust and the accretion conditions, we developed a new analytical method coupling phase cartography based on low-voltage energy dispersive spectroscopy (EDS) and conventional electron probe micro-analysis (EPMA) quantification. The aim is to simultaneously quantify: a) the composition and modal abundance of submicrometric phases, b) determine the physical properties of grains (notably the grain size), c) estimate porosity and density.

Samples: We developed the methodology through the analysis of matrices of Orgueil, Murchison and Paris. The Paris chondrite has been chosen for the FGRs study for its primitiveness [5] and because it contains lithologies showing different alteration degree.

Methods: We acquired hyperspectral chemical maps by EDS on a field emission scanning electron microscope (FESEM) at low accelerating voltage (5-6 kV) in order to reach a spatial resolution of ≈ 300 nm. Data are processed using hyperspy [6].

Phase cartography and quantification: The first step is to produce accurate maps of the X-ray counts per elements. The background is removed and Gaussian functions are fitted for each X-ray line. Then, elementary maps are analyzed by a clustering algorithm and an accurate phase cartography is obtained. For pixels showing contribution of different phases, an additional linear combination fitting is performed. We thus obtain precise grain sizes and modal abundances. To obtain bulk compositions, we measured the largest representative grains by EPMA and modal abundances are used to perform the mass balance.

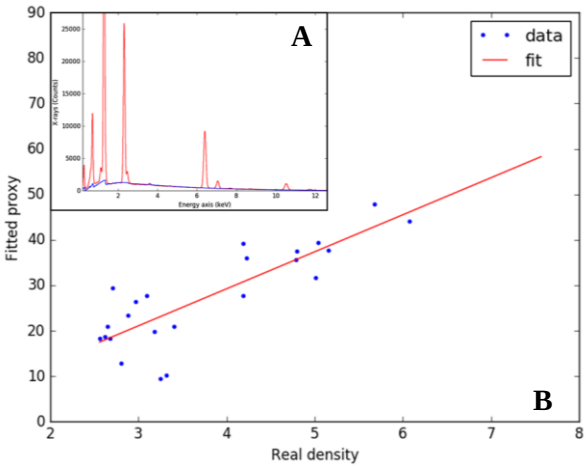

Fig 1 : *A. Bremsstrahlung modelisation of a spectrum. B. Value of fitted proxies compared to standard values.*

Volumic mass determination: To determine the amount of porosity of rims and the density of the constitutive material we modeled the EDS spectra background (Brehmsstrahlung) which is a function of density. We used a physical expression which takes into account the Kramer emission law and the absorption by the detector, the coating layer and the thick target. Compositions are known from EMPA and the mass depth "ρz" is the single free parameter which has to be fitted (Fig.1.A). The "ρz" proxy is calibrated using a series of standards (Fig.1.B) and can be used to map the volumic mass.

This thorough methodological development allows to compare modal abundances, grain size distributions, densities and bulk composition of matrices and chondrule rims of chondrites with an improved spatial resolution.

Results: Applied to different meteorites, this method highlights a mineralogical heterogeneity of matrices even if compositions are close to chondritic values. Matrices are dominated by a mixture of amorphous silicates and phyllosilicates ranges from 76±6 % in Paris, 81±3% in Murchison and up to 94±1% in Orgueil. Conversely, anhydrous silicates represent

3±0,5% of the matrix of Murchison and reach 17±2% for the unaltered part of the matrix of Paris (0% in Orgueil). Different cartographies within the same meteorite yield similar results, showing that the scale of analysis is pertinent. In Paris, the amount of amorphous silicates/phyllosilicate varies between 75±6% for the unaltered parts of the matrix to 79±6% for more altered regions. Also, anhydrous silicates fluctuate from 17±2% to 13±1,4% between these two regions.

The volumic mass determination method has been applied to one cartography in the matrix of Paris and reveals a density variation from 1.1 to 2.1 ± 0.7 g/cm^3 for the amorphous/phyllosilicate regions. Assuming a density of 2.3 g/cm^3 for the silicate itself, it would correspond to a porosity of 9% to 52%, which appears consistent with TEM observation [7].

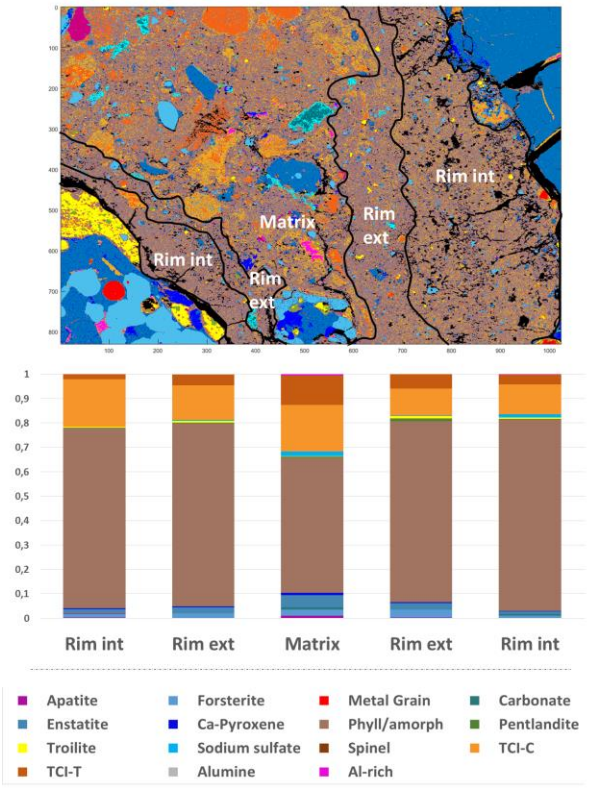

Fig 2: *Phase cartography and modal abundances of two chondrules rim contacts.*

In the Paris meteorite, FGRs are present around many chondrules, metal grains, and chondrules fragment. In addition, a few chondrules display a second external rim enclosing the internal one (Fig.2). This second rim is always fragmented and never mantles the chondrule completely. Interesting differences are observed between FGRs and the matrix. The average grain size of inclusions is about 806 nm for the internal rim, 712 nm for the external one and 1.2 µm for the matrix. The phase analysis also indicates that similar phases are present in both lithologies, but their modal abundances differ significantly (Fig. 2). Tochilinite (TCI-T) is well developed in the matrix (12% vol. %) but is less abundant in FGRs (2,5% in the internal rim and 5% in the external rim). This phase surrounds the FGRs but is limited at the interface of those two entities. The same is true for carbonates and sulfates (1 and 2% respectively in the matrix), which are almost absent from the rims (<1%). In contrast, the abundance of amorphous silicates + phyllosilicates is always higher in FGRs (91% for the internal and 88% for the external rim), compared to the matrix (74%).

Discussion: Our method allows to retrieve chondritic concentrations with some minor deviations for the fine-grained material of Murchison, Paris and Orgueil. Phase cartographies reveals that both mineralogy and modal abundances of matrices are related to the degree of alteration in agreement with [8].

The methodology implemented has made possible to highlight significant differences in modal abundances between the matrix and FGRs around chondrules. The volume of secondary phases as tochilinite, carbonates or sulfates is higher in the matrix and suggests that alteration is more advanced in the matrix, but other observations such as the higher abundance of amorphous material and phyllosilicates in the FGR, the grain size, as well as partially altered metal grains in adjacent chondrules make the interpretation ambiguous. The determination of the amorphous silicates/phyllosilicate ratio from TEM investigation as well as water content in both lithologies should help us to better determine the relative alteration degree of these two entities.

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