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Geochemical and Petrological Characteristics of the Eastern Pontide Eocene (?) Alkaline Volcanic Province, NE Turkey

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Abstract: The Eastern Pontide Alkaline Volcanic Province is developed by volcanic cycles erupted in Cenozoic era. Petrographical and geochemical data suggest presence of at least two different suits of alkaline rocks (Tonya group and Trabzon group). Petrographically, both groups consist of alkali basalt, tephrite, phonolitic tephrite, basanite, nephelinite, nepheline latite and their pyroclastic rocks. Geochemically, Tonya samples have high MgO and Ni, low LREE contents and LILE/HFSE ratios compare to Trabzon group. Preliminary studies show that these two groups of rocks are related with low level differentiation and derived from a metasomatised mantle source.

Doğu Pontid (KD Türkiye) Eosen (?) Alkalen Volkanik Provensinin Jeokimyasal ve Petrolojik Karakteristikleri

Özet: Doğu Pontid Alkalen Volkanik Provensi, Senozoyik döneminde gelişen volkanik faaliyetler sonucunda oluşmuştur. Petrografik ve jeokimyasal veriler, alkalen kayaçların iki farklı grupdan (Tonya grubu ve Trabzon grubu) oluştuğunu göstermektedir. Petrografik olarak, her iki grup, alkali bazalt, tefrit, fonolitik tefrit, bazanit, nefelinit, nefelin latit ve bunların piroklastik kayaçlarını içermektedir. Jeokimyasal olarak, Tonya grubu örnekleri Trabzon grubu örneklerine göre daha yüksek MgO ve Ni, daha düşük LREE içerikleri ve LILE/HFSE oranlarına sahiptir. İlk bulgular bu iki grup kayacın, metazomatizmaya uğramış bir manto kaynağından türeyen ve sığ derinlikte diferanzasyona uğrayan birincil bir magma ile ilişkili olabileceğini göstermektedir.

Introduction

The area of interest is within the Eastern Pontide volcanic province located along the Black Sea coast (Figure 1). The Eastern Pontides are characterised by three main volcanic cycles erupted in Jurassic, Upper Cretaceous and Eocene (Korkmaz et al., 1995; Arslan et al., 1997). So far many studies related to the evolution of these volcanics in the region have been made in terms of geochemistry and petrogenesis (eg. Adamia et al., 1977; Şengör and Yılmaz, 1981; Kazmin et al., 1986; Çamur et al., 1996). The Jurassic volcanic rocks are reported as tholeiitic or calc-alkaline-transitional tholeiitic in character (eg. Yılmaz, 1972; Tokel, 1983, Arslan et al., 1997). Upper Cretaceous volcanic rocks are tholeiitic to calc-alkaline transition (eg. Taner, 1977; Eğin et al., 1979) but Eocene volcanics are alkaline in the north and calc-alkaline in the south (Özsayar, 1971; Turkish-Japanese Cop., 1974; Arslan et al., 1997). Although many studies are subjected to Eastern Pontide volcanic rocks as complete arc cycles, there is no detail study which have been focused on petrogenesis of these unique alkaline volcanic province in the north (Trabzon-Tonya areas). In addition to lack of petrogenetic information, there is also no real age relationship established for these alkaline rocks. While Upper Cretaceous was given by Gümüş (1978), Tokel (1981) has reported Neogene age for those alkaline volcanics nearby Trabzon. Furthermore, Korkmaz (1993) has given Miocene-Pliocene age for Karadağ volcanics. Recently, Middle Miocene (15 ± 2 ma.) age was determined for Değirmendere Valley volcanic rocks by Haskin (1997, per. com.). These observations and determinations all indicate that age of these volcanics varies in large time span in Cenozoic era.

In this study, geochemical and petrological characteristics of Eastern Pontide Alkaline volcanics are given, and their petrogenetic implications are discussed based on obtained preliminary results.

Geological Background of Eastern Pontides

The Eastern Pontide arc related volcanic rocks sit on Paleozoic basement, which have limited out crops around to southern Gümüşhane, and consists of metamorphic sequences and cross-cutting granitoids (Çoğulu, 1970).

