TERTIARY EVROS VOLCANIC ROCKS, THRACE, NORTHEASTERN GREECE: PETROLOGY, K/AR GEOCHRONOLOGY AND VOLCANISM EVOLUTION.

G. CHRISTOFIDES[1], Z. PECSKAY[2], G. ELEFTHERIADIS[1], T. SOLDATOS[1] and A. KORONEOS[1]

[1] *Department of Mineralogy, Petrology and Economic Geology, Aristotle University of Thessaloniki, 541246 Thessaloniki, Greece* <christof@geo.auth.gr>

[2] *ATOMKI Institute of Nuclear Research, Hungarian Academy of Sciences, Bem ter 18/C, 4026, Debrecen, Hungary* <pecskay@moon.atomki.hu>

ABSTRACT: The Evros volcanic rocks range from basaltic andesite to rhyolite with features of calc-alkaline orogenic rocks. Based on geochemistry and Sr isotope composition, some acid rocks are considered to derive from crustal melts while the intermediate ones through AFC and/or MFC processes with the involvement of a mantle component. Three main periods of volcanic activity are distinguished based on K/Ar ages: a) Lower Oligocene (~33 Ma), b) Upper Oligocene (32-25 Ma) and c) Lower Miocene (22-19 Ma).

Key words: Greece, Evros, Rhodope Massif, volcanics, geochemistry, K/Ar age.

INTRODUCTION

In the Hellenic Rhodope Massif (HRM) and the Circum-Rhodope Belt (CRB) volcanic rocks of Tertiary age are widespread. Two major volcanic provinces have been defined, one north of Xanthi town, known as the Kalotycho volcanics (Eleftheriadis & Lippold, 1984; Eleftheriadis, 1995; Innocenti et al., 1984), and one in western Thrace, known as the Evros volcanic rocks (EVR), (Rentzeperis, 1956; Eleftheriadis et al., 1989; Arikas & Voudouris, 1998; Christofides et al., 2001). The EVR (Fig. 1), which to the north extend into the Bulgarian territory (Yanev et al., 1998 and references therein), is the result of the intensive Tertiary volcanic activity affected the Balkan Peninsula, and are considered as the result of the underthrusting of the African plate below the southern European margin.

Here, new geochemical, isotopic and K/Ar data are presented for the EVR, and general aspects of their origin are considered. Efforts are made also to contribute to the understanding of the volcanism history in the area.

TERTIARY MAGMATIC ACTIVITY

The volcanism in the area started in Middle Eocene times giving abundant volcanoclastics and ignimbrites, although some small andesitic bodies with supposed Priabonian age, crop out in Feres-Dadia area. The volcanic activity culminated during the Upper Oligocene with eruption of high-K calc-alkaline to shoshonitic volcanics of mostly intermediate to basic composition. Pyroclastics, interlayered with Oligocene sediments, rhyolitic ignimbrites of a few hundreds metres thick, breccias, lava flows and domes of basaltic andesite to rhyolite composition are also present. Volcanism ended in the Miocene with both acid and intermediate volcanic products. The Evros volcanism was developed after the thickening/uplift of the Hellenic orogen and its subsequent extensional collapse. It clearly shows a bimodal character, which is in accordance with the conclusions of Yanev et al. (1998). If, the volcanic products in Bulgarian Rhodope Massif (Harkovska et al. 1989) and the Aegean volcanism (Fytikas et al., 1985) are considered, it is obvious that there is a southward migration of the volcanic activity.

GEOLOGICAL SETTING

The EVR crop out in the eastern Rhodope Massif (ERM) and its southern margins known as Circum-Rhodope Belt (CRB). ERM extends along the Greek-Bulgarian borders, covering large areas of both countries as well as a small part of Turkey. Crystalline schists, gneisses and amphibolites predominate in the ERM, while phillites, schists, crystalline limestones and marbles constitute the CRB. The EVR are connected with fault-controlled basins (e.g. Maronia, Esimi-Kirki, Feres-Dadia-Soufli) formed under tensional tectonics, following the Eocene compressional phase of the Alpine orogeny. The development of the depressional basins started in the Lutetian and lasted up to the Pliocene. The metamorphic basement of the ERM and CRB is covered by a clastic Lutetian formation consisting of basal conglomerates, sandstones and nummulitic limestones.

