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Geochronology and Geochemistry of Basaltic Rocks in The Karasu Graben Around Kırıkhan (Hatay), S. Turkey

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Abstract: The study area, which is located in the middle sector of the Amanos mountains, covers the north of Kırıkhan (Hatay) in southern Turkey. Tectonostratigraphic rock units from Paleozoic to Cenozoic are exposed within this terrain, which is tectonically active as a result of continent-continent collision between Afro-Arabia and Eurasia. Young basaltic volcanism, located at the N-end of the Dead Sea transform fault in southern Turkey, crops out along the NE-SW trending structural lineaments within the Karasu valley (Hatay). K.Ar age determinations performed on the volcanic rocks give an age range from 0.4 Ma to 2.2 Ma that indicate Plio-Quaternary time internal for the timing of volcanism. The volcanic rocks in the area studied are dominated by alkali olivine basalts based on the petrography and immobile trace element concentrations. Major-trace element geochemistry as well as the REE patterns display geochemical characteristics of Continental Rift Zone volcanism (CRZ).

Kırıkhan (Hatay) Dolayındaki Karasu Grabeninde Yüzeyleyen Bazaltik Kayaların Jeokronolojisi ve Jeokimyası (G. Türkiye)

Özet: Çalışma alanı Amanos Dağlarının orta kesiminde bulunup Kırıkhan (Hatay)'ın kuzeyinde yeralmaktadır. Afrika-Arabistan ve Avrasya kıtalarının çarpışmasına bağlı olarak aktif teknoğin hüküm sürdürdüğü bölgede Paleozoyik-Senozoyik zaman aralığında çökelmiş tektonostratigrafik birimler yeralmaktadır. Güney Türkiye'de Ölü deniz fay zonunun kuzey ucunda yer alan KD-GB uzanımlı Karasu grabeni içerisinde genç bazaltik volkanikler gözlenmektedir. Bu volkanikler üzerinde yapılan 5 adet K-Ar jeokronolojik yaş tayini 0.4 my ile 2.2 my arasında değişmektedir ve bu da Karasu grabenindeki volkanizmanın Pliyo-Kuvaterner zaman aralığında olduğunu işaret etmektedir. Petrografik ve kimyasal analizler bu volkaniklerin alkali olivin bazaltlarla temsil edildiğini göstermekterdir. Bu bazaltların ana-iz ve nadir toprak element içerikleri bu volkaniklerin kıta içi rift zonlarında oluşmuş volkanik kayaçların genel özelliklerini taşıdığını göstermektedir.

Introduction

Wilson (1989) defined Continental Rift Zones (CRZ) as areas of localized lithospheric extension characterized by a central depression, uplifted flanks and a thinning of the underlying crust. High heat flow, broad zones of regional uplift and magmatism are often associated with such structures.

The Dead Sea transform fault zone, which is 1000 km in length, connects the active sea-floor spreading center of the Red Sea in south to the Arabia-Eurasia collision zone in the north (Girdler, 1990). The Dead Sea fault has two segments (Gharb and Karasu) in the north, and the left-lateral Karasu segment is 150 km in length (Gülen et al., 1987). Çapan et al. (1987) stated that the volcanic activity along the Dead Sea fault zone occurs at four localities and the Karasu rift valley forms one of these volcanic centers located at the N-end of this transform fault in southern Turkey.

Geological investigations in the region have focussed on the tectono-stratigraphy (Atan, 1969; Yalçın, 1980; Tinkler et al., 1981; Tekeli and Erendil, 1984; Yılmaz et al., 1984, 1993; Karig and Kozlu, 1990; Yılmaz, 1993; Kop, 1996; Ünlügenç et al., 1997), neotectonic (Arpat and Şaroğlu, 1975; Gülen et al., 1987) and geochemistry of ophiolitic rock units (Vuagnat and Çoğulu, 1967; Bürküt, 1971; Parrot, 1973; Çoğulu, 1973; Çoğulu, 1974; Delaloye et al., 1977; Selçuk, 1981; Erendil, 1984; Pişkin et al., 1986) within the Maraş Triple Junction and its surrounding. The Karasu rift valley is one of the best examples for observing geochemical characteristics and timing of volcanism associated with strike-slip depressions. Detailed geochemical studies and the structures controlling the volcanism within the Plio-Quaternary basalts of the Karasu graben have been performed by Çapan and Tekeli (1983) and Çapan et al. (1987).