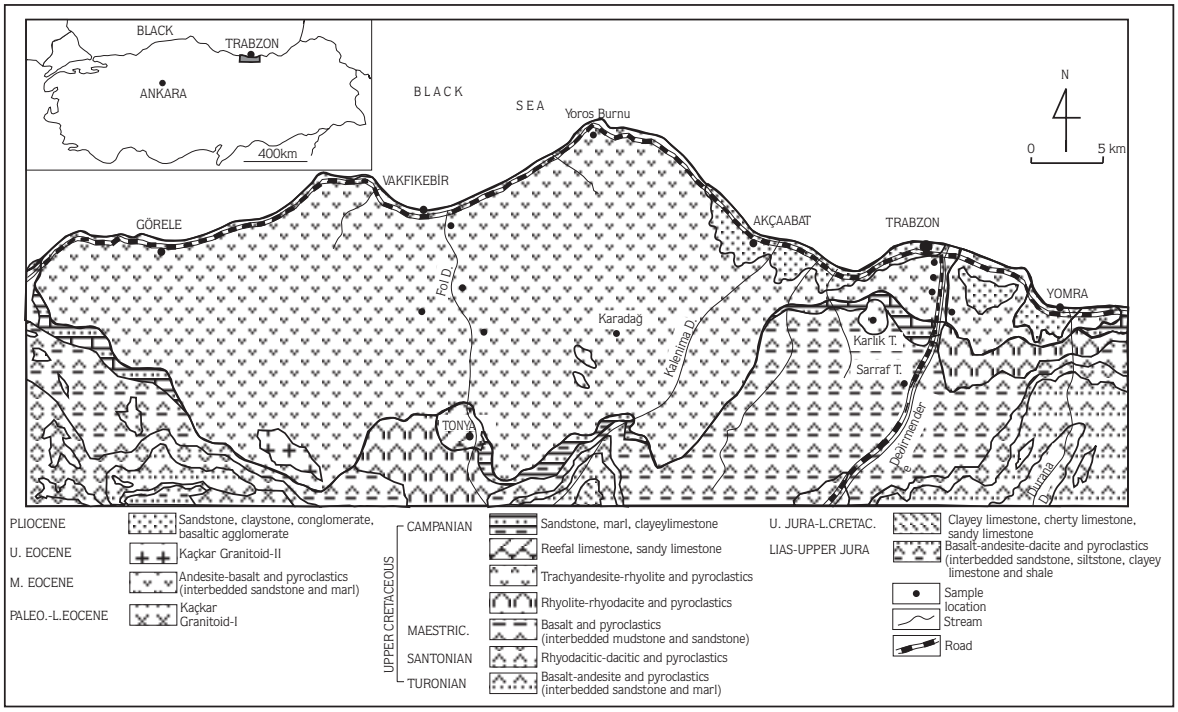

Figure 1. Geological map of the Eastern Pontide alkaline volcanic province and surrounding areas (after Güven, 1993).

Volcanic, volcano-sedimentary rocks and locally developed sediments of Liassic age rest unconformably on the basement. The Liassic volcanic rocks, tholeiitic in character and known as first arc related rocks in the Pontide arc, consist mainly of basalts and to a lesser extend andesites, trachyandesites and their pyroclastic products (Eren, 1983) and mostly crop out southern part of the Pontides. They overlain by Dogger-Malm-Cretaceous aged platform carbonates (Kırmacı, 1992). The Upper Cretaceous series disconformably overlying these carbonates are represented by mainly sedimentary rocks in the south and by mainly volcanic rocks in the north (Bektaş et al., 1987). The volcanic rocks, tholeiitic to calc-alkaline in character, are dominantly dacite and rhyolite and lesser amount of basalt, andesite and their pyroclastics. Plutonic rocks were also developed during Jurassic to Paleocene. The Eocene rocks, calc-alkaline to alkaline in character, are observed around Trabzon-Tonya-Tirebolu areas (that called Eastern Pontide Alkaline Province in this study), Gümüşhane area and Artvin-Hopa areas (Van, 1990; Arslan et al., 1997), and are mainly volcanics and less clastic sediments and carbonates. Post-Eocene uplift and resulting erosion brought clastic inputs into locally developed basins (Korkmaz and Van, 1995).

Analytical Methods

Samples were collected from Trabzon, Saraf Tepe, Karadağ, Karlık Tepe, Yoros Burnu and Tonya areas, along the Black Sea coast (Figure 1). Major and trace element analyses of these samples were carried out by XRF techniques at the University of New Brunswick (described Dunn and Stringer, 1990) and Glasgow University (described by Leake et al., 1969). Some of trace element and REE analyses were made by using ICP-MS methods at University of British Colombia, Canada, and at Scottish Universities Research and Reactor Center in East Kilbride, UK.

Petrography

The Eastern Pontide Eocene Alkaline Province is composed of alkali basalt, tephrite, phonolitic-tephrite, basanite and their pyroclastic products. Volcanic rocks are microlitic porphyritic to hyalo-porphyritic, and contain 5 to 40 percent phenocrysts of augite, plagioclase, analcite, olivine, phlogopite as a major phases and, sanidine, nepheline, cancrinite, apatite, Fe-Ti oxides as minor phases. Zeolite and calcite are common secondary phases in those rocks.