PETROGRAPHY

The Evros volcanic rocks comprise intermediate to basic (basaltic andesites, andesites to trachyandesites) and acid rocks (dacites and rhyolites) (Fig. 2). For simplicity three volcanic areas could be distinguished: a) Loutros-Feres-Dadia, b) Kirki-Esimi, c) Mesti-Petrota. In the northeastern and southwestern parts of the first area the acid rocks, mostly rhyolites, dominate while in the middle part andesite and dacite are the prevailing rock-types. Lava flows and domes, in some cases exhibiting columnar jointing, are very often associated with pyroclastics, which in most cases they intrude or cover. In the Kirki-Esimi group the most widespread rock is andesite. Rhyolites are present in the form of a dense net of dykes at the northeastern part of the area, while dacites occur mostly at the eastern part of it, west of Esimi village. In the Mesti-Petrota area, andesite is again the prevailing rock followed by dacite and rhyolite. Rhyolitic ignimbrites and tuffs are widespread.

All rocks show porphyritic texture with groundmass ranging between 40 and 80%. Phenocrysts are more abundant (20 to 60%) in basaltic andesites and andesites than in dacites and rhyolites (30 to 50%). Basaltic andesites and andesites contain mainly plagioclase (An_{90}-An_{50}) and clino- and orthopyroxene phenocrysts, set in a semicrystalline to hollocrystalline groundmass. Hornblende and, to a lesser extend, biotite, predominate in some andesites of the Kirki-Esimi and Ferres-Dadia areas. Dacites and rhyolites consist of plagioclase (An_{60}-An_{20}), sanidine (Or_{75-65}), quartz, biotite and subordinate hornblende. Some dacites have pyroxenes. Apatite, titanite and zircon are accessories in all rocks.

K/Ar GEOCHRONOLOGY

K/Ar ages were determined in the ATOMKI Institute of Nuclear Research of the Hungarian Academy of Sciences (Debrecen). Both w.r. (lavas and a few tuffs) and biotite separates were analyzed. The ages obtained range from 19.1 to 33.4 Ma, and based on them three main periods of volcanic activity could be distinguished: a) Lower Oligocene (33.4-33.1 Ma), b) Upper Oligocene (32.2-25.4 Ma) and c) Lower Miocene (22.0-19.5 Ma). Intercalations, however, of pyroclastic materials with Priamponian clastic sediments indicate that the volcanic activity started earlier than Oligocene. Bimodality is present in each volcanic period, with repeated acid and intermediate phases having, in general, similar ages. Compared with the E. Rhodope volcanism in Bulgaria (Yanev et al., 1998) the Evros volcanism seems to follow it. However, in Evros area the volcanic activity continues up to Lower Miocene. Moreover, it culminated during the Upper Oligocene.

GEOCHEMISTRY

The analyzed EVR have a wide spectrum of silica content, ranging from 54 to 76 wt%. They show features of continental orogenic volcanic rocks, such as the absence of Fe enrichment, the low TiO_2 content (<0.90 wt%), and the K_2O/Na_2O ratios, which is close to unity for many silicic rocks. Their bulk chemical compositions indicate affinities of calc-alkaline to high-K calc-alkaline and shoshonite series (Fig. 2). In the variations diagrams (Fig. 3) all major elements, except K_2O, decrease with increasing silica content. Among trace elements Sr and V decrease, Rb increases while Zr increases in the andesites and decreases in the acid rocks.

Rhyolites and some dacites show different trends than basaltic andesites and andesites. Some andesitic rocks from the Mesti-Petrota area show distinct trends for some elements (e.g. K_2O, Ba, Rb, and Zr). Similarly, some rhyolites, mainly from the Feres-Dadia area, deviate from the main trends in most variation diagrams. MORB-normalized multi-element patterns (Fig. 4) exhibit strong depletion in the HFSE relative to LILE, with distinct negative Nb, P and Ti anomalies, indicative of convergent margins magmatism. Sr I.R. ranges between 0.709 and 0.708 in the acid rocks, and is less than 0.708 in the more basic ones, increasing in general with SiO_2, particularly in the later.

