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MOR- vs. SSZ- origin of metamafic rocks in the upper high-grade basement unit of the Eastern Rhodope: geochemical diversity and tectonic significance

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Introduction

The high-grade metamorphic basement of the eastern Rhodope comprises widespread occurrences of metamafic rocks, including compositional range with ultramafic to intermediate members. The ultramafic rocks are represented by numerous slivers consisting of cumulate rocks and mantle tectonites with MORB to SSZ-like signature (Bazylev et al., 1998; Kolcheva et al., 2000), which together with the mafic metavolcanic and plutonic rocks are regarded as metamorphosed fragments of an ophiolite association (Kozhoukharova, 1984). Among metamafic rocks, the most abundant rock types are metagabbros and orthoamphibolites occurring in the basement upper structural levels. These orthoamphibolites resulted from the main amphibolite-facies metamorphism, but preserve relic eclogitic assemblage and display MORB-like geochemistry of oceanic crust protoliths (Kolcheva, Eskenazy, 1988; Mposkos, Perdikatsis, 1989). Geochemical study of amphibolites in Greece has shown their magmatic origin, whose protoliths were tholeiites with oceanic floor MORB/IAT affinities (Mposkos et al., 1989). Recently, Haydoutov et al. (2004) have documented island-arc origin of amphibolites with an arc tholeiitic to boninitic affinity. However, the geochemical database of metamafic rocks encompassing mainly ultramafic rocks and spatially associated amphibolites is incomplete to constrain more precisely past tectonic environment(s) responsible for the generation of the oceanic crust fragments. The aim of this study is to extend the knowledge on geochemical characteristics of metamafic rocks in the high-grade basement and to contribute to the better understanding of tectonic setting for their origin, which will have implications for the geodynamic evolution of the region. We report here petrography and geochemistry of metamafic rocks and discuss results with respect to their tectonic setting and constraints from the field data.

Geological setting, samples and analytical methods

In the high-grade basement, the metamafic rocks are dominantly comprised within the hanging wall upper high-grade unit that forms mantle of extensional gneiss domes, namely the Byala reka dome and the Kesebir dome, in the footwall of late Alpine detachments (fig.1, Bonev, 2006). The upper high-grade unit represents lithologically heterogeneous succession of continental-oceanic affinity consisting of intercalated metasedimentary and metaigneous rocks enclosing ultramafic slivers. The footwall lower high-grade unit consists of orthogneiss succession of continental affinity. Within the upper high-grade unit, the amphibolites occur either as layers of varying thickness alternating with other rock types, or as distinct lenses or boudins. The layers are dominated by massive and banded amphibolites, defining together with the metasedimentary lithologies the metamorphic layering. The amphibolite layers may represent lava flows or dykes. Concordant sheet-like metagabbro-diorite bodies occur alternating with plagiogneisses of transposed contacts parallel or oblique to the common foliation in both lithologies, which latter likely represent primary plagiogranite dykes. A distinct mafic-ultramafic thrust sheet is exposed in the core of the Byala reka dome. Field observations indicate magmatic origin for the thicker amphibolite layers and metagabbro bodies, the latter with weakly discernible igneous textural features. Part of finely intercalated amphibolite layers with carbonaceous and calc-silicate rocks, however, are likely of sedimentary origin as also indicated by the occurrence of metagreywacke levels in the metamorphic layering, which locally resemble turbudite-like alternation.

Six samples from thicker layers of massive orthoamphibolites and two samples of metagabbro-diorite from the upper high-grade unit, one from the