In addition to these studies, new K-Ar geochronology and geochemistry, particularly REE content, of the basaltic rocks in the eastern edge of the Karasu graben near Kırıkhan (Hatay) will be presented in this study.

Geological frame of the study area

The study area is located in the middle sector of the Amanos Mountains in Kırıkhan (Hatay) in southern Turkey (Figure 1). The presence of distinct lithostratigraphic units, ranging from the Paleozoic to the Cenozoic era, and tectonic activity express the geologic importance of the region. The basement in the study area is dominated mainly by the lower Paleozoic, which exhibits pelagic to shallow sea environmental characteristics, and the Mesozoic, which is represented by carbonates and ophiolitic rock units. These rock assemblages crop out in the middle part of the field area under investigation (Figure 2).

Tertiary units will be briefly described in terms of their lithology and stratigraphic relations to one another. The oldest unit covering the Mesozoic in the study area is the Cona formation (Maastrichtian-Early Paleocene) comprised of calcarenite, marl and clayey limestones and includes microfossils of *Omphalocyclus sp., Siderolites sp.* and *Globotruncana stuartiformis* (Figure 3). Cona formation transitionally passes upward into the Late Paleocene-Middle Eocene age Hacıdağ formation, which mainly comprises gray-white calcarenite and limestones containing *Discocyclina archiachi Schlumb, Alveolina rutimeeri Hott., Assilina cf. Laminose Gill.* and *Globorotalia velascoensis.* As a result of uplifting and thickening of the Amanos Mountains belt at the end of the Eocene, the Kıcı formation was uncomformably formed on the Hacıdağ formation due to a progressive transgressive event during the Lower Miocene (Figure 3). The Kıcı formation is mainly composed of reddish-brown pebbles derived from ophiolities, limestones and radiolarites, and presumably formed in a very shallow environment. The Kepez and Gökdere formations are of the Middle-Upper Miocene and have lateral-vertical transition contacts with each other and rest discordantly on the Kıcı formation. Kepez formation mainly consists of dark-pale gray and white clayey limestones and reefal carbonates which contain abundant corral fragments. The Gökdere formation is mainly composed of marl intercalated with sandstones and mudstones. Following fossil assemblages such as *Cyprideis seminilum* and *Cyprideis anatolica* Bassiouni indicate the precise age of the unit as Upper Miocene. The Quternary is representet by basalts and alluviums (Figure 3) (Kop, 1996).

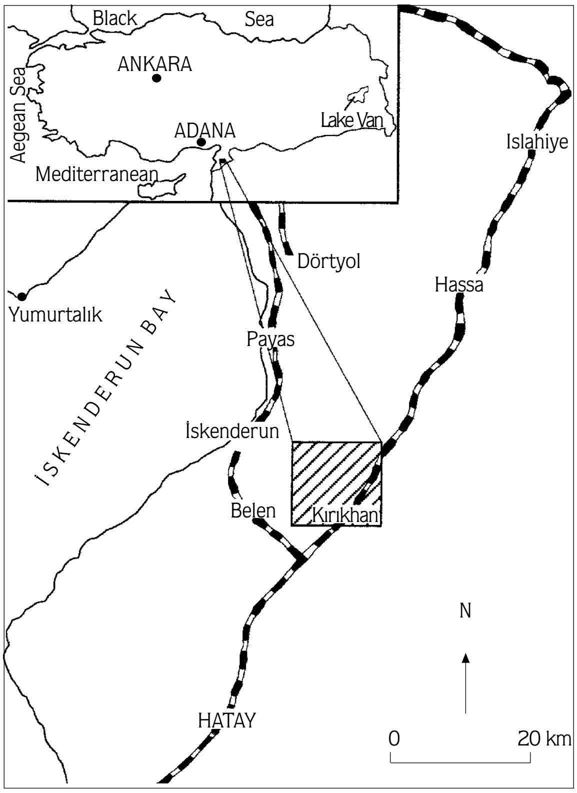

Figure 1. Location map of the study area.