CONCLUSIONS

The Evros volcanic rocks, comprising acid (rhyolite, dacite) and intermediate (basaltic andesite, andesite), have chemical characteristics typical of continental orogenic domains and belong to the high-K and shoshonite rock series. The rhyolites and some dacites, in most variation diagrams, deviate from the trends defined by the intermediate rocks. An increase of the Sr I.R. from the less evolved to the most evolved rocks of the intermediate group supports an open system (AFC, MFC) process for the evolution of these rocks. Moreover, the relatively low values of Sr isotopes along with the low silica content in these rocks are indicative of a mantle component involvement. A genetic relation between the acid rocks and the intermediate rocks is ruled out based on their chemical characteristics. The effect of continental crust either as parental magma, derived by partial melting, or as the acid member of an intense magma mixing process is indicated by the Sr isotope imprints.

REFERENCES

Arikas, K. & Voudouris, P. (1998): Hydrothermal alterations and mineralizations of magma tic rocks in the southeastern Rhodope massif. Acta Vulcanol., 10 (2), 353-365.

Christofides, G., Pecskay, Z., Eleftheriadis, G., Soldatos, T. & Koroneos, A. (2001): Petrology and K/Ar geochronology of the Tertiary Evros volcanic rocks, Thrace, northeastern Greece. PANCARDI 2001, Proc. II, Abstracts, 2pp.

Eleftheriadis, G. (1995): Petrogenesis of the Oligocene volcanics from Central Rhodope massif (N. Greece). Eur. J. Mineral., 7, 1169-1182.

Eleftheriadis, G. & Lippolt, G. J. (1984): Alterbestimmungen zum oligozänen Vulcanismus der Süd-Rhodopen (Nord-Griechenland). N. Jb. Geol. Palaeont. Mon., 3, 179-191.

Eleftheriadis, G., Christofides, G., Mavroudchiev, b., Nedyalkov, R., Andreev, A. & Hristo, L. (1989): Tertiary volcanics from the East Rhodopes in Greece and Bulgaria. Geol. Rhodopica, 1, 202-217.

Fyticas M., Innocenti F., Manetti P., Mazzuoli R., Peccerillo A. and Villari L. (1985): Tertiary to Quaternary evolution of volcanism in the Aegean region. In: "The Geological Evolution of Eastern Mediterranean", Geological Society Special Publication No 17, eds. J.E. Dixon and A.H.F. Robertson, Blackwell Scientific Publications, pp. 687-699.

Harkovska, A., Marchev, P., Machev, Ph. & Pecskay, Z. (1998): Paleogene magmatism in the Central Rhodope Area, Bulgaria – A review and new data. Acta Vulcanol., 10(2), 199-216.

Innocenti, F., Kolios, N., Manneti, P., Mazzuoli, R., Peccerillo, A., Rita, F. & Villari, L. (1984): The geology and geodynamic significance of Tertiary orogenic volcanism in Northeastern Greece. Bull. Volcnol., 47-I, 25-37.

Le Maitre, R. W. (1989): A Classification of Igneous Rocks and Glossary of Terms. Blackwell Scientific Publications, 193p.

Pearce, J. A. (1982): Trace elements characteristics of lavas from destructive plate boundaries. In: Thorpe R.S. (ed.), Andesites. Wiley, Chichester, pp. 525-548.

Peccerillo, A. & Taylor, T. S. (1976): Geochemistry of Eocene calc-alkaline volcanic rocks from Kastamonu area, Northern Turkey. Contrib. Mineral. Petrol., 58, 63-81.

Rentzeperis, P. (1956): Tertiary colcanics of Evros County. Ph.D. thesis, Aristotle University of Thessaloniki, Greece, 82 pp.

Yanev, Y., Innocenti, F., Manetti, P. & Serri, G. (1998): Upper Eocene-Oligocene collision-related volcanism in Eastern Rhodopes (Bulgaria) – Western Thrace (Greece): Petrogenetic affinity and geodynamic significance. Acta Vulcanol., 10(2), 279-291.

Fig. 1. Geological map of the EVR. K/Ar ages are shown.

