Si isotope fractionation in high-temperature metal-silicate systems: Implications for core formation

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The observed difference in Si isotopic composition between CI chondrites and bulk silicate Earth has been explained by high P-T metal-silicate Si isotope fractionation accompanying Si incorporation into Earth's core [1, 2, 3].

We have measured Si isotopes in metal alloys and co-existing silicate slags that were produced at temperatures of ~1600°C in reducing atmospheric conditions in an industrial blast furnace at Tata Steel IJmuiden, the Netherlands.

Silicon isotopes were measured with a ThermoFinnigan Neptune MC-ICPMS [3] using a modified sample digestion procedure [3, 4]. Our results show an average mass difference of 0.75 ‰ for δ^{30}Si between metals and silicates (Fig.1).

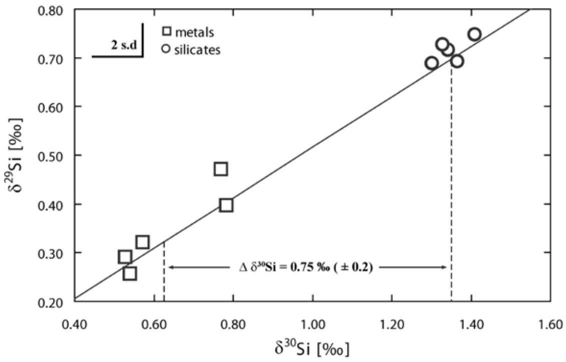

Figure 1: Three isotope plot showing Si isotope data of metals and silicates along the equilibrium fractionation line of Si.

Sign and magnitude of our results are in good agreement with results of high-pressure experiments [3] and theoretical predictions [1]. Si isotope fractionation clearly occurs in high-temperature metal-silicate systems under reducing atmospheric conditions, and high pressures are not required. Our data show that Si could have been incorporated into Earth's core during its early formation stages.

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First episode of widespread ocean oxygenation 551 Myr ago

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Increasing ocean oxygenation may have spurred the evolution of large multicellular metazoans during the Ediacaran Period (635-542 Myr ago). Fe speciation and other geochemical data from sedimentary rocks indicate that regional ventilation of the deep oceans commenced no later than 580 Myr ago but parts of the Ediacaran deep ocean remained anoxic. Reconstructing the timeline of ocean oxygenation is critical to understanding metazoan evolution, but the spatiotemporal distribuition of dissolved O_2 remains poorly understood. In contrast, the Mo isotope composition of euxinic (anoxic/sulphidic) black shales represents a proxy for global seawater and constrains global ocean redox conditions.

Here, we present Mo isotope evidence for the first known episode of widespread ocean oxygenation 551 Myr ago. High-resolution profiles through black shales at the top of the Doushantuo Formation (South China) reveal a transient excursion to heavy $\delta^{98/95}$Mo (from ~0‰ to 2‰) that approaches modern global seawater (2.3‰). The latter has heavy $\delta^{98/95}$Mo largely because isotopically light Mo is preferentially removed into oxic Fe-Mn crusts. We infer a similar extent of Mo burial in oxic sediments 551 Myr ago.

Older euxinic shales deposited between 1840 and 551 Myr ago are enriched in isotopically light Mo and indicate expanded deep ocean anoxia, including a prevalence of euxinic conditions at mid-depths along ocean margins. Between 551 and 400 Myr ago, the Mo isotope database points to an intermediate extent of oxygenation relative to older and younger oceans. We propose that there was a major increase in ocean oxygenation 551 Myr ago which sparked a major diversification of complex macroscopic metazoans.