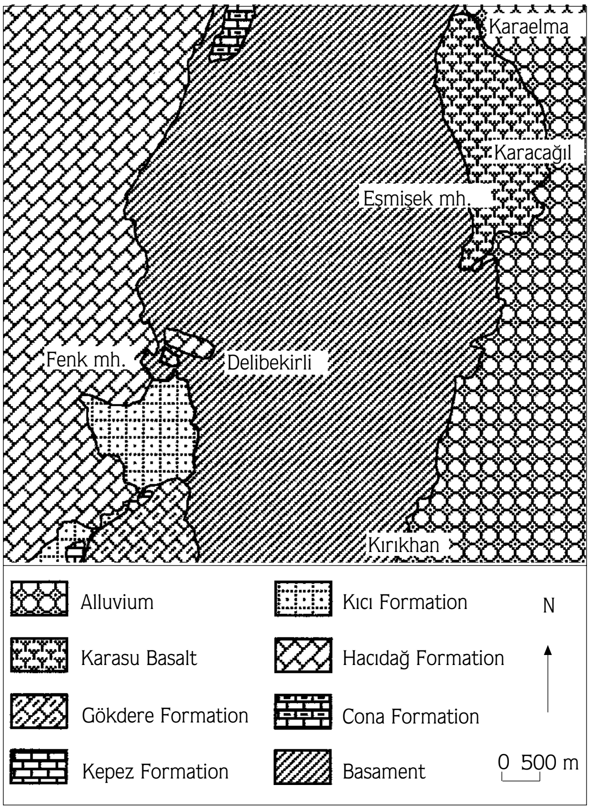

Figure 2. Simplified geological map of the study area (Simplified from Kop, 1996).

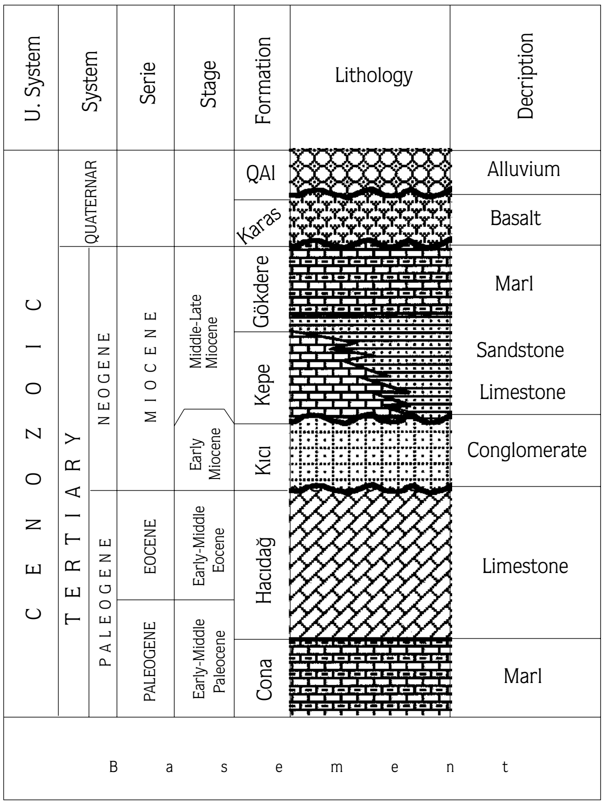

Figure 3. Columnar stratigraphic section of Kırıkhan area (Simplified from Kop, 1996).

Petrographic summary

The Plio-Quaternary volcanic rocks in the study area, which have porphritic, intersertal and glomeroporphyritic textures, are dominated by olivine basalts in the study area. Plagioclase and olivine form the main phenocryst phases in these basaltic rocks. The microcrystalline matrix is dominated by plagioclase, pyroxene and olivine.

The plagioclases, which are generally small-microliths within the matrix or phenocryst phase, form 50-60% of the basaltic rocks. The plagioclases are often euhedral or subhedral in shape and they rarely show zonation. The olivines are the second dominant (30-35%) mineral phase in the basalt. They have euhedral or subhedral crystal shapes and iddingsitization is also present at the rim of the phenocrysts. The clinopryoxenes (15-20%) are augite and generally observed in the microcrystalline matrix, but rarely seen as euhedral/subhedral phenocryst together with olivine and plagioclase in the basalts.