Fig. 2. TAS (Le Maitre, 1989) and K_2O vs. SiO_2 (inset) (Peccerillo & Taylor, 1976) classification of the EVR.

Fig. 3. Selected major and trace element variation diagrams of the EVR. Symbols as in figure 2.

Fig. 4. MORB-normalized multi-element diagram of the EVR (normalization after Pearce, 1982).

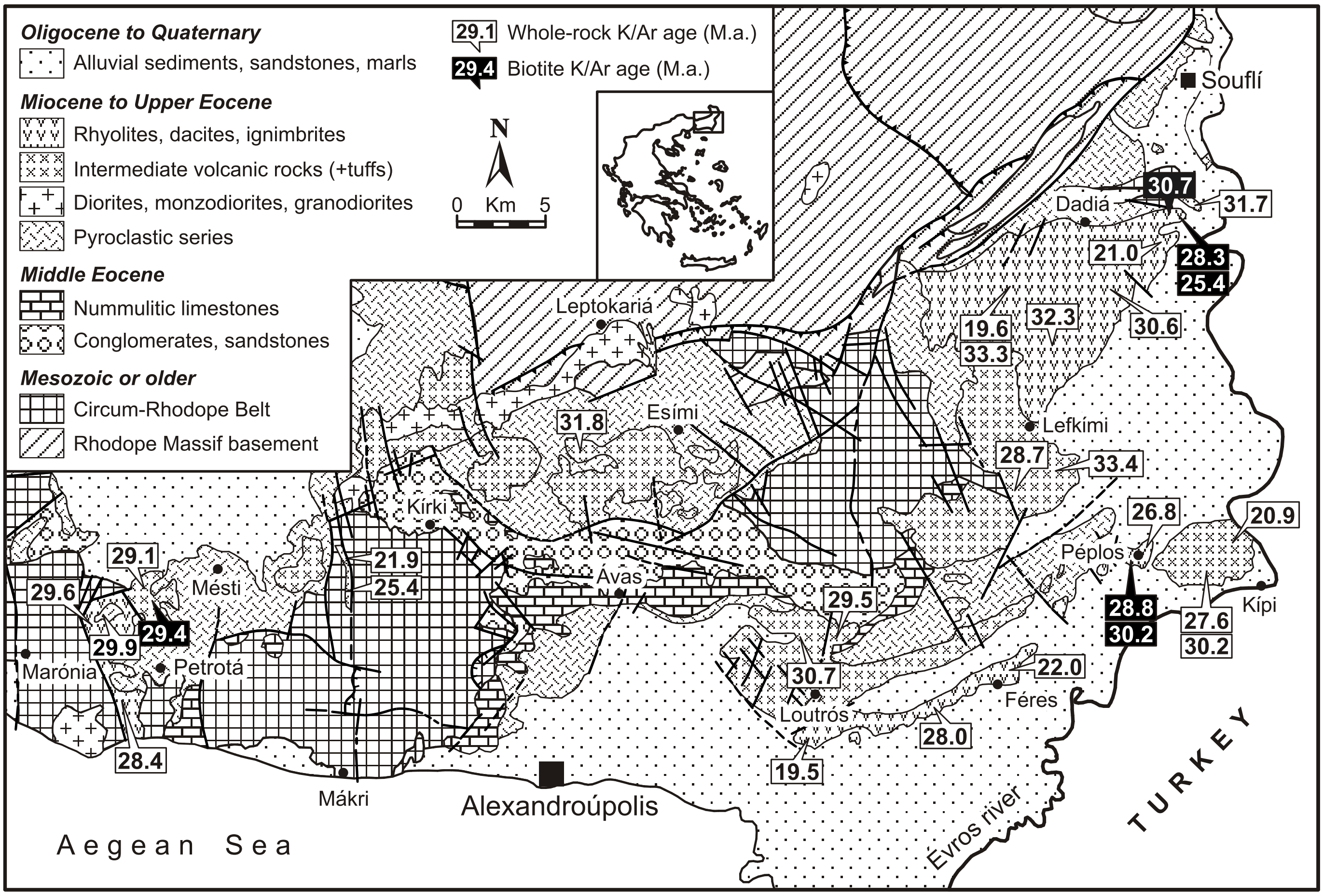
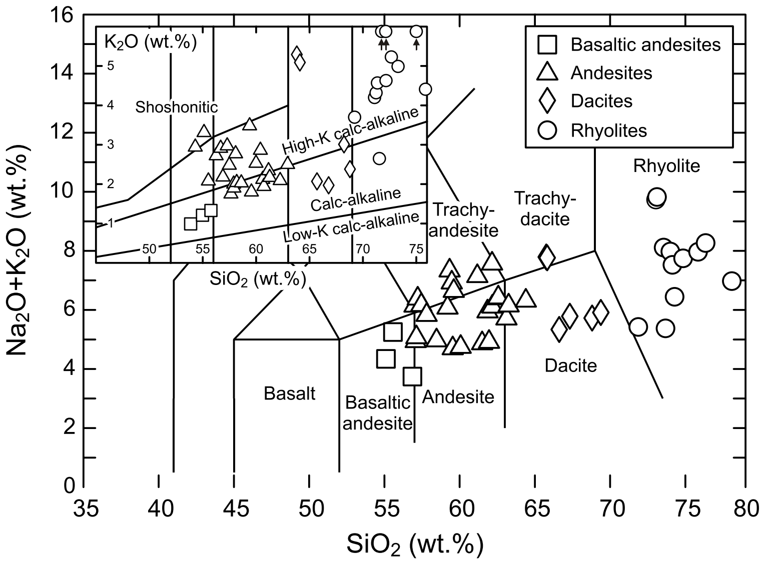
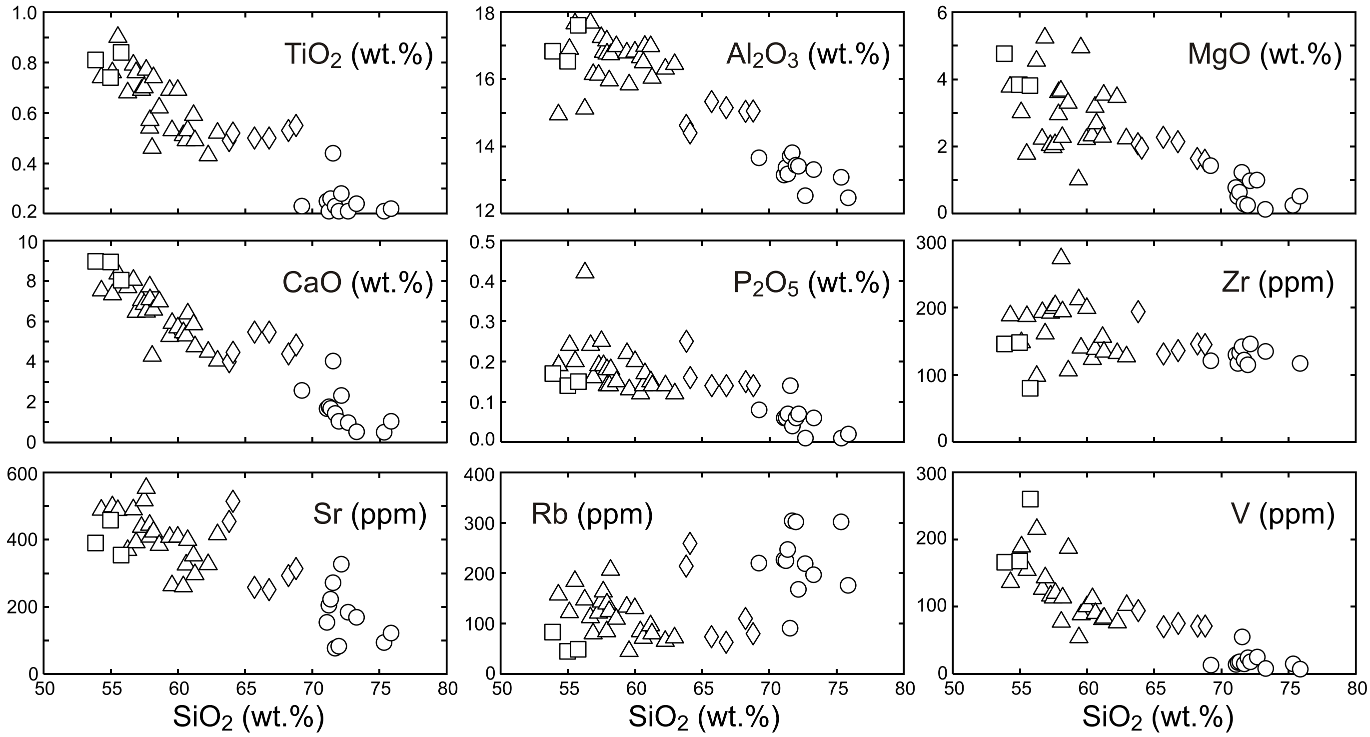

