Dating the Earth-like Reservoir Formation in the Solar Nebula with Enstatite Chondrite

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Here we report the ^{53}Mn-^{53}Cr age of chondrules extracted from the most primitive and most reduced EH3-type enstatite chondrite, *Qingzhen*. The ^{53}Mn-^{53}Cr isochron gives an initial ^{53}Mn/^{55}Mn of $(3.69\pm1.08)\times10^{-6}$ and $e^{53}Cr_i$ = -0.11±0.08 (MSWD = 0.44). Relative to the D'Orbigny age anchor with its U isotope-corrected Pb-Pb age (Amelin, 2008; Brennecka and Wadhwa, 2012) and its precise ^{53}Mn/^{55}Mn (Glavin et al., 2004; Yin et al., 2009), we obtain a 4,564.8±1.6 Ma formation age of Qingzhen's chondrules.

Unlike Allende (CV3) chondrules (Yin et al., 2009), the e^{54}Cr anomaly of each individual chondrule in Qingzhen is uniform and Earth-like (with an average ε^{54}Cr = 0.12±0.14). We argue that our Qingzhen chondrule ^{53}Mn-^{53}Cr age dates the Earth-like pre-planetary reservoir formation/isolation in the solar nebula, which is distinct isotopically from most materials in the inner Solar System. Isotopic homogeneity of this reservoir is clearly established at both micro- and macroscopic levels by 4,564.8±1.6 Ma. Because our ^{53}Mn-^{53}Cr age precede the Moon-forming giant impact (Yin et al., 2002; Kleine et al., 2009) and the fact that post-impact Earth and the Moon are isotopically very similar to ECs and aubrites, the impactor *Theia* must also have been isotopically very similar to ECs and Earth. Otherwise, the post-giant impact Earth and the Moon would deviate isotopically from that of ECs. Likewise, the isotopic similarity of Earth and ECs and the Earth's unique end-member position in multi isotopic space constrains the amount of any non-enstatite-like material accreted either before or after core closure.

We infer that the closure of the Earth/EC-like isotopic reservoir by 4,564.8±1.6 Ma represents the formation of Jupiter and the clearing of the disk immediately outside the terrestrial planet formation zone, as well as excitation of planetesimals. We suggest that the EC reservoir deviated at 4,564.8±1.6 Ma, or shortly thereafter, from that of the Earth's chemically, by SiO/SiS gas interactions with solids. The processes responsible for changes in EC chemistry must be a local phenomena, as it did not affect the bigger reservoir represented by the bulk Earth composition.