Age of the basaltic rocks

Five whole rock samples were used for K-Ar analysis. The K content of each sample was measured by atomic absorption spectrometer. Ar was extracted by total sample fusion into a pyrex line fitted up with high vacuum metal valves. The resultant gas was mixed with a ^{38}Ar spike for isotopic dilution. Contaminating gasses were separated with titanium traps and liquid nitrogen. Measurements were made in static mode with an AEI MS-10S spectrometer fitted up with a permanent magnet of 4.1 kG and connected to a computer for processing data. Samples were degassed at about 100°C for several hours before the analysis to reduce atmospheric contamination. Analytical precision is near 0.5%. For calculating the age, Steiger and Jager (1977) constants were used.

The results of K-Ar isotopic age determinations are documented in Table 1. The ^{40}Ar content of these young basalts is low (ranging from 0.5 to 8.5%). The cooling ages are between 0.4 to 2.2 Ma, indicating a Quaternary volcanic activity along the Karasu Graben, which is the tip of the Dead Sea Rift Zone in southern Turkey. Çapan et al. (1987) have documented ages ranging from 0.25 to 2.7 Ma and suggested that Karasu valley volcanism occured during the final volcanic episode associated with Dead Sea rift system.

Table 1. K-Ar ages and analytical data for the basaltic rocks in Kırıkhan-Hatay (S. Turkey).

Sample	Material	%K	^{40}Ar*mol/gX10^{-11}	%^{40}Ar*	^{40}Ar/^{36}Arx10^{2}	^{40}K/^{36}Arx10^{4}	Age (Ma)
OP-44	Whole Rock	1.06	0.41	8.50	3.23	20.92	2.20 ± 0.70
OP-46	Whole Rock	1.07	0.15	4.27	3.09	28.82	0.79 ± 0.30
OP-47	Whole Rock	1.04	0.07	0.50	2.97	6.63	0.40 ± 0.20
OP-48	Whole Rock	1.05	0.11	1.52	3.00	13.20	0.60 ± 0.30
OP-51	Whole Rock	1.06	0.19	4.99	3.11	25.43	1.05 ± 0.30

Geochemistry of the basaltic rocks

Major and trace element analyses were carried out on 10 basalt samples. Two basalt samples were analysed for REE concentrations. Major and trace element analyses were carried out by XRF on glass beads fused from ignited powders to which Li2B4O7 was added (!:5), in a gold-platinum crucible at 1150°C. REE analysis was performed by ICP-AES (Voldet 1993).

Major, trace and REE analyses of Plio-Quaternary basalts are shown in Tables 2 and 3. As is clear from the results of major element analysis, some of the reported values of the Loss On Ignition (LOI) are negative (-). This may be explained as follows: during the LOI process some samples take on some oxygen in the furnace due to oxidation of some Fe^{+2} to Fe^{+3}. Consequently, the reported value for LOI becomes lower than the actual

Table 2. Major and trace element analyses of the basaltic rocks in the study area.

Sample	OP-44	OP-45	OP-46	OP-47	OP-48	OP-49	OP-50	OP-51	OP-52	OP-53
SiO2	50.08	50.14	50.15	49.29	49.64	49.42	49.29	48.88	48.73	49.34
TiO2	2.13	2.14	2.10	2.08	2.11	1.88	1.88	1.86	1.86	1.90
Al2O3	15.46	15.46	15.24	15.20	15.39	14.73	14.71	14.49	14.52	14.83
FeO	11.58	11.70	11.44	11.38	11.33	11.26	11.32	11.16	11.13	11.28
MnO	0.14	0.14	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.16
MgO	5.61	5.15	5.69	5.19	5.21	6.82	6.91	6.67	6.80	6.66
CaO	8.43	8.44	8.35	8.81	8.69	8.76	8.64	9.00	9.26	8.50
Na2O	3.74	3.74	3.62	3.57	3.64	3.59	3.55	3.51	3.48	3.55
K2O	1.28	1.29	1.29	1.25	1.26	1.27	1.26	1.28	1.26	1.28
P2O5	0.48	0.50	0.45	0.47	0.45	0.61	0.62	0.61	0.61	0.62
Cr2O3	0.03	0.02	0.03	0.02	0.02	0.04	0.04	0.03	0.03	0.03
NiO	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
LOI	-0.47	-0.11	-0.21	0.90	0.56	-0.06	-0.11	0.46	0.43	0.10
Total	98.50	98.62	98.30	98.32	98.45	98.48	98.27	98.11	98.27	98.27
Nb	28	31	25	27	26	30	32	29	29	34
Zr	172	170	161	167	163	166	164	162	164	167
Y	13	16	14	18	17	12	13	12	12	17
Sr	632	633	597	609	613	803	810	816	794	805
U	2	2	1	0	1	2	2	1	1	2
Rb	26	26	26	25	26	28	29	28	27	27
Th	4	3	3	3	3	4	4	3	2	4
Ga	19	19	19	18	18	17	18	16	17	17
Zn	99	107	101	102	98	94	95	95	92	101
Cu	0	0	0	0	0	28	32	27	29	30
Ni	56	58	61	55	53	144	144	144	140	141
Co	74	69	63	61	59	58	57	61	55	62
Cr	162	166	179	174	160	246	244	243	235	246
V	199	211	196	206	202	193	196	193	197	210
Ba	389	429	480	377	374	471	484	469	470	528
S	68	75	61	1001	673	75	202	42	47	50
Hf	4	4	4	5	4	4	5	4	4	4

