MINERALS AS MARKERS OF FLUID ALTERATION IN PARIS CHONDRITE

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Introduction: CM chondrites can help to decipher the processes of planetary formation in the protoplanetary disk, but their record is blurred by fluid alteration [1]. Although it is widely acknowledged that the fluid alteration affect the texture, mineralogy, chemical and isotopical properties of CMs, main questions are still open: under what physicochemical conditions did the alteration occur (e.g., pH, T, fO_2)? What are the timing and the duration of the alteration? In order to better constraint that, we focused on Paris metorite that is the least altered chondrite [2] and offers the opportunity to reconstruct the earliet stages of alteration. Thus, we present here a nanoscale study of tochilinite/cronstedtite intergrowths (TCIs), TCIs being the emblematic seconday mineral assemblages of CM chondrites, formed from the alteration of Fe-Ni beads (type-I TCIs) and by pseudomorphism of anhydrous minerals (type-II TCIs) [3, 4, 5].

Experimental: TCIs analysis were perfomed on the 2010-1 section of Paris chondrite by using several techniques, such us scanning and transmission electron muicroscopy (SEM and TEM), X-ray adsorption near-edge structure spectroscopy carried out with a scanning transmission X-ray microscope (STXM-XANES), and electron diffraction tomography (EDT), to characterize the crystal structure, crystal chemistry and redox state of different minerals.

Results and Discussion: The results show that TCIs were dispersed throughout the Paris matrix, regardless of its alteration degree. Type-I TCIs are composed of tochilinite/cronstedtite intergrowths whereas type-II TCIs are characterized by a complex zoning, comprising three Fe-bearing minerals: tochilinite, cronstedtite and hydroxides. The preserved morphology and the presence of remnant are used to recognized the precursors of type-II TCIs, i.e. olvine and pyroxene crystals [3]. The mineralogical data indicate that the first stage of alteration is marked by the formation of tochilinite trough the interaction of silicate precursors with a S-rich fluid. The second stage is characterised by a change in fluid composition, which is enriched in Si and depleted in S, preventing the tochilinite crystallization and favoring the precipitation of cronstedtite. The incorporation of silicon in this mineral reduces the Si concentration in the fluid, and iron hydroxides can form in the last alteration stage. Hydroxides probably formed as ferrihydrite and then progressively converted to goethite between 50° and 80°C, a temperature range that is also favourable for cronstedtite formation [5]. The presence of cronstedtite proves that Paris alteration took place by way of serpentinization processes. The H_2 release during serpentinization is estimated using $Fe^{3+}/\Sigma Fe$ ratio obtained with STXM-XANES [5]. This ratio can be also used as proxy of alteration degree: Paris, in fact, is characterised by serpentines the lowest Fe^{3+} content with respect to those of other CMs and the oxidation degree appears to increase with the extent of CMs' alteration. Moreover, the presence of ferric iron is also detected in tochilinite (8-15%), where it is partially due to the intergrowth with tochilinite as shown by HRTEM data. Neverthless, Fe^{3+} in tochilinite is incorporate in the the hydroxide layer to balance the net negative charge resulting from the vacancies in the sulfide layer [6]. The presence of Fe^{3+} in this minerals shows that the alteration occurred under oxidizing conditions from the first stage and contradicts the thermodynamic calculations suggesting that tochilinite forms under very reduced conditions [7].

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