A NEW METHOD FOR MODAL ABUNDANCE, CHEMISTRY AND DENSITY DETERMINATION OF FINE GRAINED MATRICES OF PRIMITIVE CHONDRITES.

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Introduction: Primitive chondrites are among the most pristine material at our disposal. Their matrix inherited primordial dust from the protoplanetary disk [1]. This heterogeneous dust originates from multiple environements and has recorded nebular as well as secondary parent body processes. However, the extremely fine-grained material, heterogeneous compositions and densities make it difficult to analyze by conventional techniques such as EPMA with a defocused beam (5-20 µm) and very high resolution techniques are therefore required for its mineralogical analysis. In this study, we propose a new methodology coupling low-voltage SEM-EDS and conventional EPMA to simultaneously improve the estimation of modal abundances, acquire the chemistry and determine the density of each phase. Based on these three parameters, refined global chemistry of matrices could be established. This method is applied to the well studied Murchison, Orgueil and Paris chondrites, used as "reference samples".

Methods: We acquired hyperspectral maps by FESEM - EDS at 5 kV, providing an analytical spatial resolution of ≈ 250 nanometers. In order to obtain elemental maps, spectra were analyzed with the Hyperspy library [2]. From these maps, composition fields were plotted as a function of the different elements (Mg, Si, Fe or S). Then, cluster distribution based on relative chemistry allowed us to infer phase cartography [3], grain sizes, and modal abundances for each phase. Compositions of the largest grains were measured afterwards separately, by point EMP analyses to obtain an accurate composition for each phase. Finally the average global chemistry was obtained by the combination of modal abundances and compositions of the different phases. However, to turn chemical values into a volumic mass %, it was necessary to have access to the densities of the different phases. Most of the phases have a known density (forsterite, metal, sulfides for instance), but the density of the very fine grained regions, constituted by a mixture of amorphous, phyllosilicates and porosity, was unknown. A relation based on Bremsstrahlung emission was therefore established for the determination of density. At each pixel, Bremsstrahlung was extracted and normalized to the mean atomic number. A calibration was obtained by plotting the integrated and normalized Bremsstralhung compared to the density of known phases. This calibration, allowed us to take into account the porosity of the amorphous/phyllosilicate regions, which improved our final chemical values.

Results and discussion: Up to now, fine-grained matrix mineralogy could only be obtained quantitavely from XRD [4]. Our new approach allows us to refine the modal abundances, and provides a combined analysis of the chemistry, phase relationship, grain size distribution and density of chondritic matrices. Preliminary data show that Orgueil bulk chemistry determined with this new approach correlates well (R2 ~ 0.923) with the composition determined by wet chemistry [5]. Modal abundances are also in agreement with published values. Orgueil matrix contain 52% saponite, 45% serpentine and accessory phases such as magnetite, pentlandite and carbonates. The average density obtained with the integrated bremsstrahlung calibration (R2 ~ 0.951) in the Paris meteorite yields values of 2.3±0.11 g/cm3 for Fe-poor phyllosilicates regions and 2.9±0.14 g/cm3 for the Fe-rich phyllosilicate regions, which seems to be in agreement with nominal densities. Areas with a lower density were found as sub-parts of the same regions, and SEM high-resolution images confirm the presence of this local porosity. These results, show our new method to be most adapted for the analysis of fine-grained material and demonstrated its good robustness for different samples of the matrix. Results on the Murchison chondrite will also be presented at the conference.

Conclusion: Chemical and mineralogical improvement achieved with this new approach will be used in the future to improve our understanding of the matrix origin and evolution and to better constrain: i) the nature of the heterogeneity of matrix materials (amorphous silicate, anhydrous phases, organics); ii) hydrothermal alteration and iii) the chemical relationship between chondrules and matrix [6]. The scope of application of this method also includes the study of submicrometric mineral assemblages (analyses of rims, shocks effect on minerals, or nature of breccias).

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