Characterization of an early metamorphic stage through inclusions in zircon of a diamondiferous quartzofeldspathic rock from the Erzgebirge, Germany

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ABSTRACT

About 1000 zircon grains from a diamondiferous quartzofeldspathic rock of the Saxonian Erzgebirge were investigated for inclusions using optical microscopy and confocal laser-Raman spectroscopy. Cathodoluminescence imagery was applied to characterize the growth zone of zircon where the inclusions occurred. The most abundant inclusion minerals are microdiamonds. Coesite was not detected. However, garnet and jadeite occur as rare inclusions in zircon cores where diamonds are lacking. Jadeite was detected for the first time in quartzofeldspathic rocks from the crystalline complex of the Erzgebirge. The compositions of the pristine garnets in the zircons are similar to those of core areas of millimeter-sized garnets but the original garnet composition of the early metamorphic stage is only preserved in zircon. Intracrystalline diffusion at temperatures as high as 1000 °C resulted, for instance, in higher Ti concentrations in garnet cores compared with garnet enclosed in zircon. Rutile, quartz, and the compositions of jadeite and garnet inclusions in zircon and of phengite inclusions in cores of large garnets were applied for geothermobarometry. The results, related to an early metamorphic stage, are 650 °C and 18 kbar, which represent conditions at the base of a thickened continental crust before deeper subduction.

INTRODUCTION

In the central portion of the Variscan crystalline complex of the Erzgebirge, situated in the northwestern edge of the Bohemian Massif, Central Europe, Massonne (1999) reported microdiamonds in garnet + muscovite-rich quartzofeldspathic rocks. Such rocks occur as lenses up to several hundreds of meters in length near the Saidenbach reservoir (Massonne 2001a), about 1.5 km northwest of the village of Forchheim, in the so-called Gneiss-Eclogite Unit that dominates the central portion of the Erzgebirge in Saxony. The oval-shaped metamorphic area of the Erzgebirge extends about 80 km in a WNW-ESE direction.

Saxonian microdiamonds can reach diameters up to 30 μm. Their nature as genuine, naturally formed inclusions was proven by analyzing fully included grains inside host minerals by confocal micro-Raman spectroscopy (Nasdala and Massonne 2000). Thus, the peak pressure experienced by the diamondiferous rocks must have exceeded 45 kbar because the corresponding temperature conditions were slightly above 1000 °C derived on the basis of Ti incorporation into Al-garnet (Massonne 1999; Brandelik and Massonne 2001). According to experiments in the TiO2 system (Akaogi et al. 1992), pressures possibly as high as 80 kbar are indicated by a nanocrystal of TiO2 with the α-PbO2 structure reported by Hwang et al. (2000) from the same rock. At these ultrahigh pressures (UHP) and high temperatures, the rocks were partially molten and subsequently rose (Massonne 2001b). During the uprise and cooling, growing garnets trapped fluids from which microdiamonds were precipitated (Stöckhert et al. 2001). The compositions of the garnet rim and the matrix minerals, potassic white mica and plagioclase, in equilibrium with quartz and kyanite, led to P-T conditions close to 15 kbar and 750 °C for the final metamorphic event (Massonne 1999). Later on, minor retrogression led to the formation of biotite along some grain boundaries of potassic white mica.

A similar exhumation path was derived from diamondiferous quartzofeldspathic rocks of the Kokchetav Massif, Northern Kazakhstan (Hermann et al. 2001), where microdiamonds were first detected in crustal rocks (Sobolev and Shatsky 1990). Both occurrences are the only ones discovered thus far, where phase relations with microdiamonds can be studied “in situ” in crustal rocks. However, an estimate for P-T conditions of a stage before the onset of UHP metamorphism and diamond formation was presented only by Massonne (1999) on the basis of a preserved mineral assemblage. This assemblage is represented by inclusions of phengite, quartz, and rutile (also rarely together in single inclusions) in garnet cores, which are surrounded by a growth zone of garnet containing microdiamond inclusions. The estimated P-T conditions, although not very precise, allowed important conclusions regarding the source region of the crustal rocks that underwent subsequent UHP metamorphism.

Despite of the relatively well-known P-T evolution path, we searched for methods to improve our knowledge about the metamorphic P-T conditions. Therefore, we started an investigation to detect preserved minerals of early metamorphic stages. Micro-Raman spectroscopy is a uniquely powerful tool for such purpose. Similar applications of this technique were presented, for instance, by Katayama et al. (2000a) and Liu et al. (2001) for UHP rocks from the Kokchetav Massif and the Dabie-Sulu terrane, Eastern China, respectively.