MINERALOGICAL CHONDRULE ZONATION IN CHONDRITES.

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Introduction: A large fraction of chondrules in chondritic meteorites is mineralogically zoned [1, 2]. These zoned chondrules consist of an olivine core, surrounded by a low-Ca pyroxene rim (Fig. 1). We examine and compare the appearance, abundance and distribution of mineralogically zoned chondrules in almost 30 carbonaceous (CC), ordinary (OC) and enstatite (EC) chondrites. The results provide insights to the origin of chondrule textures, bulk compositional variations, conditions of chondrule formation and the origin of chondrule-matrix complementarity.

Methods: Chondrule zonation and mineral compositions were investigated with an electron microprobe by spot analyses and element mapping. Phase maps were created from the elemental distribution of Mg and Si with the Mathematica application PHAPS [3]. Phase maps are false color images of the minerals and can be used to identify olivine, pyroxene and mesostasis, as well as structural properties such as rim thicknesses, abundances and distributions. 3D studies of chondrule textures were performed on thick sections of Efremovka (CV3) and Moorabie (L), which we serial sectioned in steps of ~70 µm, producing a phase map of the entire section at each step.

Results: We present the 2D textural characteristics of ~1000 studied chondrules from all chondrite classes. This includes data already presented by [1] & [2], as well as new data. The fraction of zoned chondrules is, on average, 80% in carbonaceous chondrites, 63% in Rumuruti chondrites, 40% in ordinary chondrites and less than 40% in EC (Fig 1a). Determining the portion of zoned chondrules in EC is, however, still in progress. All zoned chondrules feature weak to strong poikilitic, low-Ca pyroxene rims that surround or enclose the olivine (Fig. 1b). The portion of zoned chondrules in Efremovka is 64% when determined in 2D sections, but higher when determined in 3D (~80%).

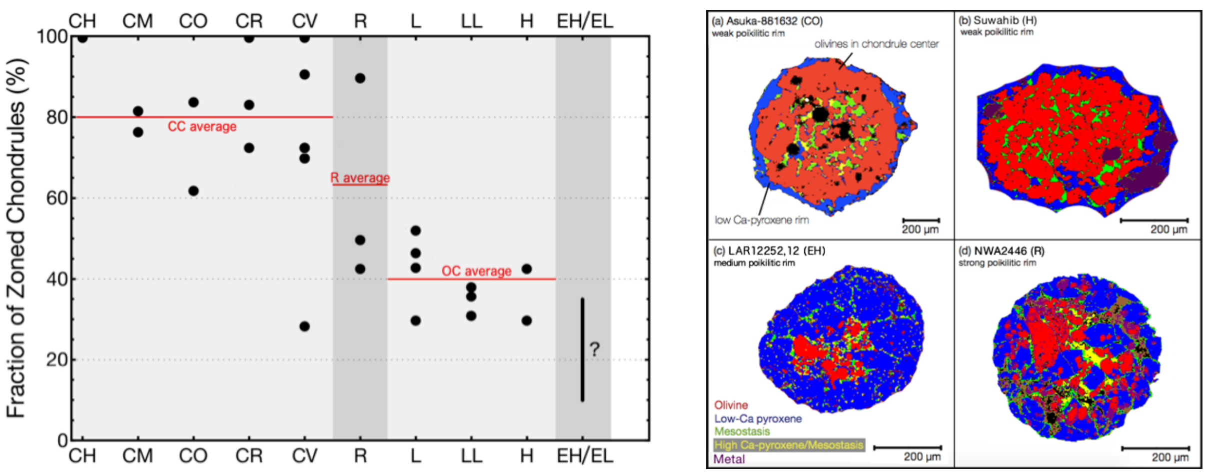

Fig. 1: Left: Fraction of zoned chondrules in different chondrites [1, 2]. Right: Examples for mineralogically zoned chondrules in (a) CO [1] and (b, c, d) L-chondrites with weak to strong poikilitic, low-Ca pyroxene rims.

Discussion: Zoned chondrules are a typical chondrule texture in all studied chondrites and represent one large subpopulation of all chondrules. The portion of zoned chondrules declines from carbonaceous to enstatite chondrites. Non-mineralogically zoned chondrules constitute the second sub-population of all chondrules. These unzoned chondrules might have formed when a portion of initially zoned chondrules were remolten and homogenized their low-Ca pyroxene rims [2]. However, some of the unzoned chondrules are simply rim-sections of mineralogically zoned chondrules, in which case these need to be added to the zoned chondrules. The true (3D) amount of zoned chondrules in a meteorite section is ~15% higher than the respective 2D count.

Conclusions: Mineralogical zonation introduces fundamental constraints on chondrule formation conditions. Low-Ca pyroxene rims formed by substantial interaction and exchange of material with the surrounding gas. Mineralogical zonation therefore strongly supports protoplanetary disk processes in which chondrules acted as open systems [1, 2, 4, 5]. The reaction was: SiO-rich gas, plus chondrule olivine, forming pyroxene. The open system scenario is in agreement with previous studies on chondrule formation, as well as chondrule-matrix complementarity [e.g. 6].

References: [1] Friend, P. et al. (2016) *Geochim. Cosmochim. Acta, 173,* 198–209. [2] Barosch, J. et al. (2018) *Geochim. Cosmochim. Acta,* in review. [3] Hezel, D. C. (2010) *Comput. Geosci., 36,* 1097–1099. [4] Tissandier, L. et al. (2002) *Meteor. Planet. Sci. 37*, 1377–1389. [5] Libourel et al. (2006) *Earth Planet. Sc. Letters 251*, 232–240. [6] Hezel, D.C. et al. (2008) *Earth Planet. Sc. Lett. 265*, 716–725.