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The geological record of base metal sulfides in the cratonic mantle: A microscale $^{187}Os/^{188}Os$ study of peridotite xenoliths from Somerset Island, Rae Craton (Canada)

A. Bragagni [a,b,*], A. Luguet [a], R.O.C. Fonseca [a], D.G. Pearson [c], J.-P. Lorand [d], G.M. Nowell [e], B.A. Kjarsgaard [f]

[a] *Steinmann Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, Germany*
[b] *Institut für Geologie und Mineralogie, Universität zu Köln, Köln, Germany*
[c] *Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada*
[d] *Laboratoire de Planétologie et Géodynamique, CNRS UMR 6112, Université de Nantes, Nantes, France*
[e] *Department of Earth Sciences, University of Durham, Durham, UK*
[f] *Geological Survey of Canada, Ottawa, Canada*

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Abstract

We report detailed petrographic investigations along with $^{187}Os/^{188}Os$ data in Base Metal Sulfide (BMS) on four cratonic mantle xenoliths from Somerset Island (Rae Craton, Canada). The results shed light on the processes affecting the Re-Os systematics and provide time constraints on the formation and evolution of the cratonic lithospheric mantle beneath the Rae craton.

When devoid of alteration, BMS grains mainly consist of pentlandite + pyrrhotite ± chalcopyrite. The relatively high BMS modal abundance of the four investigated xenoliths cannot be reconciled with the residual nature of these peridotites, but requires addition of metasomatic BMS. This is especially evident in the two peridotites with the highest bulk Pd/Ir and Pd/Pt. Metasomatic BMS likely formed during melt/fluid percolation in the Sub Continental Lithospheric Mantle (SCLM) as well as during infiltration of the host kimberlite magma, when djerfisherite crystallized around older Fe-Ni-sulfides. On the whole-rock scale, kimberlite metasomatism is visible in a subset of bulk xenoliths, which defines a Re-Os errorchron that dates the host magma emplacement.

The $^{187}Os/^{188}Os$ measured in the twenty analysed BMS grains vary from 0.1084 to >0.17 and it shows no systematic variation depending on the sulfide mineralogical assemblage. The largest range in $^{187}Os/^{188}Os$ is observed in BMS grains from the two xenoliths with the highest Pd/Ir, Pd/Pt, and sulfide modal abundance. The whole-rock T_{RD} ages of these two samples underestimate the melting age obtained from BMS, demonstrating that bulk Re-Os model ages from peridotites with clear evidence of metasomatism should be treated with caution.

The T_{RD} ages determined in BMS grains are clustered around 2.8–2.7, ~2.2 and ~1.9 Ga. The 2.8–2.7 Ga T_{RD} ages document the main SCLM building event in the Rae craton, which is likely related to the formation of the local greenstone belts in a continental rift setting. The Paleoproterozoic T_{RD} ages can be explained by addition of metasomatic BMS during (i) major lithospheric rifting at ~2.2 Ga and (ii) the Taltson-Thelon orogeny at ~1.9 Ga. The data suggest that even metasomatic BMS can inherit $^{187}Os/^{188}Os$ from their original mantle source. The lack of isotopic equilibration, even at the micro-scale,

* Corresponding author at: Institut für Geologie und Mineralogie, Universität zu Köln, Köln, Germany.
E-mail address: abragagn@uni-koeln.de (A. Bragagni).

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allowed the preservation of different populations of BMS grains with distinct $^{187}Os/^{188}Os$, providing age information on multiple magmatic events that affected the SCLM.

Keywords: Os isotopes; Base metal sulfides; Cratonic peridotites; Highly siderophile elements; Mantle metasomatism; Rae craton

1. INTRODUCTION

The ^{187}Re-^{187}Os decay system represents the most common tool to date melt depletion events in mantle lithologies (Walker et al., 1989; Reisberg and Lorand, 1995; Shirey and Walker, 1998; Carlson, 2005; Rudnick and Walker, 2009). For this reason, Re-Os model ages have been extensively used in kimberlite-hosted mantle xenoliths to constrain the age of craton formation and stabilization (e.g. Pearson and Wittig, 2008; Herzberg and Rudnick, 2012). In addition to time constraints, Re-Os model ages can provide information on the mechanism of craton formation, because different geodynamic processes are expected to produce distinct lateral and vertical age distributions in the sub-cratonic lithospheric mantle (SCLM) (Pearson, 1999; Lee, 2006).

