New structural and geochronological data for the Tertiary evolution of the Rhodopes

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The Rhodope Metamorphic Province was traditionally believed to be a craton consisting of mostly Precambrian basement rock units and separated into numerous blocks along steeply dipping brittle faults (see e.g. the official 1:100000 scale Bulgarian geological map). In the past few decades, the Rhodope Metamorphic Province was recognized as being part of the Alpine-Himalayan chain by a growing number of publications. Recent tectonic studies, including the new 1:50000 scale Bulgarian geological map, generally subdivide the Rhodope Metamorphic Province into lithotectonic units that have been deformed internally while they were transported relative to each other along low-angle faults. Despite some differences, most published tectonic maps agree that the lowest tectonic levels of the Rhodope Metamorphic Province are represented by leucocratic gneisses and thick marble in the Drama Window between the Strimon Valley and the Nestos Shear Zone and by orthogneisses exposed in the Central Rhodope, Kesebir-Kardamos, and Biala Reka-Kechros Domes. They are overlain and framed by intermediate and upper tectonic units containing small proportions of metabasic and metaultrabasic rocks that are commonly interpreted to be ophiolites. Recent studies have shown that the orthogneiss protolith ages of the lower, intermediate, and upper levels are markedly different, reflecting different palaeogeographic origins of the units comprised in these tectonic levels.

The formation of the main gneissic foliation ended before the Tertiary in upper tectonic levels which are locally overlain by Maastrichtian sediments. In the intermediate level, the formation of the main gneissic foliation continued into the Eocene and the oldest overlying sediments are (Middle to?) Late Eocene in age. Very recent radiometric data provide evidence that top-SW thrusting of the intermediate and upper tectonic levels over the lower level along the Nestos Fault continued well into the Eocene.

From the Middle or Late Eocene on, top-SW faulting in the SW Rhodopes was extensional, leading to the formation of large sedimentary basins. Our structural studies, combined with stratigraphic constraints from the basin sediments and radiometric data of pre-, syn-, and posttectonic magmatic rocks point to a two-stage history of extension in the SW Rhodopes that finally led to the formation of the Drama Window. A first Late Eocene stage of extension was accommodated along the Ribnovo-Mesta-Kerdilion fault system and followed by an Early Oligocene phase of normal faulting along steeply NE-dipping faults. After a phase of relative tectonic quiescence in the Late Oligocene and Early Miocene, a second stage of extension, related to clockwise rotation of the western Aegean domain, started in the Middle Miocene.

In the Central and Eastern Rhodopes, top-N extension took place in the Palaeogene. We found evidence for a top-N low-angle normal fault (Kyuse-Hasanlartepesi Fault) between the Central Rhodopean basement and the sediments of the Eastern Rhodope Basin that was active in the latest Eocene and earliest Oligocene. Our new LA-SF-ICP-MS U-Pb data for zircons from sheared and undeformed pegmatite veins provide evidence that an older top-N(W) extensional Fault (Borovica Fault) inside the Central Rhodopean basement was active in the Lutetian. At the same time, normal faulting went on above the Kesebir-Kardamos Dome further east.

The present-day geometry of the tectonic units exposed in the Rhodopes is largely the result of Eocene to Miocene extensional tectonics which strongly reshaped the pre-extensional geometry of the Rhodopes. Age constraints for the earlier contractional stages have been obtained mostly by dating of zircon or monazite from (ultra-) high-P eclogites and metapelites occurring in the intermediate and upper tectonic levels. These ages show a

considerable scatter between the Middle Jurassic and Middle Eocene which probably reflects complex P-T-t paths. Eocene ages for high-P metamorphism have so far only been reported from two localities in the intermediate tectonic level, i.e. the Sidironero Unit in Greece. We present new results of Lu-Hf garnet geochronology for three eclogites sampled in different localities from a part of the Starcevo Unit in Bulgaria, which belongs to the intermediate tectonic level. These data corroborate a Lutetian age of high-P metamorphism in the intermediate level while a fourth sample from the upper tectonic level (Kardžali Unit) yields a Barremian age. Exhumation of the intermediate tectonic level from a depth corresponding to the Eocene high-P metamorphism was probably accommodated by top-N shearing along the Borovica Fault (coeval with thrusting along the Nestos Fault) and later along the Kyuse-Hasanlartepesi Fault. The Borovica Fault is probably the boundary between the upper and intermediate tectonic levels.

New insights on the occurrence of a Variscan suture in the Upper Danubian Nappe (Romania, Serbia, Bulgaria) evidenced by ^{40}Ar–^{39}Ar geochronology

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The Alpine Upper Danubian Nappe crops out in the Southern Carpathians in Romania and in the North of the Balkans in Serbia and Bulgaria. The pre-alpine basement of this Nappe displays an important tectonic marker in the form of the Danubian Ophiolite. This Ophiolite (~ 500 km^2) has been dismembered by the Oligocene Alpine tectonic in four ophiolitic massifs: Tisovita Iuti in Romania, Deli Jovan and Zaglavak in Serbia and Tcherni Vrah in Bulgaria. Although the Danubian Ophiolite has been considered as Late Proterozoic during the last decades, the Deli Jovan massif has been recently dated to the Lower Devonian (U-Pb zircon age of 405 ± 2.6 Ma). Our study gives a petrostructural analysis investigated on listvenitic gabbros from the Tisovita Iuti ophiolitic massif and their adjacent rocks (Corbu Unit) and provides new geochronological data on the listvenitization processes.

Listvenitic gabbros consist of a metasomatic assemblage composed of zoisite + calcite + Cr-chlorite + Cr-muscovite developped on amphibolitized gabbros under strongly hydrated conditions at temperatures around 280°C. They are located in a thin N-S band at the Eastern part of the Tisovita Iuti ophiolitic massif and generally display a mylonitic texture. Similarly, the Corbu Unit crops out in a 2 km wide N-S band, at the eastern part of the listvenitic gabbros, and consists of a mélange of slices composed of various metamorphic rocks (volcano-sedimentary rocks, margin sediments, acid volcanic rocks and ophiolitic rocks) from low- to high-grade.

Structural data obtained on listvenitic gabbros and on Corbu rocks indicate that these two units have undergone a similar deformation, which is partitioned between highly deformed mylonites and slightly-deformed juxtaposed rocks. These rocks display high-dip North-Southward foliation planes, associated with a strong subhorizontal stretching mineral lineation and isoclinal folds parallel to this lineation. These fabric elements appear to develop during the same event, giving evidence for components of both simple and pure shear, suggesting a deformation which probably occurred in a transpressive context.

New ^{40}Ar-^{39}Ar ages performed on two Cr-muscovites from slightly and highly listvenitized gabbros give plateau ages of 372.6 ± 1.3 Ma and 360.6 ± 1.2 Ma, respectively. As the listvenitization process involves important chemical remobilisations with the presence of CO_2-rich fluids and according to the similar deformation type encountered both in the Corbu mélange and in the listvenitic gabbros, we propose that these rocks are formed close to