volatile content (Ragland, 1989). Alkali olivine basalts are represented by high SiO_2 (49.1-50.6%), TiO_2 (1.9-2.2%) and FeO (11.2-11.8%), and low Al_2O_3 (14.6-15.5%), CaO (8.4-9.1%), MgO (5.2-7%) and K_2O (1.3-1.4%) (Table 2). Total alkali (Na_2O+K_2O) content is between 4.9% and 5.2%, showing the alkaline nature of these basaltic rocks. Some of the major elements (Ti_2O, Al_2O_3, FeO, MgO, CaO, K_2O) are plotted against SiO_2 as a differentiation index. Ti_2O, Al_2O_3 and FeO are positively correlated and have a roughly linear trend with increasing SiO_2, whereas MgO and CaO are negatively correlated against increasing SiO_2 (Figure 4). On the other hand, K_2O contents in the samples might be mobilized due to low temperature alteration after eruption because they present scattered patterns rather than linear-trend with increasing SiO_2 (Figure 4).

The general characteristics of Continental Rift Zone (CRZ) magmas are their alkaline nature, enrichment in volatiles (particularly halogens and CO2) and enrichment in large ion lithophile (LIL) elements, suggesting derivation from enriched mantle sources (Bailey, 1983). On the basis of trace element ratios (Zr/TiO_2 versus Nb/Y), the basaltic rocks in the study area can be classified as alkali basalt (Winchester and Floyd, 1977)(Figure 5). Large ion lithophile (LIL) and High field strength (HFS) elements of the alkali basalts are represented by high values of Sr (597-816 ppm), Rb (25-29 ppm), Ba (377-528 ppm), Zr (161-172 ppm) and Nb(25-34 ppm) (Table 2). Some of the incompatible trace element ratios of the alkali basalts are relatively constant (Zr/Nb=4.91-6.44, Y/Nb=0.40-0.67, Ce/Zr=0.30-0.44, La/Zr=0.17-0.26). This feature is in good agreement with other Continental Rift Zone (CRZ) volcanics in the East African Rift zone (Weaver et al., 1972; Lippard, 1973) and southern Turkey (Parlak et al., 1997). Incompatible elements are those most likely to be transported by melts and other fluids passing through the mantle. Therefore, these elements are most likely to preserve evidence of

Table 3. REE analysis of the basaltic rocks in Kırıkhan (Hatay).

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Ho	Er	Tm	Yb	Lu
OP-45	23.3	48.5	5.6	24.6	5.7	1.8	5.2	4.5	0.8	2.0	0.3	1.5	0.2
OP-53	31.1	61.5	7.6	30.1	6.4	2.0	5.1	4.3	0.8	2.1	0.3	1.5	0.3

