



# On the equilibration timescales of isolated trace phases in mantle peridotites: Implications for the interpretation of grain-scale isotope heterogeneity in peridotitic sulfides



John C. Lassiter

Dept. Geological Sciences, Jackson School of Geosciences, University of Texas at Austin, United States of America

## ARTICLE INFO

### Article history:

Received 6 April 2018

Received in revised form 11 July 2018

Accepted 12 July 2018

Available online xxx

Editor: T.A. Mather

### Keywords:

sulfide

diffusion

moat effect

isotopic equilibration

mantle heterogeneity

## ABSTRACT

Geochemical studies of mid-ocean-ridge basalts (MORB) and mantle peridotites (e.g., abyssal peridotites) provide independent constraints on the composition and evolution of the convecting mantle. Recent studies have revealed systematic differences in the radiogenic isotope compositions of MORB and abyssal peridotites that call into question the complementary nature of these two windows to the upper mantle. The origin of these differences is fundamental to our understanding of MORB petrogenesis and the composition and depletion history of the upper mantle. The use of isotope variations in basalts to probe the composition and evolution of the mantle is predicated on the assumption of local (i.e., grain-scale) isotopic equilibrium during mantle melting. However, several studies have reported Os- and Pb-isotope disequilibrium in distinct populations of peridotite-derived sulfides, with sulfides included within silicate grains typically possessing more “depleted” isotopic compositions than interstitial sulfides. In principle, grain-scale isotopic heterogeneity could reflect variable radiogenic ingrowth in ancient sulfides with variable parent/daughter ratios, or partial re-equilibration of low-Re/Os and U/Pb sulfides with more radiogenic silicate phases along grain boundaries during mantle melting. This would require that sulfides fail to maintain isotopic equilibrium with neighboring phases over geologically long ( $\sim$  Ga) time scales. The preservation of Os-isotope disequilibrium in peridotites has been ascribed in several studies to the armoring effect of low-[Os] silicates, which limits diffusive exchange between isolated Os-rich sulfides. This raises the prospect that peridotite-derived melts may not inherit the Os- (or Pb-) isotope composition of their source, which could account for the recently documented systematic differences in the Os- and Pb-isotope compositions of MORB and mantle peridotites.

Although the preservation of isotopic heterogeneity in mantle sulfides is commonly ascribed to the above “armoring effect”, the diffusive equilibration timescale of spatially separated sulfides in mantle peridotites has not previously been rigorously estimated. This study examines the parameters that control this equilibration timescale (average sulfide size and spacing, Os and Pb diffusivity in armoring silicate minerals, and element partitioning between silicate and sulfide phases). Equilibration timescale estimates using available constraints on these parameters reveal that most mantle sulfides are expected to isotopically re-equilibrate with neighboring sulfides in less than a few 10 s of Myr at convecting mantle temperatures. Maintenance of isotopic disequilibrium over the  $\sim$  Ga timescales suggested by observed intra-sample Os- and Pb-isotope heterogeneity requires very large sulfides ( $>100 \mu\text{m}$ ) separated by several mm or diffusion rates ( $D < 10^{-18} \text{ m}^2/\text{s}$ ), slower than for most elements in olivine. Combined with the observation of intra-sample major element heterogeneity in sulfide Ni and Fe abundances (which should equilibrate quickly in the convecting mantle), these results suggest that the observed isotopic disequilibrium is unlikely to be an ancient feature in mantle peridotites. Instead, recent sulfide metasomatism linked to interaction with melts derived from isotopically enriched eclogite or pyroxenite (or fertile and/or metasomatized peridotite) components is a more likely explanation for observed intra-sample isotopic heterogeneity in peridotites. This interpretation is also consistent with systematic differences between the Nd- and Hf-isotope compositions of MORB and abyssal peridotites. These results further strengthen the proposal that MORB do not accurately reflect the average isotopic composition of the convecting upper mantle, and that upper mantle peridotite is, on average, significantly more depleted and refractory than suggested by MORB-based estimates. The effects of melt generation in a

E-mail address: lassiter1@jsg.utexas.edu.

heterogeneous marble-cake mantle need to be explicitly considered when using basalt compositions to constrain mantle composition and evolution.

