Coesite exsolution from supersilicic titanite in UHP marble from the Kokchetav Massif, northern Kazakhstan

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ABSTRACT

Coesite exsolved from supersilicic titanite was discovered in an impure calcite marble at Kumdy-kol in the Kokchetav UHP (ultrahigh-pressure) metamorphic terrane, northern Kazakhstan. This impure marble consists mainly of calcite, K-feldspar, diopside, and symplectites of diopside + zoisite, with minor amount of titanite, phengite, and garnet. No diamond was found in the marble. Coesite and quartz, which have needle or platy shapes measuring about 20–60 μm in length, occur as major exsolved phases in the cores and mantles of titanite crystals with minor calcite and apatite. The strongest Raman band for the coesite needles and plates was confirmed at about 524 cm⁻¹ with a weak band at about 271 cm⁻¹. To estimate the initial composition of the titanite before coesite exsolution, exsolved phases were reintegrated by measuring their area fractions on digital images. The highest excess Si in titanite was thus determined to be 0.145 atoms per formula unit (apfu). This composition requires a pressure higher than 6 GPa on the basis of phase relations in the system Ca(1-x)TiSiO₅–CaSi₂O₅. This pressure is consistent with other evidence of high pressure in the same marble, such as 1.4–1.8 wt% K₂O and over 1000 ppm H₂O in diopside. Supersilicic titanite and coesite exsolution also indicate that SiO₂ exsolution occurred in the coesite stability field during exhumation of the UHP metamorphic unit.

INTRODUCTION

The Kokchetav terrane (Fig. 1) is well known for its ultrahigh-pressure (UHP) assemblages, such as the first reported occurrence of microdiamond of metamorphic origin (Sobolev and Shatsky 1990). Further studies on metamorphic microdiamond and additional evidence indicative of ultra high-pressure metamorphism related to deep continental subduction have been reported from this area: coesite, K-rich clinopyroxene, SiO₂ rods in omphacite, and aluminous titanite (e.g., Sobolev and Shatsky 1990; Zhang et al. 1997; De Corte et al. 1998, 2000; Nakajima et al. 1998; Okamoto et al. 1998, 2000; Ishida et al. 1999; Katayama et al. 2000). In particular, the UHP rocks at Kumdy-kol show the highest-pressure conditions in the Kokchetav terrane and are attracting much attention as examples of the deepest subducted continental material that has been exhumed to the surface. Peak metamorphic conditions of eclogite from the Kumdy-kol have been estimated at >6 GPa and >1000 °C on the basis of K₂O-in-augite geobarometry and garnet-clinopyroxene geothermometry (Okamoto et al. 1998, 2000). This paper presents the first description of coesite exsolution from titanite and its implications for peak metamorphic P-T conditions of the Kokchetav UHP terrane.

METHODS

Electron microprobe analyses were performed by wavelength dispersive methods (WDS) using a JEOL JXA-8900 Super Probe at Department of Earth Sciences, Waseda University. A LaB₆ filament was used for all analyses. The conditions for spot analyses were an accelerating voltage of 15 kV, a beam current of 20 nA, a beam spot diameter of 2 μm, and a counting interval of 10 s. The data were corrected by the f-r-Z method (JEOL 1993). The conditions for X-ray mapping were an accelerating voltage of 25 kV, a beam current of 20 nA, a beam spot diameter of 2 μm, and a counting interval for each pixel of 310 ms.

Bulk-chemical compositions of titanite with coesite needles and plates were estimated by measuring areal fractions of needles and plates in host grains for a square of 200 × 200 μm² on the polished surface. Using digital image files of the photomicrographs taken under a reflected-light microscope and laser Raman spectra, needles and plates on the polished surface were discriminated on a computer screen and their areal fractions were calculated by a computer program in Adobe Photoshop 5.5.

The discrimination between calcite and dolomite was performed by the staining method using alizarine red S solution. Several grains of calcite were identified by X-ray powder diffraction.

OCCURRENCE

Abundant gneisses and eclogites occur in the Kumdy-kol area, Kokchetav Massif in northern Kazakhstan, and those rocks contain evidence for UHP conditions (e.g., Sobolev and Shatsky 1990; Kaneko et al. 2000; Katayama et al. 2000; Okamoto et