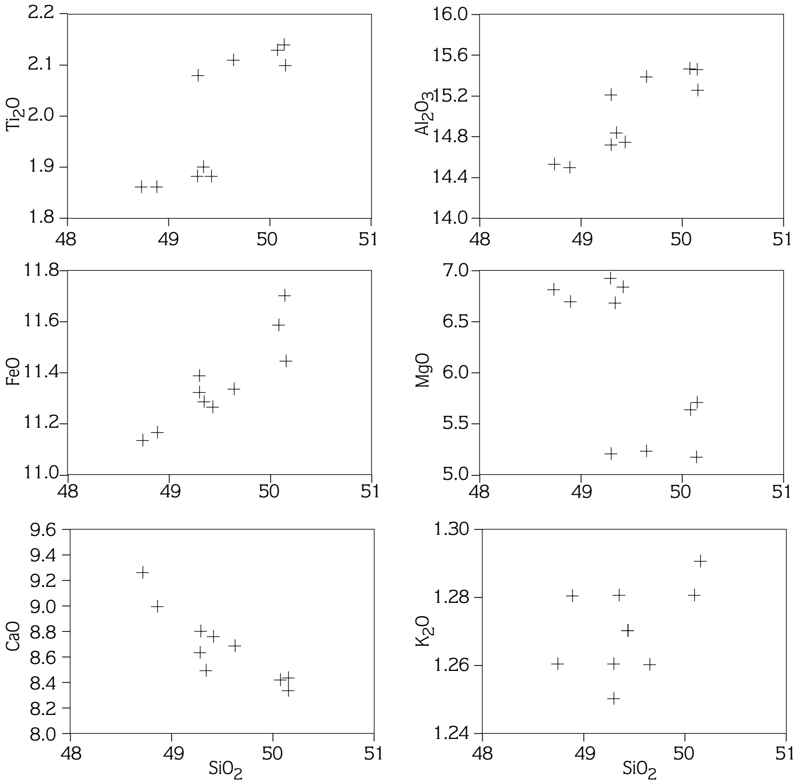

Figure 4. Selected major oxides versus SiO_2 in the basaltic rocks of the study area.

mantle enrichment and depletion processes in their relative abundances (Fitton et al., 1991). Primitive mantle normalized incompatible trace element variations of the alkaline basalts are shown together with Ocean Island Basalt (OIB) and Mid-Ocean Ridge Basalt (MORB) in Figure 6. It is clearly seen that the trace element patterns of the basaltic rocks from the study area are undistinguishable from the those of the OIB pattern. Therefore, the basaltic rocks in the Karasu graben might have been derived from an enriched mantle source.

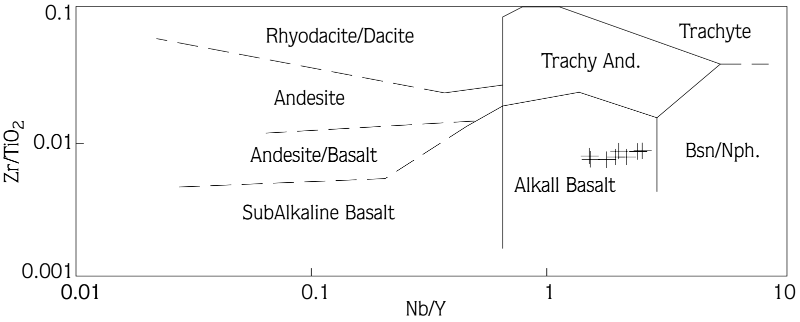

Figure 5. Zr/TiO_2 versus Nb/Y diagram showing the alkaline features of the basaltic rocks in the study area (After Winchester and Floyd, 1977).

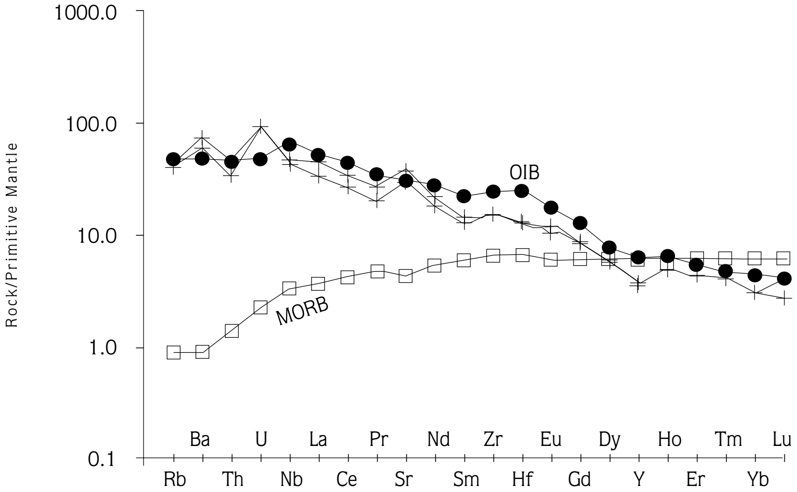

Figure 6. Primitive mantle normalized trace element patterns of two selected samples together with OIB and MORB patterns (Primitive mantle, MORB and OIB values are from Sun and McDonough, 1989).

