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Setting of equilibration process in the EH chondrites based on chondrule types and silica polymorphs

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Metamorphism on the EH-chondrite parent body caused equilibration of many EH-chondrites; however, some steps toward equilibration may have occurred during chondrule formation and possibly other heating events in the nebula, before formation of the parent body. The purpose of this study is to distinguish between parent-body and nebular settings of equilibration in the EH chondrites. If equilibration occurred only on the parent body, then all EH chondrites should have formed initially from the same types of chondrules. If some equilibration occurred during chondrule formation, then different EH chondrites might form from variable types of chondrules.

This study investigates the setting of equilibration of EH chondrites from features of chondrules and silica polymorphs. We defined chondrule type using: texture (porphyritic, microcrystalline, barred, radial); mineral composition (olivine vs. pyroxene); shape (fragmented vs. whole); and presence or absence of a SiO^2-rich rim. Silica polymorphs were identified from Raman spectra. BSE, SEM and elemental maps were obtained by electron microprobe JEOL JXA-8900 at Waseda University and were used to characterize chondrules. Raman spectra were obtained by Jobin Yvon LabRam300 micro-spectrometer (HORIA) and air cooled CCD detector at Waseda University. Chondrule types were identified in polished thin sections of the following chondrites: four EH3 chondrites (ALHA81189; MET 01018; ALH 84170; PCA 82518) and one EH5 chondrite (St. Marks).

The chondrules in St. Marks have hazy, recrystallized boundaries, whereas chondrules in the EH3 chondrites have sharp, well-defined boundaries and are easy to recognize. Chondrules with SiO^2-rich rims and olivine phenocrysts were identified in all of the EH3 chondrites. On the other hand, no olivine-bearing chondrules and no chondrules with SiO^2-rich rims were identified in St. Marks. In fact, no olivine was identified at all in St. Marks. Silica is present in St. Marks, but as relatively coarse, subhedral to euhedral crystals, in contrast to the fine silica grains present in the EH3 chondrites. The only silica polymorph identified in St. Marks is quartz. This indicates St. Marks equilibrated at relatively low temperature or slow cooling rate. The differences between the EH3s and St. Marks are in all probability due to parent-body metamorphism.

Among the EH3s, ALHA81189 has high percentage of olivine-bearing chondrules (58%) and of chondrules with SiO2-rich rims (43%). The other EH3 chondrites are composed mainly of pyroxene-rich, olivine-absent chondrules (~85%) with fewer SiO^2-rich rims (20% or less). ALHA81189 is also distinct from the other EH3 chondrites based on chondrule shapes. In ALHA81189 ~35% of the chondrules identified are whole, whereas only ~10% of chondrules in the other EH3s appear to be unfragmented.

These features indicate that ALHA81189 is distinct from the other EH3 chondrites and relatively unequilibrated; however, the only silica polymorph identified in ALHA81189 was cristobalite. In contrast, in ALH 84170, cristobalite, tridymite and quartz all are present (also see [1]).

The silica from ALHA81189 experienced rapid cooling from high temperatures suggestive of chondrule formation. Much of the silica in ALH 84170 had a similar origin, but the presence of quartz indicates some silica in this meteorite formed at higher pressures, lower temperatures or lower cooling rates. The best candidate for the origin of the ALH 84170 quartz is parent-body metamorphism; however, this meteorite is unequilibrated, suggesting that the quartz formed during metamorphism prior to accretion of the ALH 84170 parent body. The presence of quartz in ALH 84170 indicates that ALH 84170 was derived from materials that experienced parent-body processing. In contrast, ALHA81189 formed from material processed mostly during chondrule formation.

Reference: [1] Kimura et al. (2005) Meteorit. & Planet. Sci. 40, 855-868.