Petrographic observations indicate that studied samples show two different mineral assemblages (Table 1). Augite is characteristically dominant in all rock types and 0.1-0.5 cm in diameter and up to 2 cm long. Characteristically they show oscillatory and sector zoning. Plagioclase (An_{52-65}) is the second common phase. Olivine is rare, but commonly seen in Tonya group (Fol Deresi, Yoros Burnu) samples. Euhedral analcite (probably alteration product of leucite), phlogopite, nepheline and sanidine are common phases in samples from Trabzon group (Değirmen Dere, Saraf Tepe and Karlık Tepesi). Cancrinit included samples are only collected from Karlik Tepe. It probably reflects high volatile concentration (including H_2S and Cl) in their magmas.

Geochemistry

The major and trace element analyses and normative mineralogy of the samples are given in Table 2. The major and trace element data characterise the volcanics as alkali-rich and SiO_2 undersaturated. Some high LOI values are generally related to the presence of analcite, and less carbonate alteration of plagioclase.

An alkaline character of the rocks is clearly displayed in Figure 2, where Trabzon group shows strong alkaline character in contrast to Tonya group (with the exception of one sample from Karadağ). All rocks show a more or less potassic character. The K_2O/Na_2O ratio ranges from 0.5 to 2.5 in Trabzon group and relatively low values are found in Tonya samples (0.5 to 1.5; Figure 3). Chemically distinct Pontide alkaline volcanic rocks range from 4 to 13 wt % in MgO (Table 2). Tonya group rocks are relatively rich in MgO compare to Trabzon group rocks with the exception of Karadağ samples. However, MgO content of Trabzon group samples changes in very narrow range (4.0-6.5 wt %) therefore changes of the major oxides versus MgO are in narrow range, except K_2O (Figure 4). In Tonya group samples, K_2O, Na_2O, Al_2O_3 and SiO_2 decrease, $Fe^{+2}O$ increases with increasing MgO (Figure 4). In both group samples, TiO_2 is very low (<1.5 wt %), even in the most basic samples (Figure 4).

Trace element patterns of Trabzon samples also differ from those of Tonya. The difference is more pronounced in incompatible elements than in less ones. LILE (especially, Sr, Rb, Ba and Th), La and Ce show marked increase in Trabzon samples (Figure 6). Trace element contents of the Tonya samples, except Ni, do not vary with increasing MgO (Figure 5). However, Trabzon group samples have high trace element concentrations (eg. Ba, Sr, Zr and Nb; Figure 5) compare to Tonya group. In general, trace element characteristics of the rocks reflect arc volcanics (BSVP, 1981; Pearce, 1982) with a marked negative Ta and P anomalies (Pearce, 1983; Figure 6), high LILE/HFSE ratios relative to N-MORB and

Table 1. Mineralogical and textural properties of the Eastern Pontide alkaline volcanic province.

Minerals	Değirmen Dere	Saraf Tepe	Karlık Tepesi	Karadağ	Fol Deresi	Yoros Burnu
Augite	x	x	x	x	x	x
Plagioclase	❍	◇	❍	+	+	+
Analcite	◇	+	❍			
Olivine	◇		+	+	+	+
Phlogopite	+	+	◇			
Sanidine	◇	◇	◇			
Nepheline			◇			
Cancrinite			◇			
Apatite	*	*	*	*	*	*
Fe-Ti Oxides	*	*	*	*	*	*
Textures	Microlitic Porphyric	Microlitic Porphyric	Microlitic Porphyric to hyalo porphyric	Microlitic Porphyric	Microlitic Porphyric	Vesicular Microlitic Porphyric
Rocks	Alkali basalt to Phonolitic tephrite	Tephritic phonolite to Phonolitic tephrite	Phonolitic tephrite	Alkali basalt to Nephenilite	Alkali basalt to Phonolitic tephrite	Alkali basalt to Ne–latite

x – most abundant ❍ – moderate abundant + – less abundant ◇ – trace * accesory phase.

Table 2. Major and trace elements, and CIPW normative composition (min.-max.) of the Eastern Pontide alkaline volcanic rocks.