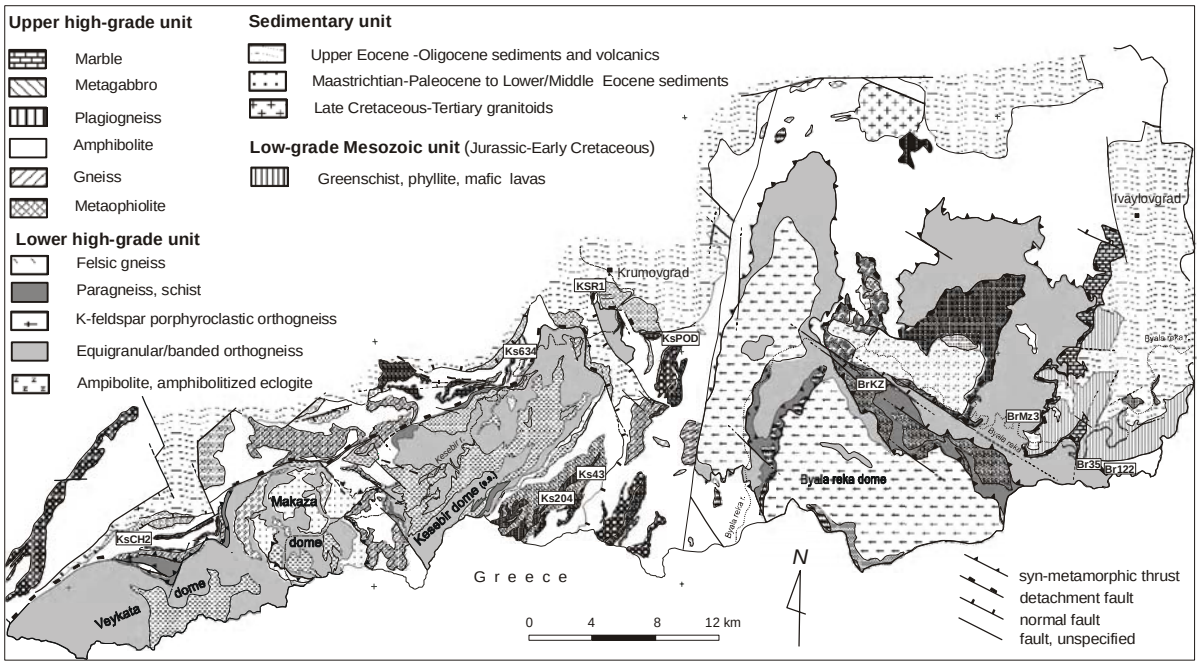

Fig. 1. Synthetic geologic map of the eastern Rhodope region (modified after Bonev, 2006), showing sample locations of the studied metamafic rocks

amphibolitized eclogite of the aforementioned thrust sheet and one from the amphibolite intercalation within the lower high-grade unit (locations in fig. 1) were analyzed for major and trace elements (XRF) and rare earth elements (LA-ICP-MS) at the University of Lausanne, Switzerland.

Petrography and geochemistry

The massive amphibolites are fine- to medium grained homogeneous meso-melanocratic rocks with weak foliation. When banded, amphibolites display layering of amphibole and plagioclase-rich bands. Flaser-banded metagabbros-diorites with pegmatoid patches and veins are common. The primary textures are largely obliterated by the high-grade metamorphism, and the rocks preserve partly original igneous grain-sizes. All studied samples show metamorphic overprint in amphibolite-facies, with variable retrogression to greenschist-facies. The mineral assemblage contains modally decreasing amphibole and plagioclase ± quartz ± garnet porphyroblasts ± epidote-clinozoisite ± chlorite ± titanite ± rutile. In a few samples primary pyroxene relics are recrystallized to amphibole. The metabasic rocks cover the range of SiO_2 43—59 wt. %, MgO 4.2—7.6 wt. %, Al_2O_3 generally < 16 wt. %, and have relatively high FeO*/MgO ratios (av. 1.74). Alkali contents are variable (e.g. Na_2O), with generally low-K abundances. The range of TiO_2 (0.58—3.76 wt. %) defines two groups of high-Ti (> 1%) and low-Ti (< 1%) metabasites, with some intermediate members that cluster around ~ 1 %. In terms of trace elements, they are characterized by high Zr (75—196 ppm), Nb (1.5—10.1 ppm), and relatively high Y (7—60 ppm) contents. Their lower Ni (11—173 ppm) and Cr (52—357 ppm) abundances differ from the primary magmas and Mg# values (36—64) indicate high degree of fractionation of the primitive mantle-derived melts. The metamafic rocks of basaltic to andesitic composition on the classification plots present dominantly tholeiitic to weak calc-alkaline (more evolved rocks) affinity.