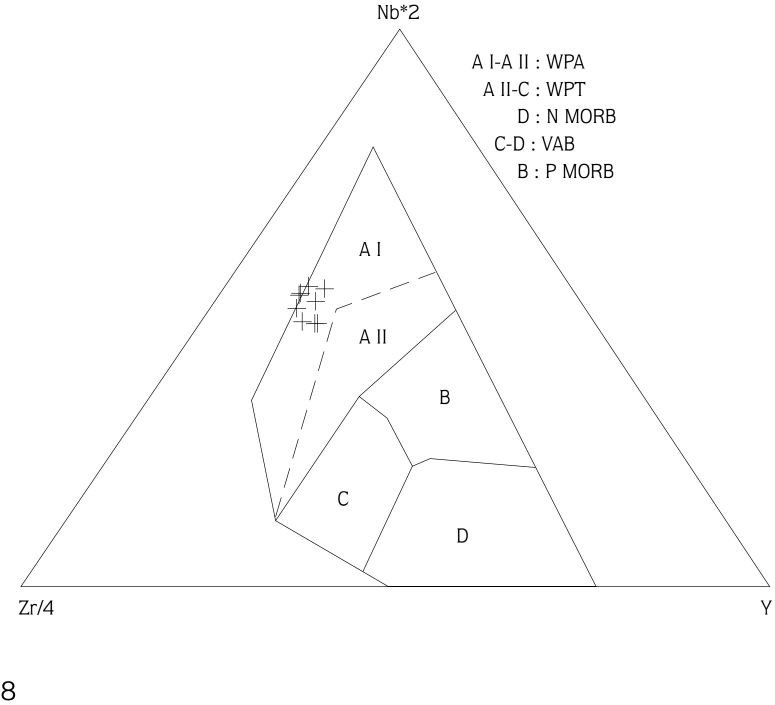

Figure 7. Nb*2-Zr/4-Y discrimination diagram indicating the tectonomagmatic setting of the basaltic rocks in the Kırıkhan region (After Meschede, 1986).

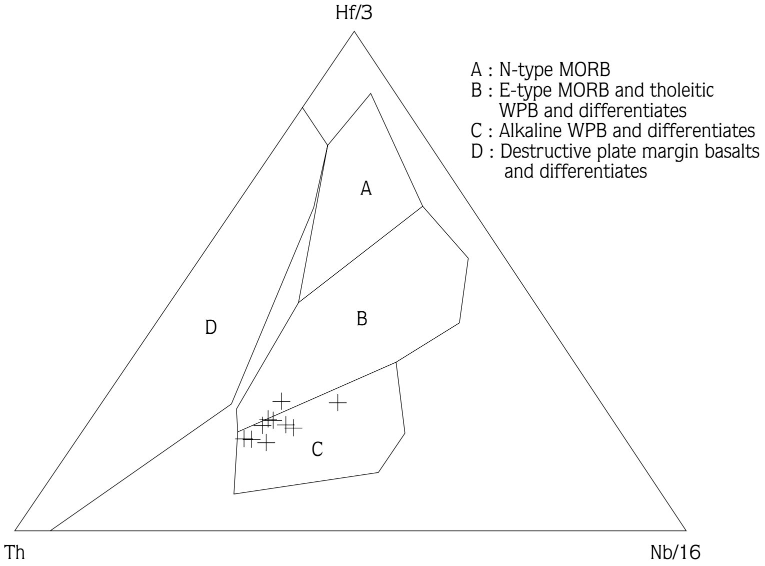

Figure 8. Th-Hf/3-Nb/16 tectonomagmatic discrimination diagram for the basaltic lavas in the study area (After Wood, 1980).