	TRABZON GROUP			TONYA GROUP		
Location Num.	Değirmendere	Sarraf Tepe	Karlık Tepe	Fol deresi	Karadağ	Yoros
of analyses	4	5	3	4	3	3
SiO_2	42.85-46.47	43.93-45.67	46.40-47.45	47.64-51.70	41.83-54.40	46.70-48.58
TiO_2	0.85-1.05	0.91-1.01	1.06-1.13	0.66-0.77	0.71-1.09	0.65-0.78
Al_2O_3	15.32-16.91	15.20-16.14	16.98-17.06	10.74-12.94	14.82-17.50	11.33-11.86
Fe_2O_3	9.67-11.55*	4.04-4.45	4.62-4.73	4.94-7.08	3.73-7.40	4.47-7.39
FeO		2.98-3.65	3.05-3.60	2.75-6.87	3.02-3.40	3.28-3.71
MnO	0.15-0.21	0.13-0.16	0.14-0.17	0.17-0.20	0.16-0.19	0.13-0.19
MgO	5.27-6.39	4.70-6.45	5.61-6.04	7.72-13.26	3.71-5.35	10.78-11.95
CaO	10.04-14.71	10.87-11.77	10.72-10.90	8.94-11.64	5.99-14.25	9.38-11.33
Na_2O	2.78-3.63	1.99-4.35	1.95-4.24	1.55-3.79	2.55-5.75	1.51-3.18
K_2O	1.43-2.55	2.50-4.68	1.55-1.95	1.85-2.54	2.13-4.44	1.84-2.40
P_2O_5	0.84-2.26	1.00-1.09	0.45-1.09	0.27-0.30	0.33-1.17	0.31-0.39
LOI	1.75-4.53	3.75-6.34	1.23-2.72	0.86-3.31	2.52-4.34	1.96-4.86
Zr	88-159	218-283	290-353	35-70	62-173	40-105
Y	24-30	22-23	25-33	14-18	20-23	16-17
Sr	773-2908	1969-2814	2426-3592	283-574	576-884	273-586
U	-	5-7	4-10	0-3	1-5	1-1
Rb	16-108	38-64	71-111	52-73	31-133	46-53
Th	13-37	21-28	25-40	0-3	4-17	4-5
Pb	4-142	25-31	28-47	12-40	12-12	9-16
Zn	92-924	80-84	77-85	67-113	51-81	51-69
Cu	50-74	50-59	80-106	81-175	97-226	87-120
Ni	0-58	38-47	38-40	121-195	28-51	133-159
Co	-	-	-	43-55	-	-
Cr	0-99	-	-	335-849	-	-
Ce	186-538	240-249	215-322	21-36	38-54	31-35
Ba	1206-3166	159-603	1845-2293	357-438	387-468	238-329
La	104-409	146-151	124-133	13-18	7-8	1-4
Nb	21-32	36-44	42-71	5-7	3-16	2-3
Ap	1.8-4.7	1.9-2.3	0.9-2.3	0.5-0.7	0.7-2.5	0.7-0.8
Il	1.6-2.0	1.8-1.9	2.0-2.4	1.2-1.4	1.4-2.1	1.3-1.5
Or	3.9-11.1	15.2-22.9	9.3-11.5	10.7-15.0	0-26.7	11.2-14.2
Ab	15.1-18.2	0-4.9	16.5-16.5	7.4-17.4	0-30.8	6.8-19.7
An	21.9-26.3	17.7-21.7	23.4-31.3	10.0-16.6	4.2-30.3	11.8-17.8
Mt	2.2-2.6	1.9-2.0	2.0-2.3	2.4-2.6	1.9-2.3	2.2-2.5
Di	18.7-26.7	23.0-28.7	15.4-20.4	23.2-34.3	10.3-26.7	27.0-30.4
Hy	-	-	0.0-3.0	-	0-3.7	-
Ol	13.6-17.6	7.2-11.6	12.5-16.0	12.7-26.2	8.4-16.0	20.3-24.9
Ne	5.9-12.6	8.7-17.9	0.0-10.8	1.1-8.8	0.0-27.1	2.8-4.5
Lc	0.0-8.65	-	-	-	0.0-17	-
$Mg^{\#}$	64.3-76.8	52.7-77.0	73.0-77.7	59.9-77.1	68.4-73.7	83.6-86.5
K/Rb	72.9-1593.8	532.0-986.8	139.6-274.6	355.8-482.7	291.9-1148.4	400.0-639.6
K/Ba	2.9-15.5	41.5-294.3	8.4-8.5	47.0-67.6	91.9-94.9	72.9-84.7
Rb/Sr	0.01-0.1	0.02-0.02	0.02-0.05	0.1-0.2	0.04-0.23	0.1-0.2
Zr/Rb	0.9-9.9	3.5-6.0	2.6-4.9	0.01-1.3	1.3-2.0	0.1-1.9
Ba/La	4.3-15.1	1.1-3.9	14.9-17.2	21.0-33.7	55.3-58.5	54.8-282