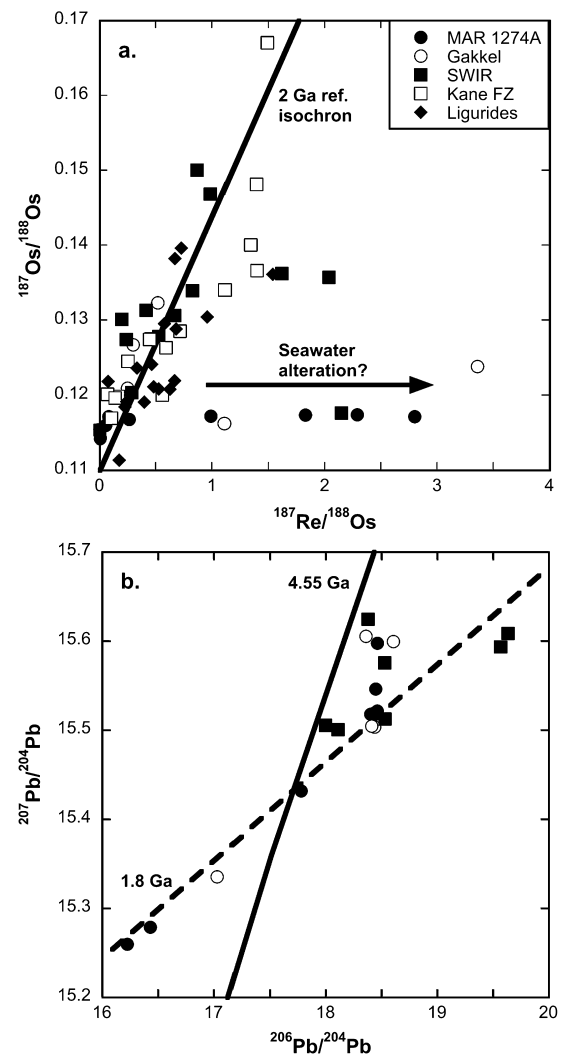
© 2018 Elsevier B.V. All rights reserved.

## 1. Introduction

Mid-ocean ridge basalts and abyssal peridotites provide complementary views into the composition and evolution of the convecting upper mantle. Most studies consider abyssal peridotites to be melt-depleted residues of recent mid-ocean ridge melt extraction, though melt/mantle interactions also affect their compositions (Niu, 1997; Salters and Dick, 2002; Kimura and Sano, 2012). The isotopic compositions of both abyssal peridotites and MORB should thus be representative of the depleted upper mantle. However, several recent studies indicate that abyssal peridotites on average have more depleted isotopic compositions than MORB (e.g., Lassiter et al., 2014; Byerly and Lassiter, 2014). In addition, some highly refractory abyssal peridotites have extremely depleted Os- and Hf-isotope compositions that reflect ancient (>1 Ga) melt extraction (Liu et al., 2008; Stracke et al., 2011). Processes such as melt–rock reaction, though clearly important, cannot account for these systematic isotopic differences.

