

Iron isotopic compositions of Mg-rich olivine grains in olivine-rich achondrites may constrain protoplanet magma ocean crystallization

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The iron isotopic compositions of Mg-rich olivines in achondrites could capture the bulk Fe isotopic composition (expressed as $\delta^{57}\text{Fe}$) of their silicate parent bodies if olivine crystallization in reduced melts does not significantly fractionate Fe isotopes. Measurements of these compositions can be used to comment upon planetary formation models that have constrained the $\delta^{57}\text{Fe}$ of the bulk silicate reservoirs of small, differentiated bodies, for constraining the effects metallic core formation has had upon the $\delta^{57}\text{Fe}$ of silicate mantles, and for deciphering the effects of possible kinetic processes on $\delta^{57}\text{Fe}$ in olivines. Therefore, we measured the $\delta^{56,57}\text{Fe}$ of several extracted Mg-rich chemically homogeneous olivines in achondrites NWA 13446 and NWA 16128 using a Nu Plasma-3D MC-ICP-MS, and chemically characterized the bulk samples using a Zeiss Evo MA10 SEM with an Oxford Ultim Max 100 mm² SDD-EDS detector at the University of Florida. NWA 13446 was crushed for manual olivine extraction. One fraction was leached in 0.5M ultra-pure HCl to remove desert weathering and another was analyzed without leaching. NWA 16128 has been paired with likely samples from the differentiated asteroid Vesta [1]. Three NWA 16128 grains were drilled with a 0.3mm WC drill and one grain was transected to investigate possible isotopic zoning. The $\delta^{57}\text{Fe}$ are mass dependent (Table 1), and the leached and unleached NWA 13446 fractions are analytically identical. Core formation studies have predicted an isotopically light Vesta mantle reservoir $\delta^{57}\text{Fe}$ of $-0.11\pm0.04\%$ [2], which is outside of uncertainty for these analyses except for NWA 13446 and the transected grain edges (analyses 16128.C1 and 16128.C3). The three transect points in Fig. 1 suggest resolvable enrichment of negative $\delta^{57}\text{Fe}$ within the grain center relative to the edges that may be due to isotopic diffusive re-equilibration as these isotopic differences are not accompanied by chemical variability. The edges of this drilled grain may represent compositions closer to equilibrium than the center. Future work will involve expanding this grain transect as an XY cross-section, and analyzing olivines from achondrites MIL 03443 and NWA 15717.

[1] Gattacceca et al. (2024) Meteorit. Planet. Sci. 7, 1820–1823.
 [2] Elardo et al. (2019) EPSL. 513, 124-134.

Sample ID	N*	$\delta^{56}\text{Fe}\pm2\text{SE} (\text{‰})$	$\delta^{57}\text{Fe}\pm2\text{SE} (\text{‰})$	$\Delta^{56}\text{Fe} (\text{‰})$	Mg#
16128.A	9	-0.218±0.017	-0.322±0.033	0.000±0.015	85
16128.B	9	-0.188±0.023	-0.280±0.034	-0.002±0.018	81
16128.C1	10	-0.059±0.019	-0.084±0.035	-0.002±0.033	78
16128.C2	7	-0.145±0.022	-0.208±0.036	0.004±0.013	78
16128.C3	10	-0.047±0.022	-0.065±0.040	-0.003±0.021	78
13446.L	9	-0.058±0.018	-0.085±0.027	-0.001±0.006	69-71
13446.UL	8	-0.045±0.017	-0.067±0.024	0.000±0.013	69-71
BIR-1	6	0.053±0.026	0.072±0.038	0.004±0.018	n/a
DTS-2	6	0.036±0.019	0.051±0.023	0.001±0.013	n/a

Table 1: Fe isotopic compositions and Mg# of analyzed olivines from NWA 13446 and NWA 16128 samples, and BIR-1 and DTS-2 standards reported for $\delta^{56,57}\text{Fe}$ and mass dependency ($\Delta^{56}\text{Fe}$) within 2 standard errors (SE) in addition to geostandards BIR-1 and DTS-1. *Number of runs

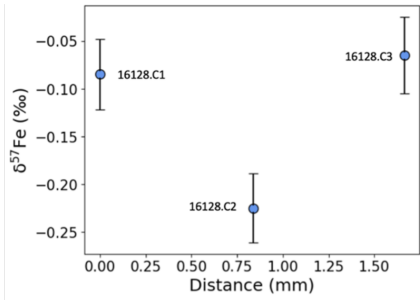


Figure 1: Isotopic compositions of a transect of a single grain in NWA 16128 with distances in mm. The points by the grain edges (16128.C1 and 16128.C3) are analytically identical to estimates for bulk silicate Vesta. All analyses are plotted with 2SE bars.