Note: Major elements and CIPW normative mineralogy are in wt.% and trace elements in ppm. (*) is total iron as Fe_2O_3. $Mg^{\#}$ (Mg number)=100xMg/(Mg+Fe^{+2}).

high Ba/Zr ratios (Saunders and Tarney, 1991). Ba/La ratios of the rocks are 21- 282 for Tonya group and 1-17 for Trabzon group samples. Thus, Ba/La values of Trabzon group samples are lower than those of typical island arc basaltic rocks (IAB=30 to 50; Davidson et al., 1988) but similar to those of OIB (8 to 13; Saunders and Tarney, 1991) whereas values of Tonya group are comparable to arc basalts.

The REE patterns are similar to the patterns of incompatible elements (Figure 7). Trabzon group samples

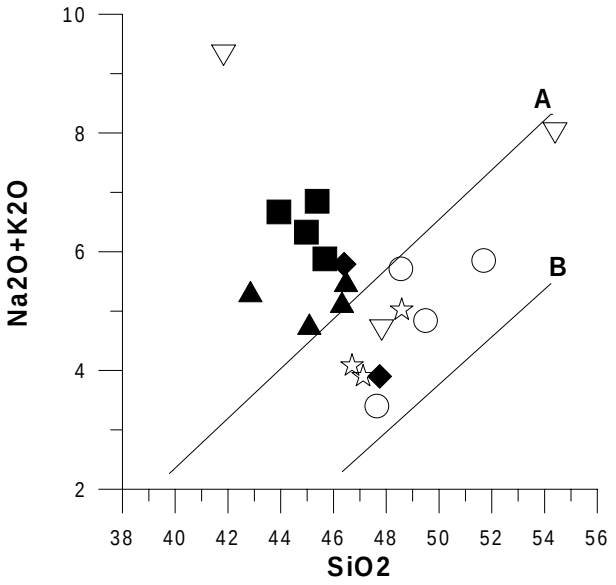

Figure 2. Na_2O+K_2O versus SiO_2 plot. Line A separates strongly alkaline (above the lines) from moderately alkaline lavas (after Saggerson and Williams 1964), line B separates alkali basalts (above the line) from tholeiites (after McDonald and Katsura 1964). Symbols; ▲–Değirmendere, ■–Saraf Tepe, ◆–Karlık Tepe, ❍–Tonya Fol Deresi, ▽–Karadağ, ☆–Yoros Burnu.

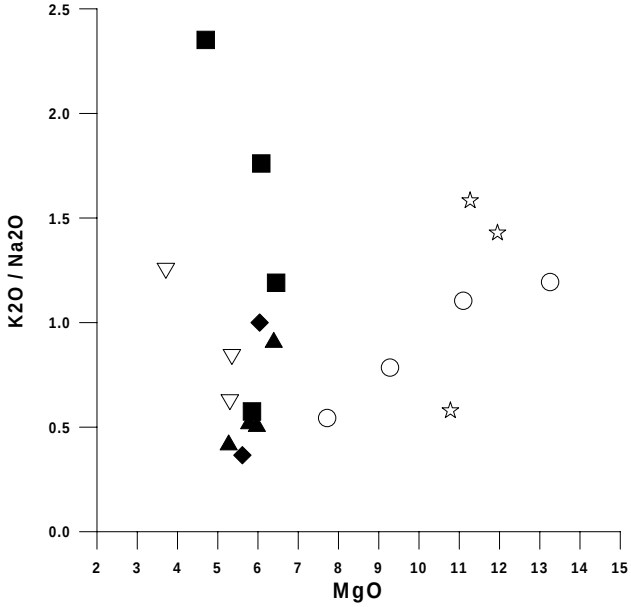

Figure 3. MgO versus K2O/Na2O diagram of the Eastern Pontide alkaline volcanic province. Symbols are as in Figure 2.

have extremely fractionated REE patterns with $(La/Lu)_N$=55-59 whereas Tonya group samples are less fractionated with $(La/Lu)_N$=6-9.

Discussions and Conclusions

The basaltic samples in the study area generally have low MgO and Ni contents except few samples from Yoros and Tonya, reflecting that they do not represent primary magma compositions and indicate that most of the lavas reached the surface relatively modified even though high Mg-numbers (> 65). Except for few tephrite samples (eg. from Karlık Tepesi) significant magma modification, such as fractionation in magma chambers or contamination by country rocks, is likely. Generally, high Mg-numbers of the samples indicate unusual iron redox stage change to near hematite-magnetite buffer during magmatic evolution. Furthermore, imprints of changing oxidation stage resulted significant ersenite ($CaFe^{+3}AlSiO_6$) component in strongly zoned augite phenocrysts present in these rocks (Şen and Dunn, in prep).

