COMPOSITIONAL DIVERSITY OF THE EVROS OPHIOLITE, THRACE, NORTHEASTERN GREECE: FIELD OCCURRENCES, PRELIMINARY PETROLOGIC AND GEOCHEMICAL DATA ON PLUTONIC SEQUENCE AND TECTONIC IMPLICATIONS

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Introduction and geological background

The Evros ophiolites in the Thrace area of northeastern Greece comprise ultramafic rocks and predominantly mafic extrusive rocks that have originated in a volcanic arc-marginal basin setting (Magganas et al., 1991). These ophiolites together with the low- to very low-grade volcanic and sedimentary rocks are regarded as part of the Circum-Rhodope Belt (Papanikolaou, 1997) in the eastern Rhodope-Thrace region. Mid-Late Jurassic age of gabbro in Evros ophiolite was determined by K-Ar hornblende and apatite fission-track data ca. 160-141Ma (Biggazzi et al., 1989). Stratigraphic ages of sediments, both from detrital fragments and in coherent strata, span from Late Permian up to Late Jurassic-Early Cretaceous (Dimadis et al., 1996, Dimadis, Nikolov, 1997, von Braun, 1993 for review). Data on petrology and geochemistry of mafic lavas and greenschists, kinematics, bulk lithologic context and detrital rocks content from the eastern Bulgarian Rhodope, collectively, confirmed the island-arc origin and the subduction-accretion setting of the corresponding parts of the Mesozoic low-grade sequence (Bonev, Stampfli, 2003). Although mafic rocks of the plutonic sequence in the Evros ophiolite were pointed out (Magganas et al., 1991, von Braun, 1993, Papadopoulos, Anastasiadis, 2002) their field occurrences and composition remain poorly known. We report here the field occurrences and preliminary petrologic and geochemical results of intrusive mafic and felsic rocks associated with tholeiite/boninite dykes from the Evros ophiolite. Finally, we discuss their petrogenesis and tectonic implications.

Field occurrences

In Thrace area, the Evros ophiolites are exposed at several scattered outcrops under the Tertiary sedimentary cover or tectonically overlie the Rhodope high-grade basement rocks (Fig.1). The main outcrop areas include, from west to east, localities at Maronia, Makri, Drimos-Melia, Micron Derion, Mandrica-Metaxades, Agriani and Didymotihon. Here, we deal solely with the easternmost exposures at Agriani and Didymotihon, however, parts of ophiolite suite in other areas will be briefly described. At Drimos-Melia sheeted dykes complex occur intrusive into pillow lavas below overlying massive basaltic lava flows, in turn, overlain by flysch succession. These lava flows seem laterally continuous northeast of Maronia. At Micron Derion, Metaxades and Mandrica in the north, mostly metavolcanics and thin sheets of basalt lava flows are present.

At Dydimotihon, predominantly mafic extrusive rocks (massive, hyaloclastic basalts, rarely pillowed basalts) form more than 150 meters-thick lava flows. There, field observations reveal occurrence of intrusive felsic rocks into basaltic lavas. The felsic rocks form a relatively large body (>100×100m) intruded by up to 1 meter-thick mafic dykes. Southwest of Agriani, an approximately 500×1500 meter-sized distinct body of mafic intrusive rocks occurs in fault contact with the high-grade basement. The plutonic body is intruded by numerous mafic dykes.

