The extensional Kulidzhik Allochthon of the Eastern Rhodopes

Екстензионният Кулиджикски алохтон в Източните Родопи

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Introduction

The Rhodope Metamorphic Complex is an Alpine nappe edifice composed of 4 allochthons (Lower, Middle, Upper and Uppermost) that were assembled together in a course of a complicate convergent history from Jurassic to Paleogene (Janák et al., 2011). Depending on their time of origin, the boundaries between different allochthons represented either north or south facing thrusts. In the Late Eocene and later in the Miocene, the area was affected by extensional tectonics that led to the exhumation of the higher grade units along top-to-the N or top-to-the S detachment faults that totally reassembled the initial nappe configuration. Since the high-grade klippen of the Kulidzhik thrust were discovered (Boyanov, 1969), the Eastern Rhodopes area is considered as a classical example of the Alpine nappe nature of the Rhodope Metamorphic Complex. This idea was further developed in a number of papers and was the base of some larger scale geodynamic reconstructions, mostly dedicated to the Early Alpine evolution of the area (Bonev et al., 2010, 2015).

Geological setting

The Kulidzhik river valley in the Eastern Rhodopes provides a well exposed section of metamorphic rocks. In the study area, the following nappes occur in superposition (from base to top): 1) an orthogneiss-dominated ***Unit I*** (corresponds to the "Lower high-grade unit" in Bonev et al., 2010); 2) garnet-bearing schists with amphibolite and serpentinite lenses of ***Unit II*** (corresponds to "Proterozoic high-grade basement with a regional diaphthoresis" in Boyanov, 1969; or to the basement units in Bonev, 2006a, 2010, have assigned these rocks to their "Greenschist-phylite unit"); 3) greenschist, phyllite, and calcschist with reported Jurassic microfossils (Boyanov et al., 1990) of ***Unit III*** (corresponds to the "Phylitoid series" and the "Greenschist series" in Boyanov, 1969; or to the "Greenschist-phylite unit" in Bonev, 2006a); 4) and muscovite-rich orthogneiss ***Unit IV*** (corresponds to the "Proterozoic metamorphic rocks from the allochthon" of the Kulidzhik thrust in Boyanov, 1969; or to the "Orthogneiss allochthon" of the Kulidzhik thrust in Bonev et al., 2010, considered as originating from Unit I). The metamorphic succession is covered by Late Eocene–Early Oligocene sedimentary and volcano-sedimentary rocks (Boyanov, 1969).

Results

We have performed a detail structural study of units I, II, III and IV as well as U/Pb zircon dating of samples collected from units I, II and IV. Our data show that Unit I was affected by two shearing deformation events with opposite kinematics: an older and higher-grade penetrative top-to-the S one; and a younger and more localized top-to-the N. The older foliation, S_{I-1}, is pervasive in the entire outcrop area except at the top of the unit where close to the boundary with Unit II and dominantly in separate shear zones the younger fabric S_{I-2} prevails. The contact area between these units is marked by a greenschist facies top-to-the N shear zone. Unit II represents a polypfase metamorphic succession that has experienced at least 3 different tectono-metamorphic events as recorded by the field, microstructural and petrological studies. The first two events were of higher grade, reaching amphibolite facies M_{II-2} and granulite facies M_{II-1}. The 3rd metamorphic event M_{II-3} developed at greenschist facies conditions and caused intensive greenschist facies retrogression. The lower-grade overprint becomes more intensive close to the boundary with the upper Unit III, where due to the shearing the rocks were transferred into phylonites. The related S_{II-3} foliation bears N-S oriented L_{II-3} stretching lineation. The related kinematic indicators show consistent top-to-the N sense of shear. The boundary between units II and III represents a thick up to 1–2 m layer of foliated cataclasites which contain slicken fibers indicating top-to-the N sense of shear. The metamorphic grade of Unit III does not exceed the greenschist facies. Since the unit is composed of greenschists, phyllites, and calcschists, it is not easy to distinguish them from the phyllonites and retrogression related greenschists of Unit II. Unit III is intensely sheared and the reliable kinematic indicators show consistent top-to-the N tectonic transport similar to the kinematics of the shearing in lower Unit II. The ductile fabric is in many places overprinted by brittle deformation which prevails within the upper structural levels of Unit III and close to the contact with Unit IV. Unit IV contacts tectonically units II and III. The contact zone represents a thick layer of cataclastic rocks composed of two domains: lower – cataclasitic and upper – cohesive to non-cohesive breccia (kakirite). The cohesive cataclasites belong to the uppermost section of units II or III, whereas the non-cohesive breccia represents the lowermost and tectonically crushed rocks of Unit IV. Flat lying secondary rank fault surfaces within the cataclastic lower domain, containing slickensides and slicken fibers show consistent top-to-the N sense of shear. The entire metamorphic section is covered by Paleogene sedimentary and volcano-sedimentary rocks. However, due to limited outcrops the particular relationships between the Upper Eocene sediments and Unit I are not precisely clear.

U-Pb dating of zircons from a K-feldspar augengneiss (Unit I), using laser ablation inductively coupled plasma mass spectrometry, yielded a protolith age of 300.7±2.6 Ma. Garnet-bearing metasediment from Unit II yielded an age spectrum with three distinct populations at 299.9±1.8 Ma (magmatic), ca.149.7±0.97 Ma, and 74–68 Ma (the last two of high-grade metamorphic origin). An orthogneiss from Unit IV yielded a wide spectrum of ages. The youngest zircon population gives a concordia age of 581±5 Ma, interpreted as the age of the granitic protolith.

Discussion and conclusions

The obtained results allow a rather clear correlation of the studied rocks to certain levels of the Rhodope Metamorphic Complex. Following the general tectonic model of Jának et al. (2011), where the Rhodope nappe stack is thought to represent an Alpine edifice of four allochthons, namely Lower, Middle, Upper and Uppermost, we address Unit I to the Lower Allochthon (Byala Reka–Kechros Dome), Unit II to the Upper Allochthon (Krumovitsa–Kimi Unit), Unit III to the Uppermost Allochthon (Circum-Rhodope Belt), and Unit IV a still higher, far-travelled unit of unknown provenance. The top-to-the S shearing in Unit I fits well to the kinematics of the top-to-the S exhumation of the Lower high-grade unit discussed in Bonev (2006b). The top-to-the N lower-grade shearing in Unit I can be related with the northward kinematics of the shearing within units II and III and thus surely postdating the south directed tectonic transport in Unit I. The greenschist facies top-to-the N shearing in Unit II postdates a Upper Cretaceous high-grade metamorphic mineral assemblage so thus, the low-grade mylonitization of the unit must be of post Late Cretaceous age. The parallelism between lineations within units II and III as well as their similar kinematics show that the last mylonitization in these units took place during same top-to-the N tectonic event. The upward decrease in the metamorphic grade from Unit I to units II and III show that the last mylonitic structure was formed in a course of a single extensional event. This structure considerably differs from the higher grade orthogneisses of Unit IV. Telescoping of the entire Rhodope nappe stack to a thickness of only a few 100 m is due to Late Eocene north directed extensional shearing along the newly defined Kulidzhik detachment which is part of a major detachment system along the northern border of the Rhodopes. Older top-to-the S mylonites in Unit I indicate that Tertiary extension evolved from asymmetric (top-to-the S) to symmetric, bivergent unroofing.

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