3D IMAGING OF GLASS INCLUSIONS FROM ALLENDE (CV3) OLIVINES: A NEW INSIGHT ON OLIVINES FORMATION CONDITIONS.

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Introduction: Glass inclusions are magma droplets trapped by growing host-minerals [1] which can be observed in chondrites, especially in olivine, both isolated or from chondrules. These inclusions resemble terrestrial melt inclusions [2] and are thus thought to have recorded the environmental conditions in which their host grew. Inclusions in Mg-rich olivine have a chemical composition that is not at equilibrium with their host [3] which origin is still debated today to be gaseous [4] or planetary melt cristallization [5]. However, experimental work on olivine formation established that inclusions did not necessarily keep the original chemical composition of the melt, depending on the process that controls the olivine growth, diffusion or interface attachment processes [6]. These two different processes can indeed take place: (1) if thermal conditions allow it, olivine grows by surface reaction and the melt of the inclusion should be representative of the original melt. (2) If olivine grows by diffusion, the melt is then what remains from the original liquid. In this last case, chondrules' thermal history may be rebuilt with diffusion profiles.

Furthermore, during their formation, melt inclusions may also trap the chemical boundary layer at the crystal-liquid interface in case of a rapid growth of the (skeletal) host crystal [6]. If this boundary layer is trapped in a glass inclusion, the liquid composition will be enriched in incompatible elements rejected from the olivine structure such as Al and Ca. As Ca diffuses much faster than Al [7], the Al_2O_3/CaO ratio should then be very sensitive to the boundary layer effect.

A recent study established at nanometric scale that no such boundary layer could be observed for inclusions from Semarkona type II chondrules, but that a two microns chemical zoning were present at the inclusion-olivine interface, that seems related to diffusion [8]. However, no such data exist for type I chondrules which origin is still presently debated. In this study, synthetic melt inclusions trapped in olivines crystallized from CMAS glasses [9] and natural inclusions in Mg-rich olivines from Allende (CV3) type I chondrules were analyzed. They were characterized as primary inclusions and chosen with a bubble and between 5 and 15 µm.

Analytical techniques: The major elements (Al, Ca, Mg, Si) were analyzed with a 130 to 200 pA Cs^+ beam to provide 3D chemical images on a 30x30 µm area in using the IMS 1280 Secondary Ion Mass Spectrometer (SIMS) at CRPG, Nancy (France). For each sample, the whole inclusion was sputered, in order to collect depth profiles.

Results and discussion: In synthetic inclusions, no enrichment of incompatible element is observed at the periphery of the inclusions. For such inclusions, trapped in slow-growing olivines formed in metastable equilibrium, this absence of boundary layer was expected. It reflects that olivine grew slowly enough for the magma to equilibrate around them at all times. These results also confirm that olivines formed in metastable equilibrium trap valuable inclusions which composition reflects the initial magma.

In Allende's inclusions, preliminary results do not show any limit layer, suggesting that whatever environment olivine grew in, they grew slowly enough to keep being chemically at equilibrium (or metastable equilibrium) with their close environment. No diffusion profile was seen so far, suggesting that olivine did not grow rapidly and therefore growth was not controlled by diffusion. These results put further constraints on growth rate of the olivines of Allende's chondrules and suggest that they must have grown slowly enough for inclusions to trap homogenous magma at metastable equilibrium with their hosts. Indeed, natural samples seem very similar to synthetic ones, which were formed by cristallization of olivine in a slow-cooling magma. Thus, our results are in favor of a planetesimal origin for the olivines.

References:

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