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Resolving the chlorine isotope composition of Earth's depleted upper mantle by examining the effects of mantle heterogeneity

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The chlorine isotope ratio (δ^{37}Cl) of Earth's depleted mantle has implications for volatile exchange between Earth's surface and mantle. However, estimates vary greatly, ranging from < −3‰ to +0.9‰ [1, 2, 3, 4]. Previous studies did not fully consider the possible impact of mantle heterogeneity on the δ^{37}Cl values of measured mid-ocean ridge basalt (MORB) glasses. To evaluate possible mantle heterogeneity, we measured the δ^{37}Cl values via IRMS and SIMS on 30 MORB glasses from several ridge segments spanning a wide range of Cl/K (0.01-0.82), trace element (Figure 1A), and radiogenic isotope (Figure 1B) compositions. By examining variations in δ^{37}Cl values with indices of subduction influence and shallow assimilation, we are able to better determine the depleted MORB-source mantle (DMM) δ^{37}Cl value and the impacts of subduction on mantle δ^{37}Cl values.

Measured MORB δ^{37}Cl values range from -1.5‰ to +1.0‰. Samples affected by shallow assimilation (high Cl/K) extend towards δ^{37}Cl values lower than seawater, suggesting assimilation of hydrothermal brines does not necessarily result in seawater-like δ^{37}Cl values. After filtering for shallow assimilation, the most depleted MORB samples from several localities have δ^{37}Cl values of −0.4 to −0.5‰ (Figure 1). For all localities, samples with lower $^{143}Nd/^{144}Nd$ and higher K_2O/TiO_2 extend to higher and/or lower δ^{37}Cl values than the most depleted MORB samples (Figure 1). This likely reflects incorporation of subducted material (altered oceanic crust and marine sediments) with heterogenous δ^{37}Cl values into the DMM with a δ^{37}Cl value of −0.4‰ to −0.5‰ (Figure 1). Much of the disagreement between previous estimates of the DMM δ^{37}Cl value can be attributed to the effects of shallow assimilation and mantle heterogeneity.

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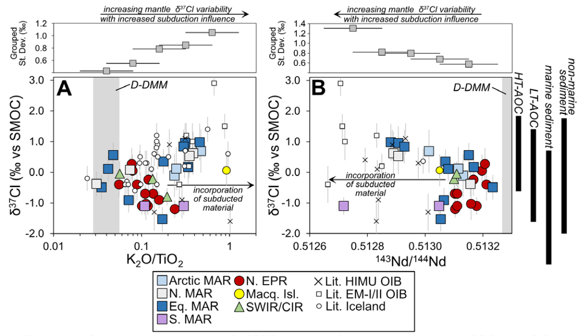

Figure 1. Chlorine isotope ratios of MORB samples from this study and MORB and OIB samples from literature filtered for Cl contamination plotted against **(A)** K_2O/TiO_2 and **(B)** $^{143}Nd/^{144}Nd$. Error bars are 2 SD. Colored symbols include MORB data from this study and from previous studies [1, 2]. Literature OIB data are from [5, 6]. Gray vertical bars are the most depleted endmember of DMM K_2O/TiO_2 and $^{143}Nd/^{144}Nd$. The black bars to the right show the range of δ^{37}Cl values in subducted materials (HT-AOC= high-temperature altered oceanic crust, LT-AOC= low-temperature altered oceanic crust). Grouped St. Dev.= grouped standard deviations, which shows the standard deviation in δ^{37}Cl values of a subset of MORB and OIB samples for a range of K_2O/TiO_2 (left) or $^{143}Nd/^{144}Nd$ (right) shown by the horizontal black lines. N. MAR= Northern Mid-Atlantic Ridge (MAR), Eq. MAR= Equatorial MAR, S. MAR= Southern MAR, N. EPR= Northern East Pacific Rise, Macq. Isl.= Macquarie Island, SWIR= Southwest Inidan Ridge, CIR= Central Indian Ridge, Lit= Literature, OIB= Ocean Island Basalt.