PETROLOGY AND GEOCHEMISTRY OF THE MID-TRIASSIC VOLCANICS OF KOZIAKAS MOUNTAINS, WESTERN THESSALY, GREECE

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Abstract

Petrographic, geochemical and mineral chemistry data are presented for the mid-Triassic volcanic rocks of the Koziakas mountains, western Thessaly, Greece. These extrusive rocks are associated with pyroclastics, and underlain cherts, radiolarites and limestones of Carnian age. Phenocrysts and microlites of zoned plagioclase, K-feldspar and clinopyroxene can be distinguished as principal primary phases. Some primary minerals are partially altered due to very low-grade metamorphism. The volcanics belong to the transitional alkaline - subalkaline series and are classified as trachyandesites. On the basis of major and trace element whole rock chemistry, clinopyroxene composition and stratigraphy, the lavas erupted in a pelagic - abyssal marine rift environment and show certain subduction characteristics, which, however, either originated from a back arc basin or they are inherited and the rift setting was of continental or mid-ocean type.

Introduction

The oldest volcanic rocks associated with the Alpine orogenesis of continental central Greece are of Palaeozoic to early Mesozoic (Triassic) age. They are distributed as small scattered occurrences in both external (Gavrovo-Tripolis and Pindos Units) and intermediate (Western Thessaly, Parnassos, Maliac and Eastern Greece Units) zones of Hellenides. These volcanics mainly occur in the areas of Tzoumerka, Lakmon, Vardoussia, Giona, Eratini, Kremasta, Northern Pindos, Othrys, Koziakas, Lokris, and Evia (Sideris, 1967; Hynes, 1974; Fleury, 1976; Courtin, 1979; Terry, 1979; Ferriere, 1982; Pe-Piper, 1982, 1983; Sideris and Skounakis, 1985; Pe-Piper and Panagos 1989; Pe-Piper and Mavronichi 1990). The Triassic volcanics are usually found in close association with pyroclastic rocks and cover a wide spectrum of petrological types ranging from sub-alkaline basalts and picrites to alkaline trachytes and keratophyres. It is considered they deposited in continental rift environment or in back ark basins accompanied by subduction zones.

In this work, we present geochemical, petrological and mineral chemical data of volcanic rocks occurring in the northern part of Koziakas mountains (western Thessaly), near to the Glykomilia village (Fig. 1). Some petrogenetical and geotectonic constrains are also given.

Geological outlines

The Koziakas mountain range is an independent geographical unit of particular geological importance and occupies a key position on Hellenides and the Hellenic Arc in general. It is made up the Western Thessaly Unit (Papanikolaou and Sideris, 1979; Papanikolaou and Lekkas, 1979), which is partly overthrusted westwards onto the Pindos Unit, while common horizons between the two units indicate local lateral transitions (Fig. 1).

Detailed field investigation including geologic mapping in the study area revealed that the following formations are present: (a) flysch of Tertiary age, (b) oolitic and microbrecciated limestones of Dogger - Malm age, (c) radiolarites, pelites and sandstones with cherts, (d) radiolarites with silex, pyroclastic volcanic fragments and limestone intercalations of Carnian age, and (e) volcanic rocks, which concordantly underlie the previous formation and hence are of Carnian or possibly mid-Triassic (Ladinian) age.

Mineralogy and Petrography

The volcanics are generally brown to grey-beige in colour. They show porphyric or glomeroporphyric structure with phenocrysts of primary feldspars and pyroxenes. Feldspars are mainly plagioclase, whereas in smaller amounts K-

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feldspars are found. Pyroxenes are of Mg-Fe-Ca type and present alteration or replacement signs by secondary minerals. Primary minerals can be also considered part of quartz crystals, opaque minerals, apatite and zircon. The groundmass consists mainly of microliths of feldspars, clinopyroxenes, ore minerals and interstitial divetrified isotropic material.

