The composition of KLB-1 peridotite

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Abstract

Electron microprobe analyses of major- and minor-element oxide components for two glassed samples of natural KLB-1 peridotite are presented. One glass was made with the aid of a phosphate flux, and the second glass was made by laser melting of aerodynamically levitated spheroids resulting in homogeneous silicate glass beads. For unknown reasons, the silicate-phosphate glass yields compositions that are incompatible with the composition of KLB-1 peridotite. However, analysis of the glass bead formed by laser synthesis is believed to give an accurate representation of the composition of KLB-1 peridotite, except for minor loss of Na2O owing to volatilization. The new data resolve conflicting FeO, CaO, and TiO2 values from two older measurements present in the literature. Mass-balance calculations using the new composition measurement combined with new analyses of the mineral compositions in KLB-1 result in a lower sum of squares of the residuals than those using the older measurements. There are appreciable differences in calculated modes from partial-melting experiments of KLB-1 when calculated using older KLB-1 analyses or our new analysis.

Keywords: Peridotite, KLB-1, microprobe, mantle, levitating/laser fusion

Introduction

Experimental investigation of the petrologic, geochemical, and geophysical properties of the deep Earth requires suitable analog starting compositions. Probably the most widely employed natural analog of the upper mantle is KLB-1, a spinel lherzolite xenolith from the Kilbourne Hole crater in New Mexico. Samples of KLB-1 have been used to represent the bulk mantle in many high-pressure experimental studies (Takahashi 1986; Herzberg et al. 1990; Agee and Walker 1993; Hirose and Kushiro 1994; Takahashi et al. 1993; McFarlane et al. 1994; Zhang and Herzberg 1994; Hirose and Kawamoto 1995; Herzberg and Zhang 1996; Hirose 1997a, 1997b; Konzett and Fei 2000; Wang and Takahashi 2000; Hirose 2002; Hirose and Fei 2002; Matsukage and Kubo 2003; Yoshino et al. 2004). For many other studies, starting materials were synthesized to approximate KLB-1 (Kawamoto et al. 1996; Kawamoto and Holloway 1997; Kogiso et al. 1998; Tronnès and Frost 2002; Ono et al. 2005; Mibe et al. 2006; Dasgupta and Hirschmann 2006, 2007, 2007). Owing to these many studies, the composition of KLB-1 has become quite influential, and many theoretical treatments commonly assume that KLB-1 is an analogue for the composition of the upper mantle (Iwamori et al. 1995; Arndt et al. 1997; Moore et al. 1998, 1999; Ogawa and Nakamura 1998; Katz et al. 2003; Komiya 2004; Dobretsov et al. 2006). However, the composition of KLB-1 is known from only two analyses (Takahashi 1986; Herzberg et al. 1990), and these are not in complete agreement. Consequently, we have undertaken a new study of the composition of KLB-1 peridotite.

Experimental petrologists and others interested in the major-element or mineralogic composition of the upper mantle rely heavily on the KLB-1 bulk composition because it is among very few natural peridotite samples that may approximate the composition of typical mid-ocean ridge basalt (MORB) source regions. In particular, compositions of MORB indicate that the convecting upper mantle is fertile with respect to major elements such as CaO, Al2O3, and Na2O (Salters and Stracke 2004; Workman and Hart 2005), suggesting compositions with appreciable modal clinopyroxene, but depleted with respect to large-ion-lithophile elements such as K2O. Virtually all natural peridotite samples from xenoliths or from orogenic peridotites are depleted in modal clinopyroxene relative to the MORB source, which has 13–18% cpx (Salters and Stracke 2004; Workman and Hart 2005), and/or have small amounts of metasomatic phases such as amphibole and phlogopite, and consequently, have non-negligible K2O and H2O. Thus, plausible natural analogues of the composition of the convecting upper mantle are rare. For this reason, experimental studies employing natural materials generally have used one of a very small number of xenolith compositions: PHN-1611 (Mysen and Kushiro 1977), KR4003 (Walter 1998), Tainagillo lherzolite (Jaques and Green 1980), or KLB-1. Among these, KLB-1 has the unique quality of simultaneously being relatively high in Na2O (~0.3 wt%); Takahashi 1986; Herzberg et al. 1990) and low in K2O (<0.03 wt%), and therefore is possibly the only readily available well-studied natural peridotite that may plausibly have major and minor elements similar to typical source regions of MORB (0.29 wt% Na2O; 0.007 wt% K2O; Salters and Stracke 2004; Workman and Hart 2005). Previous bulk analyses of KLB-1 are an analysis published originally by Takahashi (1986) and a reanalysis by Herzberg et al. (1990). In the former case, the analytical technique was not specified, although Herzberg (pers. comm.) suggested that X-ray fluorescence methods were employed. In the latter case, the analysis was by direct-current plasma analysis (DCP). Although these analyses are in close agreement for SiO2, Al2O3, MgO,