Petrography, mineral chemistry and geochemistry

Petrographic study and geochemistry revealed that the felsic rocks are plagiogranites, the mafic plutonic rocks represent gabbro, and the mafic dykes consist of tholeiitic basalts to andesites and boninites. The plagiogranites exhibit granular hypidiomorphic texture consisting essentially of quartz and plagioclase, showing also myrmekitic texture at places. Plagioclase, typically albite (An_{05}) and andesine (An_{68-38}), is also present. The ferro-

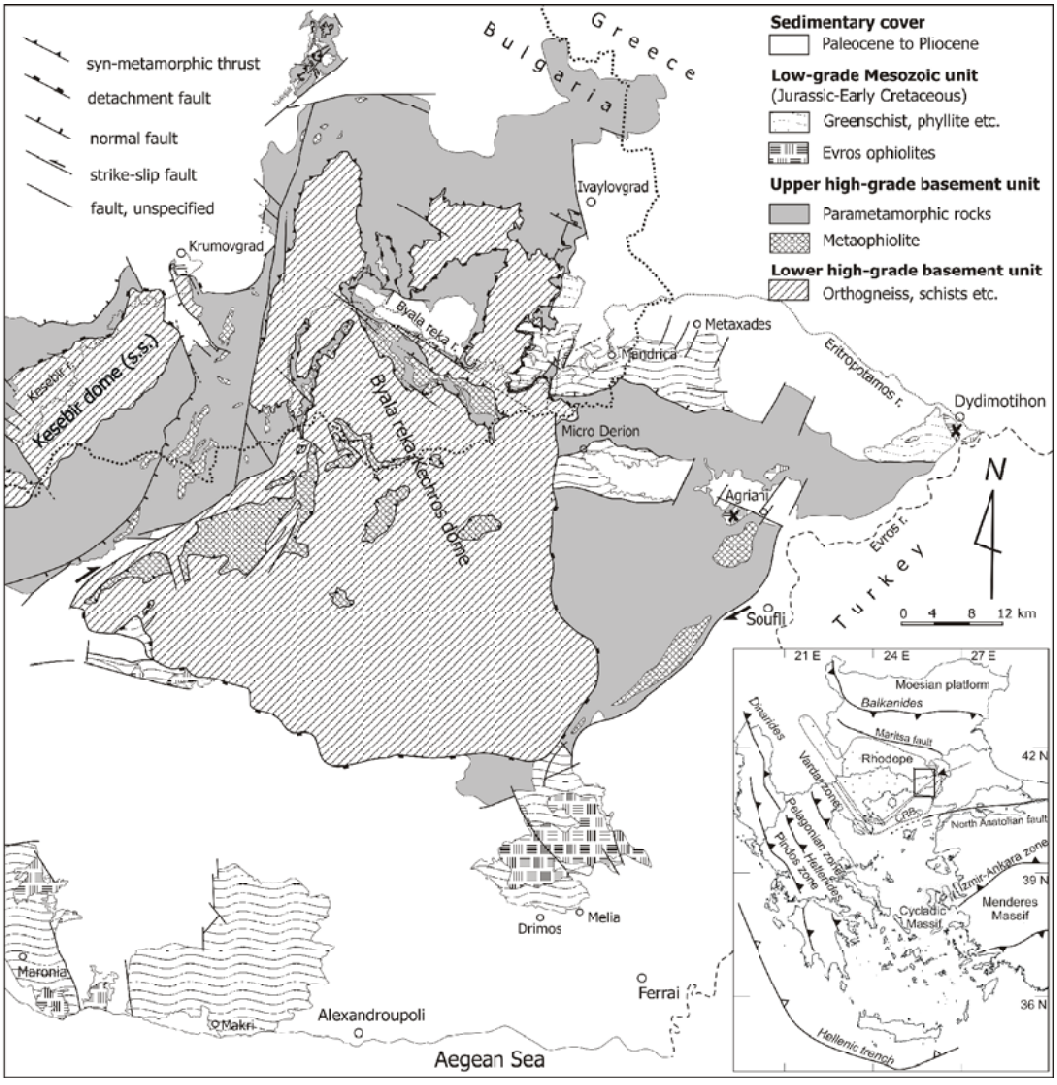

Fig. 1. Simplified geologic map of the eastern Rhodope-Thrace area (adapted from Papadopoulos and Anastasiadis, 2002 and Bonev , 2005). Locations of the studied magmatic rocks of plutonic sequence of Evros ophioites are indicated.

