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Formation ages and places of hydrated chondrite parent bodies

FUJIYA, Wataru[1*]

[1]Max Planck Institute

When and where hydrated chondrite parent bodies accreted is a key question to understand the origin of chondritic water and the dynamical processes of the solar system evolution.

The ages of aqueous alteration can be inferred from ^{53}Mn-^{53}Cr systematics of aqueously-formed secondary minerals (carbonates in CM, CI, and CR chondrites and fayalite in CV, CO, and ordinary chondrites). The ^{53}Mn-^{53}Cr ages of carbonates and fayalite in carbonaceous chondrites (CCs) are similar, 3.5 – 5 Myr after the birth of the solar system (represented by CAIs in CVs) (Fujiya et al., 2013; Doyle et al., submitted). Fayalite in ordinary chondrites (OCs) seems to have formed slightly earlier ($\sim$1 Myr) than that in CCs. These observations are consistent with ^{26}Al-^{26}Mg ages of chondrules (e.g., Kita and Ushikubo, 2012). The ^{53}Mn-^{53}Cr ages of aqueous alteration indicate that water activity on CC and OC parent bodies started almost contemporaneously, and that the dominant heat source for aqueous alteration is the decay energy of ^{26}Al (half-life: 0.7 Myr). Based on these ages, numerical simulations of the thermal history of CC and OC parent bodies suggest that they accreted 2.5 – 4 Myr after CAIs (Sugiura and Fujiya, 2014).

The formation places of chondrite parent bodies in the protoplanetary disk are more difficult to be inferred. The estimated water (ice) to rock mass ratios of CCs and OCs ($<$0.6) (e.g., Clayton and Mayeda, 1999), significantly lower than the solar value (1.2) (Lodders, 2003), suggest that CC and OC parent bodies accreted near from the snow line. The inferred D/H ratios and O isotopic compositions of water in CCs are likely to be significantly different from those of primordial (molecular cloud) water and/or most Oort-cloud comets measured so far, indicating that they must have recorded various degrees of isotopic re-equilibration between primordial water and nebular gas (Alexander et al., 2012; Krot et al., 2013). Model predictions on the location of the snow line 2.5 – 4 Myr after CAIs (e.g., Ciesla and Cuzzi; 2006) and both the temporal and the spatial distribution of H and O isotopic ratios of water in the protoplanetary disk (e.g., Yang et al., 2011, 2013) suggest that hydrated chondrite parent bodies accreted in the main asteroid belt. I am currently trying to constrain the contribution of C from cometary inorganic ice to the C inventory in CCs. Carbon isotopic ratios of carbonates in Murchison (CM) suggest that C reservoirs in primitive aqueous fluids were highly enriched in ^{13}C with δ^{13}C $>$70 ‰, which provides no evidence for C contribution from cometary ice (Fujiya et al., submitted).

Keywords: Hydrated chondrites, Formation ages, Formation places, Compositions of stable isotopes