The distribution of lead and thallium in mantle rocks: Insights from the Balmuccia peridotite massif (Italian Alps)

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ABSTRACT

Sulfides in mantle rocks sometimes have unradiogenic Pb isotopic compositions and, assuming specific conditions, may represent a low U/Pb reservoir that might balance the radiogenic Pb isotope reservoirs of the silicate Earth. A critical requirement to test this hypothesis is knowledge of typical Pb contents in sulfides from different types of mantle rocks and estimates of their contribution to the Pb budget of the mantle rocks. However, data on the distribution of Pb between mantle minerals in mantle rocks from different geologic settings are scarce. In this study, new Pb and Tl concentration data from well-characterized unserpentinized spinel-facies peridotites and pyroxenites from the Balmuccia mantle tectonite (Ivrea-Verbano Zone, Italian Alps) are presented as an example to better understand the Pb distribution in minerals and rocks of the upper mantle.

Most peridotites display variable bulk-rock Pb contents (13–97 ng/g), which tend to be lower than Pb contents in the websterites (60–254 ng/g) and clinopyroxenites (174–657 ng/g). The pyroxenites show broadly positive correlations of Pb with Al2O3, Ce, and also S contents. In situ laser ablation-ICP-MS data indicate low Pb contents in olivine, orthopyroxene, and spinel (mostly below the detection limits of 50 ng/g); whereas Pb contents are higher in clinopyroxene (from <50 to 920 ng/g) and in sulfides (typically a few micrograms per gram and sometimes higher in chalcopyrites). Mass-balance calculations indicate that silicates predominantly control Pb contents in bulk rocks (>70–80% of the Pb), with a minor role for sulfides (mostly <20%). This result from Phanerozoic subcontinental lithosphere mantle rocks is consistent with data on abyssal peridotites. As in some previous studies, bulk-rock Pb contents calculated from constituent phases of peridotites are often lower than the measured values. This imbalance mainly reflects trapped fluid inclusions in silicate minerals and, perhaps also fine-grained crystallization products of trapped melt along grain boundaries. Bulk-rock Tl contents in peridotites (0.05–3.5 ng/g) are lower than in pyroxenites (0.66–7.9 ng/g) and display no correlations with Al2O3 and S contents. The bulk-rock data probably reflect the highly heterogeneous distribution of Tl in sulfides (<0.01–110 μg/g), and, as for Pb, the effect of trapped fluid inclusion. Because the Pb budget in mantle rocks is mainly controlled by silicates, mantle sulfides with unradiogenic Pb isotopic compositions likely cannot balance radiogenic Pb isotopic compositions of oceanic basalts.

Keywords: Peridotite, pyroxenite, sulfide, lead, thallium; Planetary Processes as Revealed by Sulfides and Chalcophile Elements

INTRODUCTION

The geochemical behavior of lead in the Earth is notable for some long-standing paradoxes, some of which are still debated. The Pb isotopic composition of the bulk silicate Earth model is more radiogenic (e.g., 206Pb/204Pb = 15.50 and 208Pb/204Pb = 18.29, according to Burton et al. 2012) than models of the Pb isotopic evolution of the Earth over the last 4.56 Ga (e.g., Allegre 1969; Burton et al. 2012; Hart and Gaetani 2006; Hofmann 2008). The existence of a complementary unradiogenic Pb reservoir with low U/Pb has been a common explanation for these discrepancies (e.g., Allegre 1969). It has been suggested that during formation of the Earth, Pb may have partitioned into the metallic core (e.g., Allegre 1969; Hart and Gaetani 2006; Oversby and Ringwood 1971; Wood and Halliday 2010; Wood et al. 2008) or was vaporized during accretion (e.g., Lagos et al. 2008). Alternatively, some authors proposed that significant quantities of Pb reside in plagioclase-rich cumulates of the lower continental crust, leading to a low U/Pb of this reservoir (e.g., Kramers and Tolstikhin 1997; Moorbath et al. 1969; Newsom et al. 1986; Reid et al. 1989; Rudnick and Goldstein 1990). Recent studies have documented unradiogenic Pb isotopic compositions (e.g., 208Pb/204Pb = 16.5) in mantle rocks from the Horoman mantle tectonite in Japan (Malaviarachchi et al. 2008) and in sulfide inclusions in olivine and pyroxene of abyssal peridotites (Blusz-