magnesian minerals (minor) are chlorite and epidote after most likely pre-existing amphibole, attesting for the low-grade metamorphism. Chemically, plagiogranites are high-silica (SiO_2 76-78%), low alumina and total iron, and extremely low-K albite granites. The mafic dykes associated with the plagiogranites consist of augite ($Wo_{38-28}En_{55-45}Fs_{19-15}$), bronzite ($Wo_{0.1-3}\ En_{70-40}\ Fs_{38-29}$) and albite-bytownite ($An_{75-14}$) phenocrysts set in a fine-grained groundmass. Intersertal and seriate textures are also common. The range of SiO_2 that cluster at 41-50% and 60-64%, and MgO, TiO_2 and FeO_t (some of them Fe-enriched) contents characterizes them as subalkaline (tholeiitic) medium/low-Ti basalts to andesites and boninites. The massive gabbro (SiO_2 46-48%) presents intergranular texture of subhedral augite ($Wo_{48-25}\ En_{60-45}\ Fs_{21-5}$) and bytownite-labradorite (An_{89-51}), showing also cumulus crystals. Amphibole-bearing gabbro is also present, in which poikilitic magnesio-hornblende encloses clinopyroxene and plagioclase. Mafic dykes associated with the gabbros are pyroxene phyric extrusive rocks showing intergranular, glomero-porphyric and subophitic textures. Phenocrysts are endiopside-augite ($Wo_{45-42}\ En_{51-45}\ Fs_{19-15}$) and anorthite-bytownite (An_{97-73}). Chemically, the dykes present typical boninitic affinity in terms of major oxide (SiO_2 53-55%, Mg 6-8.5%, TiO_2 0.38-0.49%) and trace element contents.

Generally flat REE chondrite-normalized patterns characterize gabbro-boninite dyke and plagiogranite-basalt dyke pairs, both clearly individually separated at different values relative to chondritic abundances. Mafic dykes show distinct LREE enrichment having

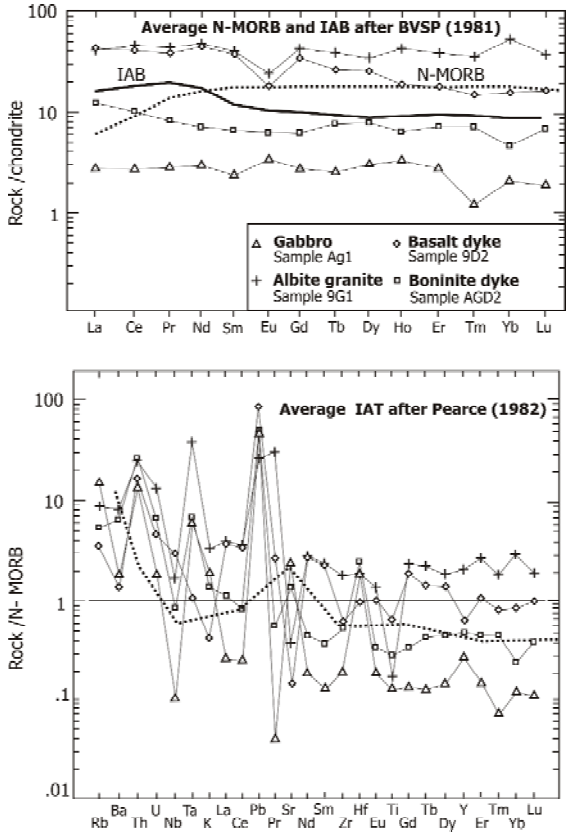

Fig. 2. REE patterns of plagiogranite, gabbro and associated mafic dykes.

