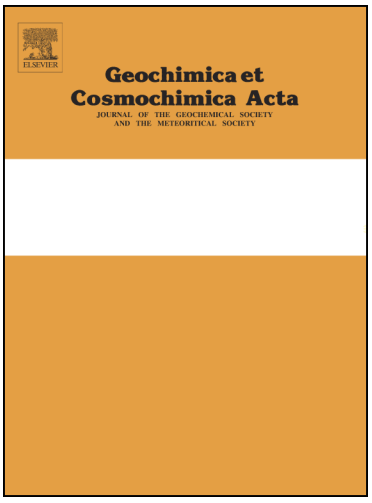

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Chronology of formation of early solar system solids from bulk Mg isotope analyses of CV3 chondrules

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Abstract

We have analysed the petrography, major element abundances and bulk Al-Mg isotope systematics of 19 ferromagnesian chondrules from the CV3 chondrites Allende, Mokoia, and Vigarano, together with an Al-rich chondrule and refractory olivine from Mokoia. Co-variations of Al/Mg with Na/Mg and Ti/Mg in our bulk chondrules suggest their compositions are dominantly controlled by reworking of different proportions of chondrule components (e.g. mafic minerals and mesostatis); their precursors are thus fragments from prior generations of chondrules. Our samples show a range in fractionation corrected $^{26}Mg/^{24}Mg$ ($\Delta'^{26}Mg$) ~60ppm, relative to precisions <±5ppm (2se) and these values broadly covary with $^{27}Al/^{24}Mg$. The data can be used to calculate model initial $^{26}Al/^{27}Al$, or $(^{26}Al/^{27}Al)_0$, of the chondrule precursors. Our resolvably radiogenic chondrules yield model $(^{26}Al/^{27}Al)_0$ ~1-2x10^{-5}, equivalent to model "ages" of precursor formation ≦1Ma post CAI. However, many of our chondrules show near solar $\Delta'^{26}Mg$ and no variability despite a range in $^{27}Al/^{24}Mg$. This suggests their derivation either from younger precursor chondrules or open system behaviour once ^{26}Al was effectively extinct ($(^{26}Al/^{27}Al)_0$<0.8x10^{-5}, given the resolution here). Evidence for the latter explanation is provided by marked rims of orthopyroxene replacing olivine, indicating reaction of chondrules with a surrounding silicate vapour. Concurrent isotopic exchange of Mg with a near chondritic vapour during late reworking could explain their isotopic systematics. One ferromagnesian object is dominated by a high Mg# olivine with elevated Ti and Ca abundances. This refractory olivine has a markedly negative $\Delta'^{26}Mg$ = -16±3 ppm (2se), reflecting its early removal (model age of <0.5Ma post CAI), from a reservoir with evolving $\Delta'^{26}Mg$. If representative of the chondrule forming region, this grain defines a minimum interval of radiogenic ingrowth for CV chondrites commensurate with $(^{26}Al/^{27}Al)_0$>3.4±0.6x10^{-5}. Overall, our samples record a sequence of events from the formation of ferromagnesian objects within 0.5Ma of CAI to re-equilibration of chondrules and