

Ancient lead trapped in the Earth's upper mantle

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The isotope composition of lead (Pb) in the Earth's upper mantle (sampled by oceanic basalts) is far too radiogenic for evolution from chondritic (primitive solar system) material over 4.57 billion years, the so called 'Pb paradox' [1]. Loss of Pb to the core [2] or arrival in a late veneer [3], have both been proposed as mechanisms to account for this imbalance. Alternatively, recent Pb isotope data for orogenic peridotites suggests that such rocks could serve as a complementary reservoir of unradiogenic Pb [4]. However, orogenic peridotites may not be representative of the asthenosphere underlying present-day mid-ocean ridges, furthermore, it is unclear why such material is not sampled by oceanic basalts.

Here we show that sulphides trapped as inclusions in silicate minerals in abyssal peridotites from the North Atlantic ocean (ODP Leg 209; Site 1274A) preserve extremely unradiogenic Pb isotope compositions, some corresponding to an age of ca 1.8 billion years. These ages are indistinguishable from those preserved by Os isotopes in sulphides from the same abyssal peridotites [5], and demonstrate that both Pb and Os isotopes preserve an unequivocal record of ancient melt depletion in the sub-oceanic mantle. Therefore, at least, some of the Pb in the Earth's mantle is unradiogenic and complements the composition of oceanic basalts. That these sulphides contribute little of their Pb to the isotope composition of oceanic basalts may be due either to their entrapment in host silicate phases or else that they are generally present in refractory domains in the mantle that are little sampled by later melting events.

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Fe isotope cycling in ferruginous and anoxic Lake Pavin (France) from water column to sediment

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Fe isotopes are an emerging biogeochemical paleoproxy that can improve our understanding of the Fe cycle in early Earth's ocean and early microbial evolution. Sediments deposited during the Precambrian record a large range of $\delta^{56}\text{Fe}$ values, with an exceptional negative excursion (down to -3.5‰) between 2.9 and 2.3 Ga, a transition period believed to be marked by stratified redox ocean basins. The origin of this negative excursion is still debated but may be linked to a unique period of water column Fe cycling or a time of enhanced microbial Fe reduction in Fe-rich sediments.

Lake Pavin is a unique stratified aquatic system characterized by permanent anoxic and ferruginous deep water (from 60 to 92 m depth) topped by oxic shallow water (from 0 to 60 m), and can thus be regarded as a modern analog for Archean ocean. In the present work, we have studied Lake Pavin Fe isotope cycling along a profile in the water column down to the sediment in order to bring new insights into the record of ancient rocks. Four sediment cores were drilled and analyzed: (1) in the oxic zone, (2) at the oxic-anoxic boundary, (3) under the peak of H_2S production from SO_4^{2-} reduction and (4) at the bottom of the lake. In the water column, dissolved Fe concentration increases with depth from 2 μM at the oxic-anoxic boundary to 1200 μM at the lake bottom, with $\delta^{56}\text{Fe}$ increase from -1.67 to +0.31‰. The very negative $\delta^{56}\text{Fe}$ of the oxic-anoxic boundary reflects the residue of Fe oxidation and precipitation. The $\delta^{56}\text{Fe}$ increase with depth is interpreted as a coupling between (1) diffusion of Fe enriched in heavy isotopes from the bottom of the lake towards the oxic-anoxic boundary and (2) a combination of Fe reduction of downgoing Fe(III) particles and ferrous-ferric Fe interactions. Analyses of bulk sediment show $\delta^{56}\text{Fe}$ values close to the purported detrital source (i.e. basalts with $\delta^{56}\text{Fe} \sim 0.20\text{‰}$). In contrast, Fe sequential extraction in sediments shows a significant variation in $\delta^{56}\text{Fe}$. Iron isotope mass balance calculation in both water column and pore waters of the sediment cores indicate that Fe isotope variability in iron sulfides reflects mostly Fe chemistry in the water column rather than isotopic fractionation during diagenetic processes or sulfide precipitation in the sediment.