Experimental constraints on the partial melting of sediment-metasomatized lithospheric mantle in subduction zones

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ABSTRACT

Sedimentary diapirs can be relaminated to the base of the lithosphere during slab subduction, where they can interact with the ambient lithospheric mantle to form variably metasomatized zones. Here, high-pressure experiments in sediment-harzburgite systems were conducted at 1.5–2.5 GPa and 800–1300 °C to investigate the interaction between relaminated sediment diapirs and lithospheric mantle. Two end-member processes of mixed experiments and layered (reaction) experiments were explored. In the first end-member, sediment and harzburgite powders were mixed to a homogeneous proportion (1:3), whereas in the second, the two powders were juxtaposed as separate layers. In the first series of experiments, the run products were mainly composed of olivine + orthopyroxene + clinopyroxene + phlogopite in subsolidus experiments, while the phase assemblages were then replaced by olivine + orthopyroxene + melt (or trace phlogopite) in supersolidus experiments. Basaltic and foiditic melts were observed in all supersolidus mixed experiments (~44–52 wt% SiO2 at 1.5 GPa, ~35–43 wt% SiO2 at 2.5 GPa). In the phlogopite-rich experiment (PC431, 1.5 GPa and 1100 °C), the formed melts had low alkali contents (~<2 wt%) and K2O/Na2O ratios (~0.4–1.1). In contrast, the quenched melt in phlogopite-free/poor experiments showed relatively higher alkali contents (~4–8 wt%) and K2O/Na2O ratios (~2–5). Therefore, the stability of phlogopite could control the bulk K2O and K2O/Na2O ratios of magmas derived from the sediment-metasomatized lithospheric mantle. In layered experiments, a reaction zone dominated by clinopyroxene + amphibole (or orthopyroxene) was formed because of the reaction between harzburgite and bottom sediment-derived melts (~62.5–67 wt% SiO2). The total alkali contents and K2O/Na2O ratios of the formed melts were about 6–8 wt% and 1.5–3, respectively. Experimentally formed melts from both mixed and reaction experiments were rich in large ion lithosphile elements and displayed similar patterns with natural potassium-rich arc lavas from oceanic subduction zones (i.e., Mexican, Sunda, Central American, and Aleutian). The experimental results demonstrated that bulk sediment diapirs, in addition to sediment melt, may be another possible mechanism to transfer material from a subducting slab to an upper mantle wedge or lithospheric mantle. On the other hand, the breakdown of phlogopite may play an important role in the mantle source that produces potassium-rich arc lavas in subduction zones.

Keywords: Bulk sediment, lithosphere, partial melting, potassium-rich arc lava

INTRODUCTION

Subducted sediment is thought to have played an important role in creating mantle heterogeneity and the origin of potassium (K)-rich magmas in subduction zones (e.g., Tatsumi et al. 1986; Blundy and Sparks 1992; Prouteau et al. 2001). High-pressure experimental studies have demonstrated that subducted sediment may experience partial melting or dehydration because of heating from the surrounding mantle (e.g., Hermann and Spandler 2008; Hermann and Rubatto 2009; Castro et al. 2010; Mann and Schmidt 2015; Schmidt and Poli 2014; Schmidt 2015), which could release trace elements to the upper mantle wedge and contribute to the origin of arc lavas (e.g., Peacock 1990; Ulmer and Trommsdorff 1995; Shimoda et al. 1998; Bindeman et al. 2005; Duggen et al. 2007; Turner et al. 2012; Spandler and Pirard 2013; Kendrick et al. 2014; Harvey et al. 2014; Scambelluri et al. 2015; Shu et al. 2017). The recycling of sediment melt or fluid back into a mantle wedge has been demonstrated by matching the isotopic and trace-element properties of sediment input and volcanic magma output (e.g., Plank and Langmuir 1993; Peate et al. 1997; Porter and White 2009; Turner et al. 2012).

Recent numerical simulations and geochemical analyses have revealed that subducted sediments could detach from a downdropping slab at temperatures of 500–850 °C to form buoyancy diapirs (Behn et al. 2011). Then, a portion of the cold diapir would rise buoyantly from the surface of the subducting slab and relaminate