LREE-depleted (fig. 2A) and variable degrees of LREE-enriched chondrite-normalized patterns with unfractionated HREE trends characterize high-Ti group (fig. 2B). Matagabbro (KS204) and metadiorite (KS43) samples show flat to slight LREE-enriched patterns similar to high-Ti group, whereas low-Ti group exhibits both LREE-enriched and strongly depleted, fractionated REE patterns (sample BR122). The Eu anomalies indicating accumulation/fractionation involving plagioclase possibly reflect processes in the mantle source. N-MORB normalized trace element profiles define high LILE/HFSE ratios, moderate to severe HFSE and HREE depletion of the low-Ti group, and close to N-MORB to slightly enriched HFSE-HREE trend of the high-Ti group. Pronounced negative Nb and to lesser extent Ti anomalies characterizes some samples; however, other samples show no Nb anomalies and most of them have magnitudes always higher than MORB abundances, except strongly depleted sample (fig. 2C). On various discrimination incompatible element plots majority of high-Ti group metamafic rocks display clear MORB affinity and few samples having

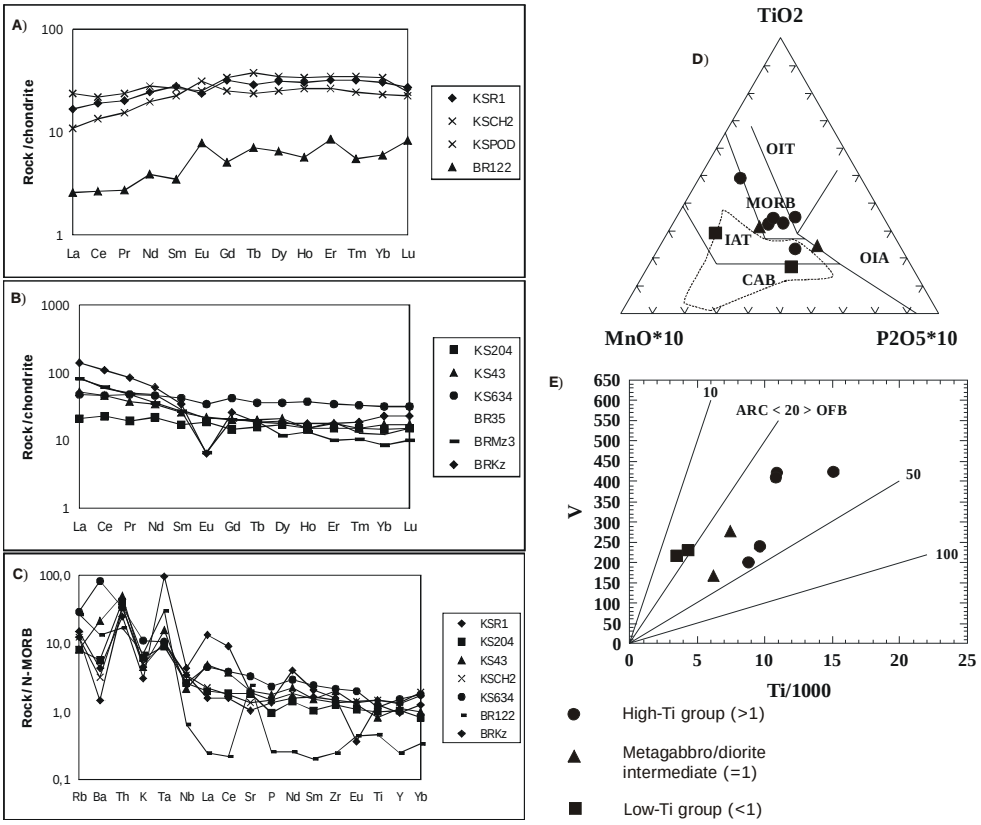

Fig. 2. (A, B) chondrite-normalized patterns, (C) N-MORB normalized profiles, (D, E) discrimination diagrams of metamafic rocks, contoured area in D corresponds to the field of the samples in Haydoutov et al., (2004)

high Zr/Y ratios plot in the WPB field of oceanic island tholeiites, whereas low-Ti metamafic rocks show island arc tholeiite (IAT) affinity (fig 2D, E). The metagabbro-diorite samples of intermediate Ti contents have transitional MORB/IAT signature.

