OXYGEN ISOTOPIC DIVERSITY OF CHONDRULE PRECURSORS AND THE NEBULAR ORIGIN OF CHONDRULES.

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Introduction: Chondrules (millimeter-sized igneous spheroids containing silicates, metal, sulfides, and glass) are the major high-temperature components of primitive meteorites (chondrites), suggesting that most inner solar system materials were affected by their formation. However, the underlying mechanism(s) of their formation remains a mystery and diverse scenarios are debated in contemporaneous literature. A key clue to their origin would be the identification of the precursor material that was melted to form chondrules. In this effort, cosmochemists may find help in the incomplete melting of most chondrules, as evidenced by their widespread porphyritic texture. Relict olivine grains could correspond to (i) early condensates from the gas of the solar protoplanetary disk [1], (ii) collisional debris from early-generation planetesimals [2] and/or (iii) earlier generations of chondrules [3]. Progress on the identification of the origin of relict olivine grains is frustrated by our poor understanding of their abundance, distribution and specific chemical compositions. Here we report a method combining high-resolution X-ray maps, electron microprobe analyses, and SIMS oxygen isotope measurements to quantitatively assess for the first time the nature of relict olivine grains in type I chondrules.

Materiel and methods: High-resolution X-ray element distribution maps were performed at the Institut des Sciences de la Terre (ISTerre, Grenoble, France) with an acceleration voltage of 20 kV, beam current of 500 nA, 1.5-μm step size, and dwell time of 500 ms. Al, Ca, Cr, Mn and Ti were measured by WDS while Fe, Si and Mg were measured by EDS. Quantitative analyses of all olivine grains large enough to be isotopically characterized by SIMS were then performed with the following conditions: accelerating voltage 20 kV, probe current 900 nA, beam diameter 1 μm, and 320 s total peak/background counting time. Such a high current and long counting time allow very low detection limits estimated to be 10 ppm for Al, Ca, Ti, Cr and Mn.

Results: Our high-resolution titanium X-ray maps of porphyritic chondrules reveal different populations of olivine grains characterized by variable titanium contents. Ti-poor olivine grains are mainly located in the center of chondrule but also occur as the center of olivine crystals dispersed throughout the chondrules. The oxygen isotopic compositions of Ti-poor olivine grains differ markedly from those of their hosts (olivine grains with higher Ti concentrations). Our results thus demonstrate that olivine Ti concentrations allow the relict and host olivine grains to be distinguished.

Discussion: Coarse-grained olivine aggregates showing 120° triple junctions, such as in our PO chondrules analyzed, were interpreted by [2] as potential fragments of differentiated planetesimals that experienced disruption early in the Solar System history. Our results show that large mass-independent O-isotope variations occur within chondrules showing triple junctions. This does not support a planetary origin of granoblastic olivine aggregates as crystallization from a magma ocean would result in very limited *and* mass-dependent O-isotopic fractionation.

We propose that porphyritic chondrules formed during gas-assisted melting of nebular condensates comprising relict olivine grains with varying $\Delta^{17}O$ values and Ca-Al-Ti-rich minerals such as those observed within amoeboid olivine aggregates. Incomplete melting of chondrule precursors produced Ca-Al-Ti-rich melts (CAT-melts), allowing subsequent crystallization of Ca-Al-Ti-rich host olivine crystals *via* epitaxial growth on relict olivine grains. Incoming MgO and SiO from the gas phase induced (i) the dilution of CAT-melts, as attested by the positive Al-Ti correlation observed in chondrule olivine crystals, and (ii) buffering of the O-isotope compositions of chondrules, as recorded by the constant $\Delta^{17}O$ values of host olivine grains. The O-isotopic compositions of host olivine grains are chondrule-specific, suggesting that chondrules formed in an array of environments of the protoplanetary disk with different $\Delta^{17}O$ values, possibly due to variable solid/gas mixing ratios.

References: [1] Jacquet E. & Marrocchi Y. (2017) *Meteoritics & Planetary Science* 52: 2672-2694. [2] Libourel G. & Krot A.N. (2007) *Earth and Planetary Science Letters* 254:1-8. [3] Ruzicka et al. (2007) *Geochimica et Cosmochimica Acta* 79: 79–105.