A second, potentially related observation is that many peridotites from both oceanic and continental settings possess significant isotopic heterogeneity at the grain scale, particularly with respect to mantle sulfides. Alard et al. (2005) noted that magmatic sulfides from abyssal peridotites are shifted to more radiogenic Os-isotope values than included monosulfide solid solution (MSS) phases, and bridge the Os-isotope gap between MORB and bulk abyssal peridotites. Many peridotites appear to contain multiple generations of sulfides, including sulfides with compositions consistent with sulfide melt (usually occurring as interstitial sulfides), and sulfides with residual MSS compositions (most common as inclusions in olivine or other silicate phases) (Harvey et al., 2016). Interstitial sulfides often have more radiogenic  $^{187}\text{Os}/^{188}\text{Os}$  than included MSS phases (Alard et al., 2005; Harvey et al., 2006). A similar picture is observed for Pb-isotopes. Individual abyssal peridotites contain sulfides with variable Pb-isotope compositions, and included MSS phases often have significantly less radiogenic  $^{206}\text{Pb}/^{204}\text{Pb}$  and  $^{207}\text{Pb}/^{204}\text{Pb}$  than either interstitial sulfides or most MORB (Burton et al., 2012; Warren and Shirey, 2012). Significantly, many included MSS grains have Pb-isotope compositions that plot to the left of the geochron. Thus, included sulfides could represent a significant unradiogenic Pb reservoir in the mantle under-sampled during MORB petrogenesis, providing a potential solution for the long-standing “first Pb paradox” (Warren and Shirey, 2012).

The hand-sample-scale heterogeneity in interstitial and included sulfide Pb- and Os-isotopes in abyssal peridotites presents a “chicken or the egg” problem whose solution is critical for the interpretation of isotopic variations in both MORB and abyssal peridotites. Previous studies have suggested that because sulfides have much higher [Os] and [Pb] than the major silicate phases in peridotites, isotopic heterogeneity can be preserved for geologically long periods of time due to the “armoring effect” of low-[Os], low-[Pb] phases that physically separate sulfides. This armoring effect slows diffusive exchange between neighboring sulfides, so that the equilibration timescale is much longer than the diffusive timescale suggested by sulfide spacing. Burton et al. (2012) and Harvey et al. (2006) suggested that  $^{206}\text{Pb}$ – $^{207}\text{Pb}$  and  $^{187}\text{Re}/^{188}\text{Os}$ – $^{187}\text{Os}/^{188}\text{Os}$  correlations observed in peridotite sulfides represent internal isochrons, with ages of ~1.8–2.1 Ga (Fig. 1). If spatially separated sulfides can preserve Os- and Pb-isotope variations for geologically long periods, then it is possible that mantle



**Fig. 1.** a.  $^{187}\text{Os}/^{188}\text{Os}$  variations in individual sulfides from MAR, SWIR, and Gakkel ridge abyssal peridotites as well as from the Liguride ophiolites. b.  $^{206}\text{Pb}/^{204}\text{Pb}$ – $^{207}\text{Pb}/^{204}\text{Pb}$  variations in peridotite sulfides (data from Alard et al., 2005; Harvey et al., 2006; Burton et al., 2012, and Warren and Shirey, 2012). 2.0 and 1.8 Ga isochrones shown for reference. Sulfides from multiple localities fall along similar  $\text{Re}/\text{Os}$ – $^{187}\text{Os}/^{188}\text{Os}$  and  $^{206}\text{Pb}$ – $^{207}\text{Pb}$  trends which can be interpreted either as isochrons or as mixing trends. See text for details.

melting preferentially samples Os and Pb contained in (radiogenic) sulfides present along grain boundaries, but under-samples the less radiogenic sulfides present as inclusions in silicate phases (Alard et al., 2005). Although this model does not explain the different Nd- or Hf-isotope signatures of MORB and abyssal peridotites (Byerly and Lassiter, 2014), it could explain the overlap between MORB and interstitial sulfide Os-isotopes. Alternatively, if such heterogeneities cannot be preserved for geologically long periods, then the observed heterogeneity would suggest that many peridotites have experienced recent enrichment via melt/rock reaction, most likely associated with melt production beneath the modern mid-ocean ridge, with the isotopically “enriched” melts responsible for this refertilization potentially generated by melting of pyroxenitic or eclogitic components in the convecting upper mantle. Thus, the origin of grain-scale isotopic heterogeneity in abyssal peridotites

Download English Version:

<https://daneshyari.com/en/article/8906737>

Download Persian Version:

<https://daneshyari.com/article/8906737>

[Daneshyari.com](https://daneshyari.com)