If the samples having the highest MgO and Ni contents are assumed that they represent unmodified primary magma composition, the REE partial melting models based on metasomatised mantle of Şen (1994) suggest that they can be produced 5 to 10 percent partial melting of highly metasomatised spinel lherzolite source (Figure 8).

The differences between Trabzon and Tonya samples must be explained by combination of fractionation, crustal contamination and differentiation of magmas at different levels in chambers. High to low pressure crystal fractionation must be important in the evolution of the Eastern Pontide alkaline rocks. Mass balance calculations suggest that olivine and plagioclase played major role in the fractionation of highly differentiated Karlık tephrites from more primitive Tonya alkali basalts. Differentiation, dominantly at high pressures and variable partial melting are considered as the most important factors in the evolution of the province. Furthermore, Arslan et al. (1997) suggest that Tonya group show polybaric crystallisation whereas Trabzon group reflect low pressure crystallisation conditions. Cognate and cumulate xenoliths from Trabzon area support both high and low level fractionation in crustal magma chambers (Şen and Dunn, in prep).

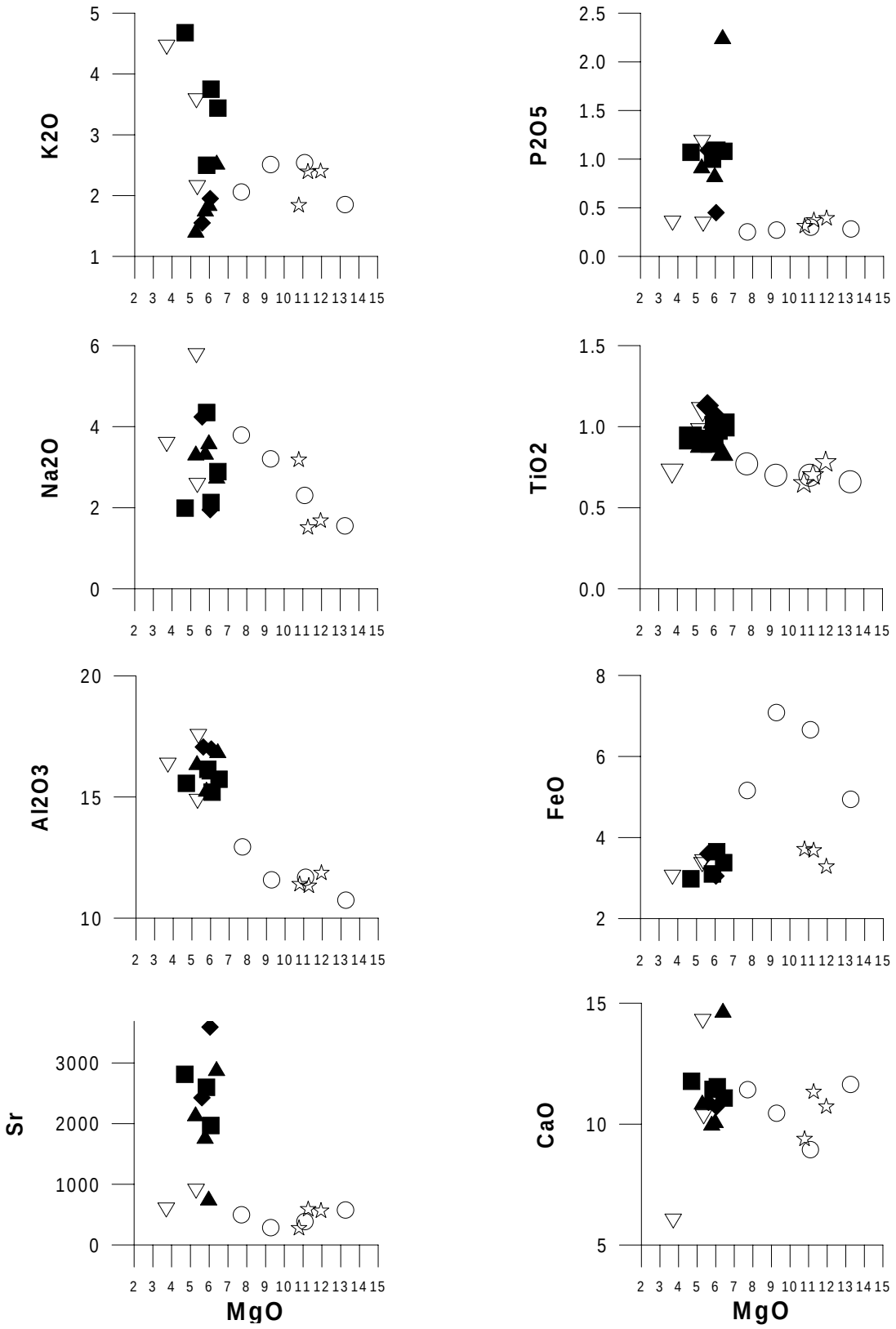

Figure 4. MgO versus major element variation diagrams. Symbols are as in Figure 2.