Discussion and tectonic significance

Petrographic study and geochemistry reveal magmatic nature of the protoliths of metamafic rocks in the upper high-grade basement unit. A major group of high-Ti metamafic rocks are indistinguishable from MORB-type tholeiites in terms of their HFS and HREE abundances and normalized patterns, bearing evidence for geochemical fingerprint of subduction zone-related component. The intermediate in Ti content metagabbros-diorite pair shares similar trace and REE characteristics with the high-Ti group showing transitional MORB/IAT signature, whereas low-Ti group display typical island arc (IAT) affinity with clearly defined subduction-related component. However, HFSE-enriched patterns, particularly Ta and Nb contents higher than MORB abundances, as well as the fields where high-Ti group and metagabbro-diorite plots on the discrimination diagrams, suggest contribution of OIB component involved in the petrogenesis of magmatic precursors. Thus, complex chemistry of metamafic protoliths indicate their origin primarily from depleted mantle source similar to MORB, substantially modified by subduction-zone derived LIL- and LREE-enriched melts and contribution of HFSE-enriched component that produce oceanic island tholeiites. Compositional diversity of metamafic rocks including magma types with MORB, transitional MORB/IAT and IAT affinity, in turn call for the origin of their protoliths in a paired ocean ridge-island arc environment. Modern analogues of such tectonic setting displaying transitional compositions between MORB and island-arc basalts are many back-arc basins. Therefore, we attribute supra-subduction origin for the protoliths of metamafic rocks, which were generated in an island arc/back-arc setting. SSZ setting most completely characterizes origin and geochemical affinity of the metamafic rocks, which is also consistent with previous data on geochemistry of ophiolitic mafic-ultramafic assemblage. In this tectonic scenario, the arc tholeiitic to boninitic magmatic precursors trace subduction initiation or immature arc (e.g. Haydoutov et al., 2004, and this study), whereas MORB and transitional MORB/IAT-type metamafic rocks recognized in the present study testify for the magmatic products erupted during subsequent evolution of subduction that relates to

rifting/sea-floor spreading. Clastic and carbonate turbidite-like metasedimentary successions associated with metamafic ophiolitic rocks, which may represent deposits from distinct regions of the arc/back-arc system (e.g. fore-arc or intra-arc), fits interpretation of supra-subduction tectonic setting.

Conclusions

1. Field data indicate that metamafic rocks in the upper high-grade basement unit may represent extrusive and plutonic suite intimately interstratified with metasedimentary successions of turbidite-like character.
2. Petrography and geochemical data indicate magmatic origin of tholeiitic protoliths of metamafic rocks that have originated by fractional crystallization of melts derived primarily from MORB-type mantle source, modified by subduction-zone influenced and likely enriched mantle components involved in their petrogenesis.
3. Geochemical diversity of metabasic rocks with MORB, transitional MORB/IAT and IAT affinities hints their supra-subduction origin in an island arc/back-arc system, with identifiable arc-related and rifting/sea-floor spreading magmatic products. Sedimentary package associated with the metabasic rocks fits SSZ interpretation.

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Срединноокеански хребет срещу супрасубдукционнен произход на метамафични скали в горната високостепенна единица от метаморфния фундамент на Източните Родопи: геохимично разнообразие и тектонско значение

Николай Бонев, Калоян Пейчев, Диана Низамова

Резюме. Метамафичните скали в горната високостепенна единица от метаморфния фундамент на Източни Родопи асоциират с метаседименти и метаултрамафити. Морфологията и взаимоотношенията на метамафитите насочват за принадлежността им към вулканска и плутонична асоциация. Петролого-геохимичните резултати определят преходен афинитет на протолитите с характер на толеитови магматити от срединноокеанските хребети, островни дъги и вътрешността на океанските плочи. Геохимичният характер насочва към супрасубдукционния произход на метабазитите, съвместим с типа на метаседиментите. Резултатите са дискутирани във връзка с теренна позиция, петрогенезис и тектонски контекст.