



Timing of extensional exhumation of the Eastern Rhodope high-grade basement (Bulgaria): $^{40}\text{Ar}/^{39}\text{Ar}$ age constraints

Времеизява на екстензионната ексхумация на високостепенния фундамент в Източни Родопи (България): $^{40}\text{Ar}/^{39}\text{Ar}$ възрастови ограничения

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Background and objectives

The Cenozoic crustal extension governed the late-stage tectonic evolution of the Alpine orogen in the north Aegean region (e.g. Bonev, Beccaletto, 2007 and references therein). The extensional tectonic pattern of the Eastern Rhodope-Thrace region in Bulgaria and Greece is manifested by detachment-bounded core-complex type domes (the Kesebir-Kardamos and the Byala reka-Kechros domes) (Bonev, 2006). The Maastrichtian-Paleocene to Lower Eocene (Ypresian) clastic sediments (Goranov, Atanasov, 1992) that occur as syn-tectonic deposits in the hanging wall of the detachment bounding the Kesebir-Kardamos dome provide stratigraphic age constraints for the onset of the extension as late as the Early Eocene (Bonev et al., 2006a). $^{40}\text{Ar}/^{39}\text{Ar}$ mica ages of 37.73 Ma and 38.13 Ma in the footwall (Bonev et al., 2006b) and a mica age of 36.9 Ma in the hanging wall (Márton et al., 2010) were documented for the Kesebir-Kardamos dome. For the Byala reka-Kechros dome were reported $^{40}\text{Ar}/^{39}\text{Ar}$ mica age of 39±1 Ma in the footwall; and a hornblende age of 45±2 Ma (Mukasa et al., 2003) and mica $^{40}\text{Ar}/^{39}\text{Ar}$ ages of 39.3 Ma (Márton et al., 2010) and 39.66 Ma (Bonev et al., 2010) in its hanging wall. These ages define cooling history in the interval 500–350–300 °C of the extensional system in both domes. A relatively limited number of $^{40}\text{Ar}/^{39}\text{Ar}$ ages provide only general outline of the timing of the extensional exhumation of the high-grade metamorphic basement in the Eastern Rhodopes of Bulgaria.

This contribution provides a regional-scale $^{40}\text{Ar}/^{39}\text{Ar}$ timing of the cooling history of the high-grade basement within the extensional system of the Eastern Rhodopes in Bulgaria. It further discusses the exten-

sional tectonic context relative to the hydrothermal and volcanic rocks in the area, with the aim to extend our knowledge on the interrelations between the processes involved in the late-stage extensional evolution.

Samples and results

Four samples of protomylonitic to mylonitic orthogneisses were collected in the footwall of both domes from which white mica and biotite concentrates were separated and analyzed. Two amphibolite and a gneiss samples from the hanging wall were collected in which hornblende and white mica or biotite concentrates in each sample were separated and analyzed. Additionally, a white mica concentrate from a gneiss clast sample derived from a drill core of a borehole through the hanging wall sediments of the Byala reka-Kechros dome was separated and analyzed. The analyses resulted in flat Ar spectra giving well-defined plateau ages. The footwall samples of the Kesebir-Kardamos dome have supplied 35.50±0.27 Ma biotite and 36.18±0.21 Ma white mica $^{40}\text{Ar}/^{39}\text{Ar}$ ages. In the hanging wall of the same dome a hornblende age of 39.21±4.13 Ma and a biotite age of 38.88±0.38 Ma were obtained in a single sample of the southern flank, whereas another sample in the northern flank of the dome has yielded a hornblende age of 37.27±0.34 Ma and a biotite age of 34.10±0.48 Ma. The footwall rocks of the Byala reka-Kechros dome have yielded 35.93±0.19 Ma biotite and 37.97±0.61 Ma white mica $^{40}\text{Ar}/^{39}\text{Ar}$ ages. The hanging wall sample of the same dome supplied a hornblende age of 64.69±4.38 Ma and a white mica age of 39.72±0.48 Ma. The gneiss clast sample gave 41.70±0.20 Ma white mica $^{40}\text{Ar}/^{39}\text{Ar}$ plateau age.