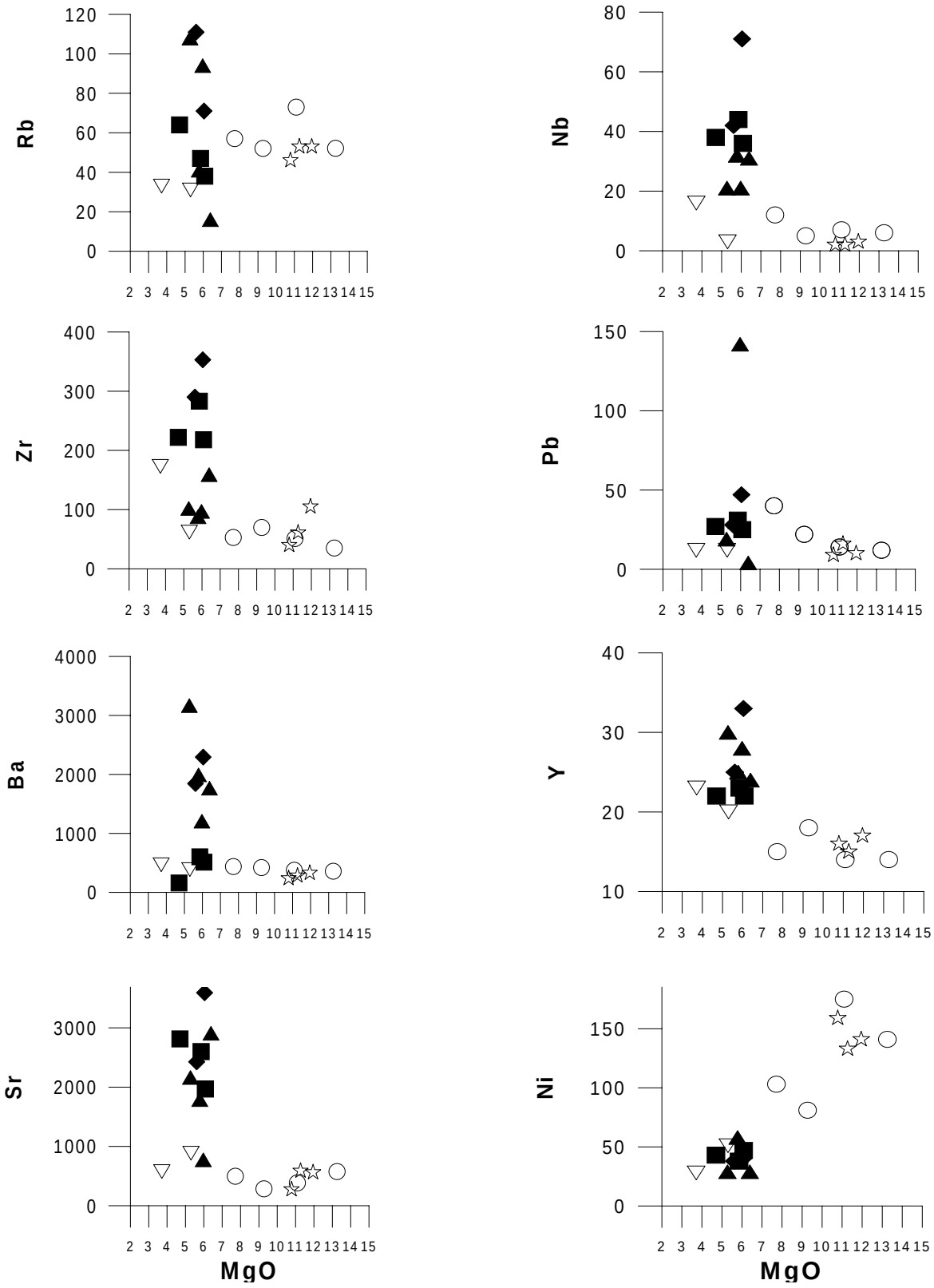

Figure 5. MgO versus trace element variation diagrams. Symbols are as in Figure 2.

