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A zircon study from the Rhodope metamorphic complex, N-Greece: Time record of a multistage evolution

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Abstract

Zircons from an eclogite and a diamond-bearing metapelite near the Kimi village (north-eastern Rhodope Metamorphic Complex, Greece) have been investigated by Micro Raman Spectroscopy, SEM, SHRIMP and LA-ICPMS to define their inclusion mineralogy, ages and trace element contents. In addition, the host rocks metamorphic evolution was reconstructed and linked to the zircon growth domains.

The eclogite contains relicts of a high pressure stage (ca. 700 °C and >17.5 kbar) characterised by matrix omphacite with Jd_{40-35}. This assemblage was overprinted by a lower pressure, higher temperature metamorphic event (ca. 820 °C and 15.5–17.5 kbar), as indicated by the presence of clinopyroxene (Jd_{35-20}) and plagioclase. Biotite and pargasitic amphibole represent a later stage, probably related to an influx of fluids. Zircons separated from the eclogite contain magmatic relicts indicating Permian crystallization of a quartz-bearing gabbroic protolith. Inclusions diagnostic of the high temperature, post-eclogitic overprint are found in metamorphic zircon domain Z2 which ages spread over a long period (160 – 95 Ma). Based on zircon textures, zoning and chemistry, we suggest that the high-temperature peak occurred at or before ca. 160 Ma and the zircons were disturbed by a later event possibly at around 115 Ma. Small metamorphic zircon overgrowths with a different composition yield an age of 79 ± 3 Ma, which is related to a distinct amphibolite-facies metamorphic event.

The metapelitic host rock consists of a mesosome with garnet, mica and kyanite, and a quartz- and plagioclase-bearing leucosome, which formed at granulite-facies conditions. Based on previously reported micro-diamond inclusions in garnet, the mesosome is assumed to have experienced UHP conditions. Nevertheless, (U)HP mineral inclusions were not found in the zircons separated from the diamond-bearing metapelite. Inclusions of melt, kyanite and high-Ti biotite in a first metamorphic zircon domain suggest that zircon formation occurred during pervasive granulite-facies metamorphism. An age of 171 ± 1 Ma measured on this zircon domain constrains the high-temperature metamorphic event. A second, inclusion-free metamorphic domain yielded an age of 160 ± 1 Ma that is related to decompression and melt crystallization.

The similar age data obtained from the samples indicate that both rock types recorded a high-T metamorphic overprint at granulite-facies conditions at ca. 170 – 160 Ma. This age implies that any high pressure or even ultra-high pressure metamorphism in the Kimi Complex occurred before that time. Our findings define new constraints for the geodynamic evolution for the Alpine orogenic cycle within the northernmost Greek part of the Rhodope Metamorphic Complex. It is proposed that the rocks of the Kimi

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Complex belong to a suture zone squeezed between two continental blocks and result from a Paleo-ocean basin, which should be located further north of the Jurassic Vardar Ocean.

Keywords: UHP metamorphism; Rhodope; Zircons; U–Pb geochronology; Trace elements

1. Introduction

The Rhodope Metamorphic Complex (RMC) in northern Greece is considered to be a nappe stack of metamorphic units derived from continental and oceanic crust (e.g. Burg et al., 1996; Ricou et al., 1998). Existence of Variscan (Carboniferous–Permian) and Alpine (Late Cretaceous–Tertiary) metamorphism is supported by radiometric data (Jones et al., 1994; Peytcheva and von Quadt, 1995). Since UHP metamorphism was reported by Mposkos and Kostopoulos (2001), the RMC became object of several geochronological studies (Liati et al., 2002; Liati 2005; Turpaud and Reischmann, 2005). Despite controversial discussions about diamond and other UHP indicators like multicrystalline polygonal quartz (Mposkos and Kostopoulos, 2001; Beyssac and Chopin, 2003), a number of different UHP metamorphic ages were recently reported for the RMC (e.g. Liati, 2005 and ref. therein). Perraki et al. (2006) reported micro-diamond inclusions in metapelitic garnet from Kimi Complex, north-eastern Rhodope and confirmed the UHP metamorphic event in the RMC, already proposed by Mposkos and Kostopoulos (2001).

The Rhodope UHP Metamorphic Complex, similarly to other UHP terranes (see a review in Carswell and Compagnoni, 2003), likely had a complex metamorphic evolution characterised by multiple stages and strong re-equilibration. This has been suggested by a number of petrological and geochronological studies of the massif (e.g. Mposkos and Krohe, 2000; Liati et al., 2002). In order to add further time constraints to this complex high-grade evolution, ages need to be linked to metamorphism. To achieve this goal we use a combination of petrography, mineral chemistry, and detail investigation of the trace elements and U–Pb composition of zircons. Due to the composite nature of the zircon, ages have been measured by SHRIMP (Sensitive High Resolution Ion MicroProbe), which combines high spatial resolution with analytical precision (e.g. Williams, 1998). This approach has been successful in the past in establishing timing and conditions of prograde and retrograde metamorphic histories even in highly reworked samples (e.g. Hermann et al., 2001; Wu et al., 2006).

The link between absolute zircon ages and metamorphic events is difficult because zircon formation can be induced by various processes within a wide range of pressure (P) and temperature (T) conditions. Zircon crystals may record a prograde as well as a retrograde stage of the P–T path (e.g. Hermann et al., 2001; Wu et al., 2006), but reversely zircon does not necessarily record all the metamorphic events that a rock underwent (e.g. Hoskin and Black, 2000).

One possibility to correlate zircon ages with metamorphic events is to consider the trace element composition of the zircon and surrounding minerals (e.g. Rubatto, 2002). Trace element characteristics of zircon can reflect coeval growth of some mineral phases like plagioclase, which is a sink for Eu, garnet which sequestrates the HREE, or rutile because of its affinity for Nb or Ta (Li et al., 2005). Another direct link between metamorphic history and the formation of zircon is provided by its mineral inclusions. Their diagnosis is restricted to the surface when using standard secondary electron microscopy and electron microprobe technique. Raman micro-spectroscopy however has the capability to below-surface investigation and thus is a powerful complementary tool to determine inclusions on a micrometer scale. In addition, phase identification based on structural information of polymorphs (Al_2SiO_5, diamond/graphite, quartz/coesite) is possible (e.g. Nasdala et al., 2004).

In this paper, we present new geochronological data, trace element chemistry and a detailed investigation of zircon inclusion mineralogy of a diamond-bearing garnet micaschist and an eclogite. We link petrological data of the host rocks with zircon inclusion mineralogy and trace element characteristics to correlate metamorphic events with age data from metamorphic zircon domains. The aim of this study is to decipher the *PT*-time history of the RMC by investigating zircon from one eclogite and a recently established, diamond-bearing UHP metapelite.

2. Geological setting

The tectonic units of the RMC represent the northern part of an Alpine nappe stack in the Aegean region that formed during the convergence of Africa and Europe since the Middle Jurassic (e.g. van Hinsbergen et al., 2005). The Complex extends over large areas of Northern Greece and Bulgaria and contains mainly continental