Oligocene to Quaternary
Alluvial sediments, sandstones, marls
Miocene to Upper Eocene
Rhyolites, dacites, ignimbrites
Intermediate volcanic rocks (+tuffs)
Diorites, monzodiorites, granodiorites
Pyroclastic series
Middle Eocene
Nummulitic limestones
Conglomerates, sandstones
Mesozoic or older
Circum-Rhodope Belt
Rhodope Massif basement
29.1 Whole-rock K/Ar age (M.a.)
29.4 Biotite K/Ar age (M.a.)
N
0 Km 5
Souflí
Dadiá
Leptokariá
Esími
Lefkími
Kirki
Péplos
Kípi
Ávas
Mésti
Petrotá
Marónia
Loutrós
Féres
Mákri
Alexandroúpolis
Aegean Sea
TURKEY
Évros river
30.7
31.7
21.0
28.3
25.4
19.6
33.3
32.3
30.6
31.8
28.7
33.4
26.8
20.9
29.1
29.6
21.9
25.4
29.4
29.9
29.5
28.8
30.2
27.6
30.2
30.7
22.0
28.4
28.0
19.5

Fig.1



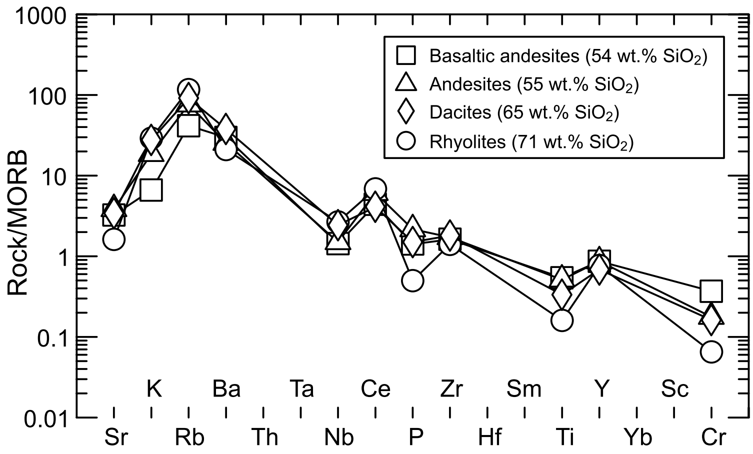
Basaltic andesites
Andesites
Dacites
Rhyolites
K2O (wt.%)
Shoshonitic
High-K calc-alkaline
Calc-alkaline
Low-K calc-alkaline
SiO2 (wt.%)
Rhyolite
Trachy-dacite
Trachy-andesite
Basalt
Basaltic andesite
Andesite
Dacite
Na2O+K2O (wt.%)
SiO2 (wt.%)

Fig.2



TiO2 (wt.%)
Al2O3 (wt.%)
MgO (wt.%)
CaO (wt.%)
P2O5 (wt.%)
Zr (ppm)
Sr (ppm)
Rb (ppm)
V (ppm)
SiO2 (wt.%)
SiO2 (wt.%)
SiO2 (wt.%)

Fig.3



Rock/MORB
1000
100
10
1
0.1
0.01
Basaltic andesites (54 wt.% SiO2)
Andesites (55 wt.% SiO2)
Dacites (65 wt.% SiO2)
Rhyolites (71 wt.% SiO2)
K
Ba
Ta
Ce
Zr
Sm
Y
Sc
Sr
Rb
Th
Nb
P
Hf
Ti
Yb
Cr

Fig.4