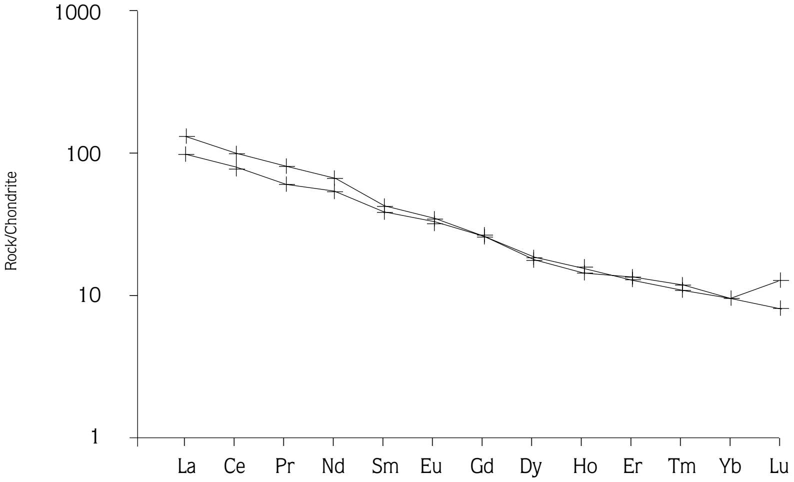

Figure 9. Chondrite-normalized REE abundance of the alkali basalts in the Kırıkhan region (Normalizing values from Sun and McDonough, 1989).

Selected incompatible trace elements such as Zr, Nb, Y, Hf and Th are considered to be immobile during alteration processes, and these incompatible elements can be used to characterize petrological affinities and tectonic setting of volcanic suites (Hart, 1970; Thompson, 1978; Wood, 1980; Meschede, 1986). In the Nb*2-Zr/4-Y tectonomagmatic discrimination diagram of Meschede (1986) the alkaline volcanics are plotted in the field of Within Plate Alkali (WPA) basalt (Figure 7). When we plot these volcanics on a Wood (1980) Hf/3-Th-Nb/16 discrimination diagram, they cluster around alkaline within plate basalt (WPB) and differentiates (Figure 8).

Chondrite normalized REE patterns of the alkali olivin basalts are plotted in Figure 9. They are represented by LREE enrichment and LREE abundance (La, Ce, Pr) of the two selected samples are 100 and 150 times higher than chondrite values (Figure 9). This high REE fractionation ($[La/Yb]_N$ ratio is between 11.2 and 14.88) suggests an enriched mantle source component probably derived from asthenosphere. The REE pattern of the Alkali basalts in Karasu graben is similar to those found in continental rift zones such as the East African Rift, the Ethiopian Rift and the Rio Grande Rift (Wilson, 1989), and also to the REE pattern of the basaltic rocks along the African-Anatolian

boundary (Parlak et al., 1997). LREE enrichment, no Eu anomaly and Eu/Sm=0.32 of the basaltic rocks in Karasu rift valley near Kırıkhan all indicate the characteristic features of volcanism within the Continental Rift Zone (CRZ) (Cullers and Graf, 1984; Wilson, 1989). Parlak et al. (1997) observed similar geochemical features in the volcanics in the area between Yumurtalık (Adana) and Erzin (Osmaniye) along the African-Anatolian plate boundary in southern Turkey.

Conclusions

In this study, the volcanic rocks along the NE-SW trending Karasu graben near Kırıkhan (Hatay) were studied in detial. The conclusions obtained here are as follows:

1) Basaltic rocks in the study area are represented by alkali olivine basalts.

2) Major and trace elements as well as REE geochemistry of these basaltic rocks are akin to those of within-plate alkali basalts (WPA), suggesting an enriched mantle source component probably derived from asthenosphere. Volcanic activities in continental rift zones (CRZ) as seen in the East African rift zone (Wilson, 1989) and the Plio-Quaternary basaltic suites along the African-Anatolian plate boundary (Parlak et al., 1997) in southern Turkey are good analogues of the rocks studied in this paper.

3) The cooling ages obtained by K-Ar geochronology range from 0.4 Ma to 2.2 Ma, indicating the Plio-Quternary time interval, which is compatible with the timing of transtensional tectonic regime in the Karasu graben.

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