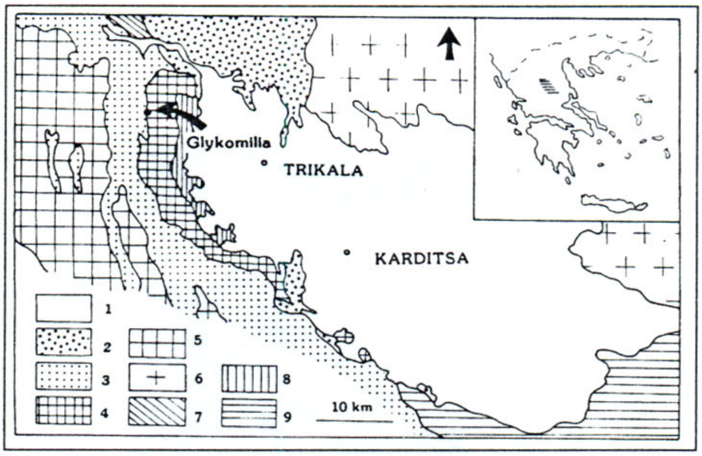

Fig. 1. Geological sketch map of the area of Western Thessaly. 1= Quaternary; 2= Oligocene-Lower Miocene molassic sediments; 3 = Tertiary flysh of Pindos Unit; 4 = Unit of Western Thessaly; 5 = Mesozoic sequence of Pindos Unit; 6 = Unit of Eastern Greece; 7 = Northern ophiolite; 8 = Koziakas ophiolite; 9 = Othrys ophiolite and transgressive Creteceous sediments.

Secondary minerals due to low grade metamorphism are occasionally found. They are consisting of calcite, albite, pumpellyite, Fe-oxides, chalcedonic quartz, chlorite and seldom epidote and white mica. Pumpellyite present veinlets or small accumulations of radiated yellow-brown crystals, and along with chlorite replace partly or totally phenocrysts of pyroxenes and feldspars.

Representative primary mineral microprobe analyses, which were undertaken in the energy dispersive spectrometer of the University of Athens, are given in Table 1. The analysed clinopyroxene crystals are classified as ferrous-magnesian augites. Their relatively high TiO_2 content, which range between 0.47 % wt. and 0.90 % wt., may reflect respective concentrations of the parent magma. The low Cr amount and the high Ti/Al_{tot} ratio reveal an orogenic (volcanic arc) calc-alkali character of the volcanic host rock (cf. Leterrier et al. 1982). The plagioclase phenocrysts and microphenocrysts are labradorite (An_{54-57}). The major part of albitic plagioclase (Ab_{70-100}, Or_{0-19}, An_{0-11}) are interpreted to result from secondary subsolidus processes, as replacement phases of more calcic plagioclase or K-feldspars. Two distinct populations of K-feldspars phenocrysts were determined, one with Or_{42-58} and the other is more potassic with Or_{70-88}. The analysed opaque minerals are mainly titaniferous magnetite, with TiO_2 ranging from 15.93 to 16.73 % wt.

Geochemistry

In representative samples of volcanics chemical analyses of major elements and certain trace elements were performed by XRF in the laboratories of University of Pisa (Italy) (Table 2). The samples analysed present relatively small ranges in most measured elements as well as low LOI content. However, as evidenced by the development of several secondary mineral phases, mobilization may has taken place in at least some chemical elements.

Applying the diagram Nb/Y vs. Zr/TiO_2 of Winchester and Floyd (1977), which uses immobile elements only, the volcanics are plotted in the field of trachyandesite (Fig. 2). Nevertheless, with the TAS diagram, which is constructed by mobile alkali elements and silica, the volcanics fall in the trachyte field and belong to the transitional (between alkaline and sub-alkaline) series (Fig. 3). The transitional character is also detected, considering the ratio Nb/Y, which is high enough and ranges between 0.75 and 1.30 (cf. Pearce, 1982). Finally the volcanics seem to have been derived from a subduction-related magma, as shown in the plot Ti vs. Zr of Pearce (1982) (Fig. 4)

Table 1. Representative microprobe analyses of minerals from the mid-Triassic Koziakas volcanics. Chemical formula recalculation is based on 6 (O) for clinopyroxene (=cpx), 8 (O) for plagioclase (=plag), albite and K=feldspar (=K-fsp).