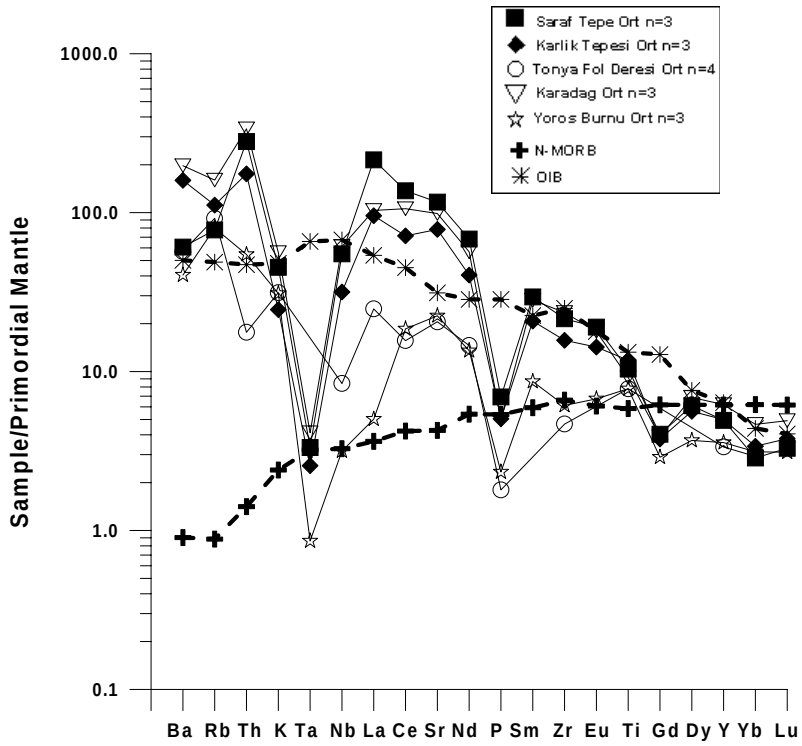

Figure 6. Spider diagram of trace elements for the Eastern Pontide alkaline volcanic province. Primordial mantle, N-MORB and OIB normalised values are from Sun and McDonough (1989).

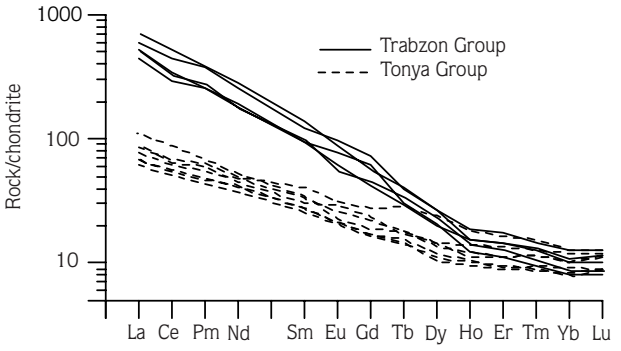

Figure 7. REE patterns of Eastern Pontide Alkaline Volcanic Province. Chondrite normalised values are from Anders and Ebihara (1982). Symbols are as in Figure 2.

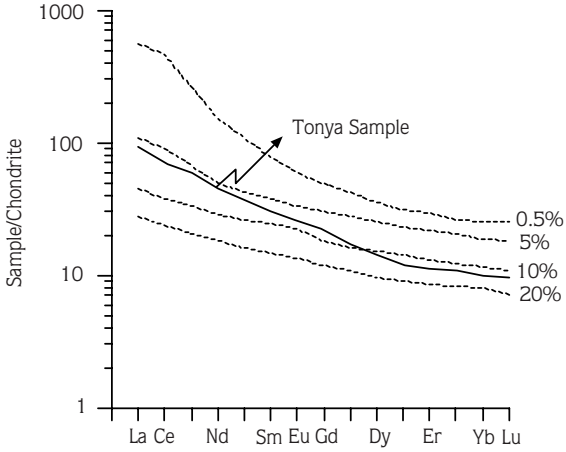

Figure 8. The REE pattern of the most primitive sample from Fol Deresi, compared to 0.5%, 5%, 10% and 20% REE partitioning models of a moderately metasomatised mantle (after Şen, 1994). Chondrite normalised values are from Anders and Ebihara (1982).

Although age relationships between Trabzon group and Tonya group is still unknown, petrographic (eg. fresh hyalo-textures) and morphologic (eg. cone shaped structures in the field) data suggest that at least some of localities around Trabzon area are younger than those of Tonya area.

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