Discussion and conclusion

The $^{40}\text{Ar}/^{39}\text{Ar}$ results reveal new and more complete age constraints for temporal spread of the footwall extensional exhumation and cooling below 350–300 °C between 35.5–38 Ma. The hornblende age of 64.7 Ma in the sample of the hanging wall of the Byala reka-Kechros dome testify for the first time an older Paleocene age for the cooling history below 500 °C of the last regional metamorphism in amphibolite facies. The hanging wall progressive cooling below 350–300 °C continued through the Eocene between 39.72–34.1 Ma. The $^{40}\text{Ar}/^{39}\text{Ar}$ age obtained from the hanging wall sediments provide evidence for a latest Middle Eocene sedimentation (which is poorly biostratigraphically constrained) in the hanging wall of the Byala reka-Kechros dome. Compared with $^{40}\text{Ar}/^{39}\text{Ar}$ ages of the hydrothermal rocks at Ada tepe deposit and Rosino prospect, the footwall cooling and exhumation coincides with the hydrothermal activity in Late Eocene. The onset of the latest Late Eocene volcanic activity at Iran Tepe paleovolcano also coincides with the extensional exhumation of the high-grade basement and hydrothermal activity at Ada tepe deposit, but in this

paleovolcano and other volcanic edifices volcanism typically persisted through the Oligocene times.

In conclusion, (i) the hanging wall of extensional system gradually cooled between 500–300 °C in Paleocene to Late Eocene times (64–34 Ma), (ii) largely followed by progressive cooling below 350–300 °C and exhumation of the footwall beneath the detachments in the Middle–Late Eocene times (35.5–38.13 Ma), (iii) extensional exhumation, hydrothermal activity and volcanism overlaps each other during the Late Eocene, when all these processes are temporarily undistinguishable. This implies close relationships between the tectonic, ore-forming and magmatic processes involved in the late-stage extensional evolution, (iv) a clear tendency is observed for westward progressive younging of the cooling history of the high-grade basement, and (v) syn-tectonic latest Middle Eocene sedimentation in the hanging wall of the Byala reka-Kechros dome is proven.

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References

- Bonev, N. 2006. Cenozoic tectonic evolution of the eastern Rhodope massif (Bulgaria): basement structure and kinematics of syn- to postcollisional extensional deformation. – In: Dilek, Y., S. Pavlides (Eds.). *Postcollisional Tectonics and Magmatism in the Mediterranean Region and Asia*. *Geol. Soc. Amer., Spec. Paper*, 409, 211–235.
- Bonev, N., L. Beccaletto. 2007. From syn- to post-orogenic Tertiary extension in the north Aegean region: constraints on the kinematics in the eastern Rhodope-Thrace, Bulgaria-Greece and the Biga Peninsula, NW Turkey. – In: Taymaz, T., Y. Yilmaz, Y. Dilek (Eds.). *The Geodynamics of the Aegean and Anatolia*. *Geol. Soc. London, Spec. Publ.*, 291, 113–142.
- Bonev, N., J.-P. Burg, Z. Ivanov. 2006a. Mesozoic-Tertiary structural evolution of an extensional gneiss dome – the Kesebir-Kardamos dome, eastern Rhodope (Bulgaria-Greece). – *Int. J. Earth Sci.*, 95, 318–340.
- Bonev, N., P. Marchev, B. Singer. 2006b. $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology constraints on the Middle Tertiary basement extensional exhumation, and its relation to ore-forming and magmatic processes in the Eastern Rhodope (Bulgaria). – *Geodinam. Acta*, 19, 267–282.
- Bonev, N., R. Spikings, R. Moritz, P. Marchev. 2010. The effect of early Alpine thrusting in late-stage extensional tectonics: Evidence from the Kulidzhik nappe and the Pelevun extensional allochthon in the Rhodope Massif, Bulgaria. – *Tectonophysics*, 488, 256–281.
- Goranov, A., G. Atanasov. 1992. Lithostratigraphy and formation conditions of Maastrichtian-Paleocene deposits in Krumovgrad District. – *Geologica Balc.*, 22, 71–82.
- Márton, I., R. Moritz, R. Spikings. 2010. Application of low-temperature thermochronology to hydrothermal ore deposits: Formation, preservation and exhumation of epithermal gold systems from the Eastern Rhodopes, Bulgaria. – *Tectonophysics*, 483, 240–254.
- Mukasa, S. B., I. Haydoutov, C. W. Carrigan, K. Kolcheva. 2003. Thermobarometry and $^{40}\text{Ar}/^{39}\text{Ar}$ ages of eclogitic and gneissic rocks in the Sredna Gora and Rhodope terranes of Bulgaria. – *J. Czech Geol. Soc.*, 48, 94–95.