Mineral	cpx	cpx	plag	albite	K-fsp
SiO_2	51.04	51.09	52.97	67.92	63.17
TiO_2	0.90	0.62	-	-	0.64
Al_2O_3	2.27	1.56	28.63	20.07	18.23
FeO	10.56	10.47	0.70	0.42	0.45
Cr_2O_3	0.15	-	-	-	-
MnO	0.37	0.15	-	-	0.10
MgO	14.96	14.79	0.31	-	-
CaO	20.25	19.68	11.18	0.24	0.68
Na_2O	0.45	0.58	4.36	10.28	0.90
K_2O	0.03	0.21	0.36	0.06	14.78
Total	100.98	99.15	98.51	98.99	98.95
Si	1.88	1.91	2.43	2.99	2.95
$Al^{(IV)}$	0.10	0.07	1.55	1.04	1.05
$Fe^{3+(IV)}$	0.02	0.02	-	-	-
$Al^{(VI)}$	0.00	0.00	-	-	-
Ti	0.02	0.02	-	-	0.02
Fe^{3+}	0.10	0.10	-	-	-
Cr	0.01	0.00	-	-	--
Mg	0.82	0.83	0.02	-	-
Fe^{2+}	0.21	0.21	0.03	0.02	0.02
Mn	0.01	0.01	-	-	-
Ca	0.80	0.79	0.55	0.01	0.03
Na	0.03	0.04	0.39	0.88	0.08
K	0.00	0.01	0.02	0.00	0.88
Sum cat	4.00	4.01	4.99	4.94	5.03

Table 2. Whole rock major and trace element chemical analyses and CIPW norms of representative mid-Triassic volcanic rocks from Koziakas mountain.

Sample	KG-1	KG-3	KG-5	KG-7	KG-8	KG-11
SiO_2	64.67	64.80	64.84	64.66	64.62	64.31
TiO_2	0.72	0.75	0.73	0.74	0.73	0.72
Al_2O_3	14.95	14.80	14.83	14.90	14.82	14.93
Fe_2O_3	2.87	3.63	2.77	2.94	2.36	2.84
FeO	1.38	1.12	1.32	1.35	1.10	1.50
MnO	0.05	0.06	0.06	0.06	0.09	0.06
MgO	1.84	2.05	1.72	1.95	1.23	1.82
CaO	2.86	3.26	2.61	3.34	4.15	3.16
Na_2O	4.01	3.94	4.08	4.06	4.14	4.13
K_2O	4.73	4.10	4.85	4.27	4.53	4.42
P_2O_5	0.20	0.20	0.19	0.19	0.19	0.19
LOI	1.55	1.35	2.01	1.33	1.74	1.84
Total	99.83	100.06	100.01	99.79	99.70	99.92
Rb	114	102	114	107	110	104
Sr	224	254	210	252	232	227
Zr	240	238	240	251	247	239
Nb	8	10	9	11	10	10
Y	8	8	11	8	9	8
An	21	24	18	22	19	21
Q	16	18	16	16	15	16
Or	28	24	29	25	27	26
Ab	34	33	35	34	35	35
An	9	11	8	10	8	9
C	0	0	0	0	0	0
Di	3	3	3	4	7	4
Hy	3	4	3	3	0	3
Wo	0	0	0	0	1	0
Mt	3	2	2	2	2	3
Il	1	1	1	1	1	1
Hem	1	3	1	1	1	1
Ap	0	0	0	0	0	0

