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Micromagnetic and Microstructural Analyses of Individual Chondrules From the Allende Carbonaceous Chondrite

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Results of micromagnetic and microstructural studies of individual chondrules from the Allende meteorite are presented. Allende is a member of the CV3 carbonaceous chondrites, and part of the oxidized meteorites with iron in silicates and oxides. For this study, we separated 100 individual chondrules from a piece of Allende. Magnetic hysteresis data in terms of plots of parameter ratios give relationships with chondrule size and shape, in particular with magnetization ratio (Mr/Ms) and coercivity (Hc). Morphology, internal structure and elemental composition are investigated by scanning electron microscope and WDS spectrometer analyses. Chondrules show low ranges of magnetization ratios (Mr/Ms from 0 to 0.22) and coercivity (Hc from 3 to 24 mT). Low values suggest that chondrules are susceptible to alteration and re-magnetization, which affects paleointensity determinations for the early planetary magnetic fields A linear relation of Mr/Ms as a function of Hc is found up to values of =0.17 and 17 mT, respectively. This relation correlates with internal microstructure and composition, with compound chondrules showing higher hysteresis ratio and parameter values. Chondrules with hysteresis parameters falling outside the major trend show internal structures, composition and textures indicative of compound chondrules, and fragmentation and alteration processes. SEM and WDS analyses show distinct mineralogical assemblages with spatial compositional variation related to chondrule size, shape and microstructure. We also analyze the internal spatial elemental distribution of Fe, Ni and S in minerals within selected individual chondrules, which were selected to cover the range of sizes and micromagnetic properties in terms of hysteresis coercivity and magnetization ratios. Variation in micromagnetic properties appear correlated to the external and internal morphologies and mineralogical assemblages. For the analysis we applied a mathematical technique for image analysis to the SEM-EDS images. The resulting compositional images illustrate the complexity in composition and microstructural morphologies of individual chondrules, and show that closely spaced chondrules within given sectors of Allende meteorite have major differences in elemental content and distribution, in addition to differences in shape, size, density, texture, mineralogy and rock magnetic properties, which support that chondrules underwent distinct thermal, shock, alteration and evolutionary histories, related to chondrule formation and alteration processes, in the early stages of evolution of the planetary system.