Notwithstanding the common Archean ages derived from Re-Os model ages, the Re-Os decay system can be vulnerable to metasomatism, as suggested, for example, by the variable highly siderophile elements (HSE – Pt, Pd, Rh, Ru, Ir, Os, Re, and Au) signature of residual rocks (e.g. Pearson et al., 2004; Luguet et al., 2015; Aulbach et al., 2016; Luguet and Reisberg, 2016). Further evidence that petrological processes such as melt or fluid percolation are able to affect the Re-Os system arises from mineralogical and textural investigations of base metal sulfides (BMS), which represent the main host phase of HSE in mantle lithologies along with platinum group minerals (PGM) (Keays et al., 1981; Luguet et al., 2007; Lorand et al., 2008). Base metal sulfides are commonly observed as micro-phases (typically <500 μm across) and their origin can be residual (i.e. left over after melt extraction) or metasomatic (i.e. introduced by percolating melts or fluids) (e.g. Alard et al., 2000; Luguet et al., 2003, 2004; Lorand and Grégoire, 2006; Lorand et al., 2010). While the modal abundance of residual BMS decreases with increasing degree of partial melting, the sulfide content of metasomatized residual peridotite typically increases due to percolation of silicate melts (e.g. Alard et al., 2000; Luguet et al., 2003, 2004; Lorand et al., 2003) or volatile rich fluids (Alard et al., 2011; Delpech et al., 2012). Residual BMS usually show unradiogenic $^{187}Os/^{188}Os$ and metasomatic BMS typically display more radiogenic $^{187}Os/^{188}Os$ (Alard et al., 2002), attesting a significant chemical and isotopic disequilibrium at the microscale that can be preserved for billions of years. Therefore, whole-rock Re-Os model ages can be significantly affected by the presence of multiple BMS generations, which can be residual and metasomatic in origin (e.g. Alard et al., 2002; Griffin et al., 2004; Wainwright et al., 2015; Harvey et al., 2016).

Whole-rock investigations on mantle xenoliths from Somerset Island (Rae craton, Canada) show Re-Os T_{RD} model ages (i.e. Re-depletion ages, Walker et al., 1989) of 2.7–2.8 Ga (Irvine et al., 2003), which are similar to those observed in other cratons (for compilations see Pearson and Wittig, 2008; Aulbach et al., 2016) and in the nearby Slave (cf. Heaman and Pearson, 2010), Superior (Smit et al., 2014), North Atlantic (Wittig et al., 2010), and central Rae (Liu et al., 2016) cratons. Interestingly, Irvine et al. (2003) observed a correlation between Re-Os model ages and HSE signatures in bulk peridotite xenoliths. Namely, peridotites with a residual HSE signature (i.e. strongly depleted in Pt, Pd, and Re relative to Os, Ir, and Ru) yielded the oldest T_{RD} (or T_{RD} eruption, i.e. corrected for ^{187}Os ingrowth back to the age of the host magma eruption) model ages of 2.7–2.8 Ga. In contrast, samples that were metasomatically re-enriched in Re and Pd display a larger spread in T_{RD} ages extending toward Proterozoic ages (Irvine et al., 2003). Another interesting feature of this suite of samples, which was not reported before, is that a subset of xenoliths defines a clear trend in the Re-Os isochron diagram, yielding an errorchron age that is essentially the same as that reported for the host kimberlite eruption. Such features attest to a clear disturbance of the whole-rock Re-Os system due to mantle metasomatism and kimberlite magmatism. Therefore, this suite of samples offers the opportunity to investigate such processes at the mineral scale and to constrain their role in affecting whole-rock Re-Os model ages.

In this study, we have performed $^{187}Os/^{188}Os$ analyses on single BMS grains along with detailed mineralogical and textural investigations of BMS and silicates. We examine the effect of different metasomatic events on the Re-Os systematics and test the reliability of Re-Os model ages in whole-rocks with increasingly overprinted HSE signatures. Moreover, Re-Os model ages from whole rocks and single BMS grains are compared to evaluate their different abilities to discriminate geological events. Finally, T_{RD} ages from metasomatic and residual BMS grains are compared to understand their age significance, prior to interpreting them in the geodynamic context of the Rae craton. In this regard, it will be shown that the distribution of T_{RD} ages of BMS grains correlates with the ages of major tectonic events that occurred in the Rae craton during the Neoarchean and Paleoproterozoic.

2. GEOLOGICAL SETTING

Somerset Island is located in the northern extension of the Queen Maud Block (Schultz et al., 2007) of the Rae craton (Fig. 1), one of the cratonic blocks that comprises the Canadian Shield. The Rae craton is separated from the Slave craton to the west by the Taltson-Thelon tectonic zone, and from the Hearne craton to the south-east by