Ultra-deep subduction of Yematan eclogite in the North Qaidam UHP belt, NW China: Evidence from phengite exsolution in omphacite

LEI HAN¹, LIFEI ZHANG¹,* AND GUIBIN ZHANG¹

¹MOE Key Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing 100871, China

ABSTRACT

Phengite exsolution in omphacite from the Yematan eclogite, North Qaidam UHP belt, NW China, is described. Mineralogical investigations show that the precursor omphacite in the Yematan eclogite contains up to 1.16 wt% K₂O and ~10,000 ppm H₂O. Experimental studies document this omphacite to be formed at pressures higher than 6 GPa (at 900 °C). The pressure-temperature conditions of 3.68 GPa and 892 °C for phengite exsolution in omphacite associated with garnet during the exhumation were obtained by using Grt-Omp-Ph geothermobarometer. We conclude that omphacitic-clinopyroxene in subducted eclogites may act as a robust medium to transport H₂O and potassium deep into the interior of the Earth. This study suggests that the Yematan eclogite in North Qaidam UHP metamorphic belt, NW China, may have been subducted and exhumed from depths of more than 200 km.

Keywords: Phengite exsolution, eclogite, ultra-deep subduction, North Qaidam, China

INTRODUCTION

Since Switzer and Melson (1969) found 0.3 wt% K₂O in pyroxene from a diamond-bearing eclogite from the Roberts Victor Mine, potassium-rich clinopyroxenes and exsolved potassium-mineral lamellae in clinopyroxenes have been extensively reported from ultrahigh-pressure (UHP) rocks. For example, some eclogitic omphacites (Reid et al. 1976; Harlow and Veblen 1991; Xiao et al. 2000), as well as clinopyroxenes from carbonate (Sobolev and Shatsky 1990; Ogawara et al. 2002) and ultra-basic rocks (Bindi et al. 2003) were reported to contain unexpectedly high potassium abundances. Potassium-bearing minerals have also exsolved in clinopyroxenes from calsiculate rocks (Katayama et al. 2002; Zhu and Ogawara 2002; Bozhilov et al. 2009; Schertl and Sobolev 2013) and eclogites (Schmädicke and Müller 2000). Moreover, according to studies of diamond-bearing eclogite xenoliths (Reid et al. 1976; Harlow and Veblen 1991; Okamoto et al. 2000), as well as from experiments (Harlow 1997; Luth 1997; Okamoto and Maruyama 1998, Wang and Takahashi 1999), it is known that potassium-rich (~1 wt% K₂O) clinopyroxene is stable at pressures above 4 GPa. For example, there is ~1 wt% K₂O in subsolidus clinopyroxene at 6 GPa (Wang and Takahashi 1999).

The North Qaidam UHP metamorphic belt in northwestern China consists of three coesite-bearing eclogite terranes and one diamond-bearing garnet peridotite terrane. The coesite-bearing terranes, from west to east are the Yuka, Xitieshan, and Dulan; the diamond-bearing rocks are represented by the Lüliangshan peridotite terrane (Fig. 1a). To date, the Lüliangshan peridotite terrane has been confirmed to have been subducted to depths greater than 200 km (Song et al. 2004, 2005); for the other three coesite-bearing eclogite terranes, depths of ~100 km have been suggested (Zhang et al. 2009a, 2009b, 2009c; Liu et al. 2012). Potassium-bearing mineral exsolution in eclogite is rarely reported. Phlogopite exsolution lamellae in eclogitic garnet from the No.50 kimberlite pipe of Fuxian County, Liaoning Province, China (Zhou 1997) and potassium-white mica lamellae in omphacite from the Erzgebirge crystalline complex (Schmädicke and Müller 2000) have been qualitatively identified by transmission electron microscope (TEM) and energy-dispersive X-ray spectrometry (EDX). Here we report phengite exsolution in omphacite from two eclogite samples and discuss its implication for ultra-deep subduction of the Yematan UHP terrane, NW China.

GEOLOGICAL SETTING AND SAMPLE DESCRIPTION

The Yematan UHP terrane is located in the eastern part of the North Qaidam ultrahigh-pressure (UHP) metamorphic belt (Fig. 1). The North Qaidam UHP belt (Song et al. 2003) is located in northwestern China and contains four metamorphic terranes (Fig. 1a). From east to west: they are the Dulan terrane; the Xitieshan terrane; the Lüliangshan terrane; and the Yuka terrane.

The Yematan eclogite and peridotite occur as blocks, boudins or layers in host para- and ortho-gneiss. The discovery of coesite inclusion in zircon from the Yematan host paragneiss indicates that Yematan eclogitic rocks may have been subjected to UHP metamorphism (Yang et al. 2001). Two eclogite samples (11ym26 and 12ym05) with phengite exsolution in omphacite were collected in the Yematan area. They occur with four types of eclogites (biminaral eclogite, phengite-epidote eclogite, phengite eclogite, and epidote eclogite), serpentinitized peridotite (some peridotite contain garnet; Mattinson et al. 2007), garnet-bearing pyroxenite (Song et al. 2003), and the host para- and ortho-gneiss. The two eclogite samples (Fig. 1b) with phengite exsolution in omphacite, 11ym26 and 12ym05, consist of garnet (35–40%) + omphacite (30–40%) + quartz (5%) + rutile (5%) + phengite (2%), with up to 10% amphibole + plagioclase or diopside +...