$(La/Yb)_n$=3.68. Both plagiogranites and associated dykes exhibit negative Eu anomaly, indicating fractionation involving plagioclase. N-MORB normalized REE pattern defines high LILE/HFSE ratios, more pronounced HREE depletion of gabbro-boninite dyke relative to N-MORB and pronounced negative Nb and Ti anomalies (Fig. 2). Pagiogranite-basalt dykes exhibit also high LILE/HFSE ratios, showing HREE patterns close to MORB (dyke) or enriched (plagiogranite). Trace elements and REE abundances (Rb, Nb, Ta, Y, Yb) define an oceanic-ridge origin for the plagiogranites. On various discrimination plots gabbro and mafic dykes display island arc tholeiite (IAT) affinity.

Discussion: petrogenesis and tectonic implications

Comprehensive petrologic study of mafic extrusives and greenschists with IAT and MORB affinity has shown crystal fractionation involved in their petrogenesis (Magganas, 2002). Plagiogranites associated with ophiolite complexes are considered as end-products of fractional crystallization of a mafic magma (Coleman and Peterman, 1975), but other processes such as assimilation and anatexis are also involved in their petrogenesis (Taylor, 1980, Spera, Bohrson, 2001). In the case of studied plagiogranites, the fractionation obviously is the main process that led to their crystallization. Field data show the lack of xenoliths, and together with the virtually identical REE patterns with associated mafic dykes, it indicates the origin from parental MORB-type basaltic/gabbroic magma as end-product of magmatic crystallization.

Gabbros and typical boninite dykes obviously represent distinct arc-related magmatic suite, which call for the magmatic products emplaced in the fore-arc region of an island arc system. Their derivation from depleted to an average N-MORB source in a mantle wedge is likely, as they show IAT affinity and trace element characteristics that document a greater subduction component. La, Ce, Ti anomalies on N-MORB plot suggest fractionation of Fe-Ti oxides and plagioclase during crystallization.

The Evros ophiolite sequence exhibits range of magma types from MORB, IAT and transitional IAT to MORB that are consistent with island arc/back-arc tectonic environment. Regional geological setting of the whole ophiolite suite and associated sedimentary successions generally shows distinct parts of an arc/back-arc rifting system south-southeastwards, consistent with north-northwest facing Vardarian arc/back-arc system on the Eurasian plate margin (Stampfli, Borel, 2002).

Conclusions

1. Field data reveal much extensive occurrences of a plutonic sequence of the Evros ophiolite in addition to the widespread upper part extrusive sequence. Plagiogranites and massive gabbros are associated with tholeiite/boninite dykes.
2. Petrologic and geochemical data indicate that plagiogranites originated by fractional crystallization process of MORB-type mantle source, whereas gabbro and mafic dykes present complex MORB depleted and subduction zone influenced sources involved in their petrogenesis.
3. Compositional diversity of Evros ophiolite suggests preserved distinct segments of an arc/back-arc system, where arc-related and rifting/sea-floor spreading products occur progressively south-southeastwards.

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РАЗНООБРАЗИЕ В СЪСТАВА НА ОФИОЛИТИТЕ ЕВРОС, ТРАКИЯ, СЕВЕРОИЗТОЧНА ГЪРЦИЯ: ТЕРЕННА ПОЗИЦИЯ, ПРЕДВАРИТЕЛНИ ПЕТРОЛОГО-ГЕОХИМИЧНИ ДАННИ ВЪРХУ ПЛУТОНИЧНАТА АСОЦИАЦИЯ И ТЕКТОНСКО ЗНАЧЕНИЕ

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Офиолитите Еврос се разкриват в няколко локалитета в областта Тракия на Северна Гърция. Под това наименование се разглеждат мафичните ефузивни скали и асоцииращи зелени шисти. Тук ние представяме нови теренни, петроложки и геохимични данни за офиолитите Еврос (Агриани и Димотика), разширявайки и допълвайки представата за техния състав. Теренните и петроложки данни насочват за присъствие на плутонична асоциация (плагиогранити, габра) и мафични дайки (толеити и бонинити) с принадлежност към магматити от срединнокеанските хребети и островни дъги. Резултатите са дискутирани от гледна точка петрогенезис и тектонски контекст.