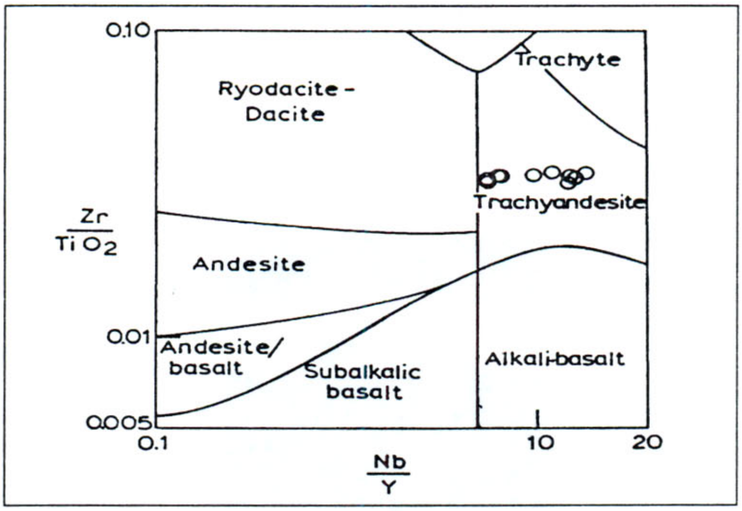

Fig. 2. Zr/TiO_2 vs Nb/Y plot of Winchester and Floyd (1977) for the Koziakas volcanics classification.

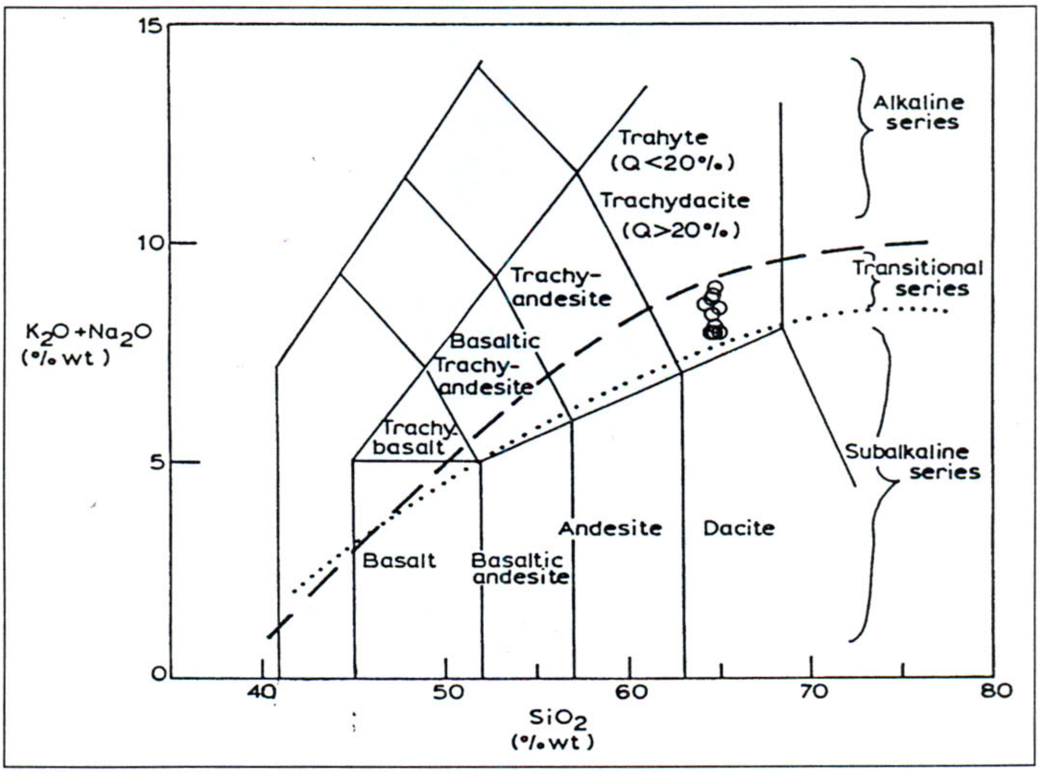

Fig. 3. Koziakas Triassic volcanics classification in the TAS (total alkali - silica) diagram of the Le Maitre (1989). Dash line from Irving and Baragar (1971), dot line from Kuno (1966). Q = normative quartz.

