**Potential host phase of aluminum and potassium in the Earth’s lower mantle**

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**ABSTRACT**

An Al-rich phase produced by phase transformation from a natural mid-oceanic ridge basalt under lower mantle conditions was studied by X-ray diffraction and analytical transmission electron microscopy. The phase, coexisting with silicate perovskites, the Ca-ferrite-structure phase, and stishovite, has hexagonal symmetry (space group \(P6_3/m\)) and the composition \([M^+\cdot Ca\cdot(Mg,Fe)_{2}\sum_{3}(Al,Si)_{5.5–6.0}O_{12}\), where \(M = Na^+, K^+\). The alkali-free phase with the complex solid solution, \([Ca_{0.79}Mg_{0.12}\sum_{0.91}[Mg]_{2.00}\sum_{5.57}Al_{4.09}Si_{1.48}O_{12}\) has a unit cell with \(a = 8.765 \text{ Å}, c = 2.762 \text{ Å}, V = 183.7 \text{ Å}^3, Z = 1\), a formula weight = 429.31, and a calculated density = 3.88 g/cm\(^3\) at 0 GPa and 4.16 g/cm\(^3\) at 23 GPa. This Al-rich phase is considered to be same as the hexagonal phases recently reported, and thus the hexagonal phases can potentially host alkali and alkali-earth elements in the lower mantle.

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**INTRODUCTION**

Recent information about the Earth’s lower mantle obtained from seismic data and laboratory experiments at high pressure makes us think that the mineralogy of the lower mantle may be simple in comparison to that of the crust and upper mantle, consisting of (Mg,Fe)SiO\(_3\)–Al\(_2\)O\(_3\) orthorhombic perovskite, CaSiO\(_3\) cubic perovskite, and (Mg,Fe)O magnesiowüstite. No Al-rich phases, except for perovskites, are considered to exist in the main part of lower mantle (Irifune 1994; Kesson et al. 1998). However, aluminum-rich basaltic rock (e.g., mid-oceanic ridge basalt, MORB) is an important component of subducting slabs and the deep subduction may therefore give rise to chemical heterogeneities in the mantle (e.g., Irifune and Ringwood 1993; Kesson et al. 1994b; Faust and Knittle 1996; Hirose et al. 1999; Wang and Takahashi 1999; Funamori et al. 2000). In fact, high-pressure laboratory experiments on constituent materials of subducting slabs (e.g., MORB, continental crust and related minerals), together with petrographic information obtained from inclusions in diamonds and xenoliths that originated in the lower mantle, indicate that various Al-rich phases can form under lower mantle conditions, although not all the structures of these Al-rich phases have been identified (Madon et al. 1989; Ahmed-Zaïd and Madon 1991; Irifune et al. 1991; Ahmed-Zaïd and Madon 1995; Irifune et al. 1996; Gautron et al. 1997; Harris et al. 1997; Funamori et al. 1998; Kondo and Yagi 1998; Miyajima et al. 1999; Wang and Takahashi 1999; Collerson et al. 2000; Oguri et al. 2000).

No systematic interpretation, however, has yet been made on what controls the occurrence of such Al-rich phases. Some Al-rich phases that also contain alkali elements are of interest because these could pertain to the behavior of sodium and potassium in the lower mantle (Akaogi 2000; Wang and Takahashi 2000; Gasparik et al. 2000). Phase transformations in MORB containing Na and K are the key to clarification of the behavior of aluminum and alkali elements under conditions of the lower mantle. Here, we report on an Al-rich phase (denoted as “NAL” by Miyajima et al. 1999 and Oguri et al. 2000) that resulted from transformation in a K-bearing natural MORB, and also the occurrence of similar phases in natural garnets subjected to conditions of the lower mantle. The phase is considered to be same as the hexagonal phases already reported (Kesson et al. 1994a; Gasparik et al. 2000; Miura et al. 2000) and K phases II and III (Wang and Takahashi 2000) and is therefore a candidate for hosting K and Na in MORB and alkali-