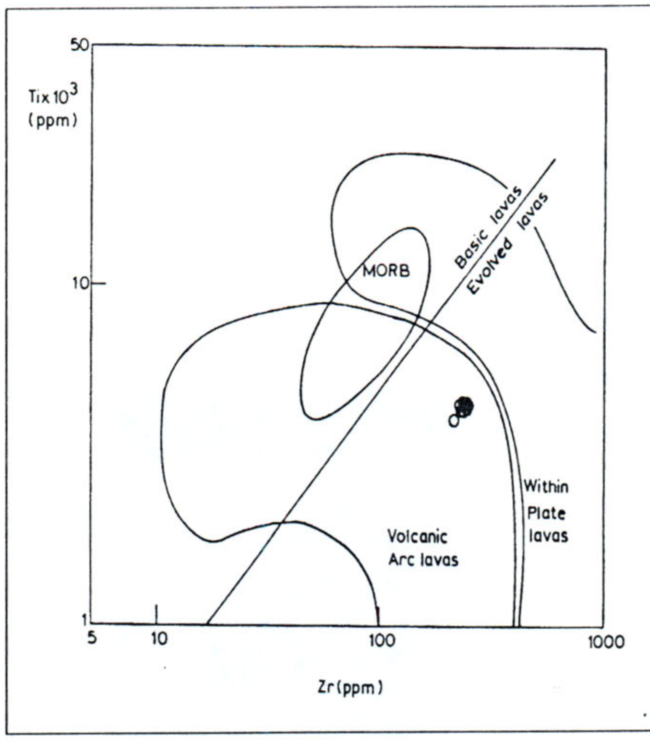

Fig. 4. Distribution of Koziakas Triassic volcanics in the discrimination diagram Ti vs Zr of Pearce (1982).

Discussion

The Koziakas trachytic volcanics should be products of high grade differentiation. As they are not directly associated with other type volcanic rocks in the Koziakas mountain area, an approaching to the exact differentiation procedure, from which they originated, is difficult to be given. However, assimilation of crustal rocks in the parent magmas and complex fractional crystallization or magma mixing in magma champer can be suggested (cf. Wyers and Barton 1986; Wilson, 1989).

Although there is a general agreement that the Triassic volcanism in Hellenides developed in rifting environment only, a dispute has been raised, whether this setting shows or not subduction characteristics, that is, if it was about marginal back arc or continental rift or even mid-ocean basin. The dominance of andesites and the presence of shoshonites and high Th - strong Nb and Ta depleted basalts call for descending slab activity (Rocci et al., 1980; Pe-Piper and Panagos, 1989). On the other hand, several authors believe that for the subduction in the Triassic Pindos basin there is only little independent regional evidence, whereas any determined weak destructive features could originated either from lithosphere contamination or from an inherited older metasomatized mantle (Hynes, 1974; Duncan, 1987; Robertson et al., 1990).

The trachytic extrusives of Koziakas were probably erupted in a deep rift marine basin and during a relatively short period, as respectively indicated by their transitional type chemistry, as well as by their small thickness and close association with silica rich pyroclastics and cherts. Even though they occupy small volume and they are not accompanied by more basic or acid differentiates, subduction imprints are clearly observed in their trace element geochemistry and clinopyroxene composition. However, in order to be definite, whether these subduction characteristics could be ascribed to a back arc basin setting or they are inherited and the rift was of pure continental or mid-ocean type, much more evidences are needed. Such evidences can be search out e.g. in the study of rare earths and isotopic content, which is our next future target.

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