



Trace element and Sr-Nd isotope geochemistry of the alkali basalts observed along the Yumurtalık Fault (Adana) in southern Turkey

Güney Türkiye'de Yumurtalık fayı (Adana) boyunca gözlenen alkali bazaltlarının iz element ve Sr-Nd izotop jeokimyası

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ABSTRACT

Young volcanics erupted since late Pliocene as a result of lithospheric extension within the transtensional zones along the NE-SW trending left-lateral Yumurtalık fault zone that mark the boundary between the African and the Anatolian plates in southern Turkey. These volcanics are characterized by alkali olivine basalts. The REE patterns exhibit a strong fractionation characterized by $(La/Yb)_N$ ratio between 22 and 6. Primitive mantle normalized incompatible trace element patterns exhibit close similarity to OIB. Ratios of some selected incompatible trace elements (i.e., $Ce/Y=1.4-3.8$, $Zr/Nb=3.9-6.5$, $La/Ba=0.05-0.1$, $La/Nb=0.6-0.8$, $Zr/Ba=0.4-0.8$) are also well comparable to those of ocean island basalts. The $^{87}Sr/^{86}Sr$ ratios show low values (between 0.703081 to 0.703920), whereas the $^{143}Nd/^{144}Nd$ ratios show high values (ranging from 0.512601 to 0.512986), suggesting an OIB signature. All the evidence suggest that the intracontinental volcanics in this region were derived from an asthenospheric mantle following the fractures of the continental lithosphere that resulted from the left lateral strike-slip fault system bounding the African-Anatolian plates since Late Pliocene in southern Turkey.

Key Words: Adana, alkali basalt, Sr-Nd isotopes, Turkey, Yumurtalık fault

ÖZ

Güney Türkiye'de, genç volkanikler Geç Pliyosen'den beri litosferin gerilmesi sonucu Afrika-Anadolu plakalarını sınırlayan KD-GB gidişli sol yönlü Yumurtalık doğrultu atımlı fayı boyunca gelişen açılma zonlarında yüzeye ulaşmışlardır. Bu volkanik kayaçlar alkali olivinli bazaltlar ile temsil edilirler. Bu volkaniklerin nadir toprak element içerikleri yüksekk derecede ayrımlaşma $[(La/Yb)_N=22-6]$ göstermektedir. İkisel mantoya göre normalize edilen uyumsuz iz element içerikleri okyanus adası bazaltlara yakın benzerlik göstermektedirler. Bazı uyumsuz iz element oranları da ($Ce/Y=1.4-3.8$, $Zr/Nb=3.9-6.5$, $La/Ba=0.05-0.1$, $La/Nb=0.6-0.8$, $Zr/Ba=0.4-0.8$) okyanus adası bazaltlarıyla uyumluluk göstermektedir. $^{87}Sr/^{86}Sr$ oranları düşük (0.703080-0.703918 arasında) olup, buna karşın $^{143}Nd/^{144}Nd$ oranları yüksektir (0.512600-0.512985) ve okyanus adası bazalt özelliğine sahiptir. Bu volkanik kayaçlardan elde edilen jeokimyasal veriler, güney Türkiye'de gözlenen kita içi volkaniklerin Geç Pliyosen'den beri Anadolu-Afrika plakaları arasındaki sınırı teşkil eden sol yönlü doğrultu atımlı fayların neden olduğu kitasal kabuktaki kırıklar boyunca astenosferik mantodan türediklerine işaret etmektedir.

Anahtar Kelimeler: Adana, alkali bazalt, Sr-Nd izotoplari, Türkiye, Yumurtalık fayı

INTRODUCTION

Alkali basalts all over the world namely the Columbia River (Nelson, 1980; Carlson et al., 1981; Carlson, 1984), the Deccan (Mahoney et al., 1985; Mahoney, 1988), the Parana (Hawkesworth et al., 1986), and the Siberian Flood basalts (Sharma et al., 1991), the Massif Central (Chauvel and Jahn, 1984), and the Karoo basalts (Hawkesworth et al., 1984), the alkali-olivine basalts along the African-Anatolian plate boundary (Parlak et al., 1997) and Karasu valley-northern part of Dead Sea rift- basalts (Çapan et al., 1987; Parlak et al., 1998) from southern Turkey, and the volcanics of Aegean region (Seyitoglu and Scott, 1992; Yilmaz, 1990) have been studied in terms of their major-trace element and Nd-, Sr-, Pb- and O-isotopic compositions since more than a decade. Petrogenetic problems of alkali basalts have been widely discussed in recent years, both from geochemical/isotopic and experimental/petrologic points of view (Chauvel and Jahn, 1984). Models for alkaline rock genesis can be extremely various, i.e. some of them involve very small degrees of partial melting (Gast, 1968; Kay and Gast, 1973), whereas the others large degrees of melting (Sun and Hanson, 1975). For the source characteristics of alkaline basalts; some people favored chondritic mantle source (Sun and Hanson, 1975; Frey et al., 1978; Sharma et al., 1991) whereas others favoring a mantle metasomatism in order to account for the enrichment in highly incompatible (LREE-enrichment) elements (Carter et al., 1978; Menzies and Murthy, 1980; Wass and Rogers, 1980; Chauvel and Jahn, 1984). Such detailed studies were carried out in distinct part of Turkey. Yilmaz (1990) compared the young volcanic rocks both in western and eastern Anatolia and stated that the calcalkaline rocks dominated by andesitic group occurred during the Late Oligocene-Early Miocene in compressional regime and the alkaline rocks dominated by basalts occurred during the extensional regime (Middle Miocene and younger). Seyitoğlu and Scott (1992) studied the Late Cenezoic volcanic rocks within the grabens of the Aegean region. They pointed out that the young volcanic rocks (Late Miocene and younger) exhibit alkaline character due to continued extension after the Late Oligocene-Early Miocene and contribution

of the asthenospheric material. Parlak et al (1997) have presented the major-trace element as well as the mineral chemistry of the basaltic rocks along the African-Anatolian plate boundary and pointed out that the volcanic rocks in this region are mainly dominated by alkali-olivine basalts and erupted within the transtensional zones along the African-Anatolian plate boundary since Late Pliocene.

In this paper, Sr-Nd isotopic and trace (including REE) element data on the alkali-olivine basalts erupted along the Yumurtalık fault are presented in order to characterize the isotopic composition of these rocks and hence their mantle source.

REGIONAL GEOLOGY

The Maraş triple junction has a complex structural interrelation where Anatolian, African and Arabian plates collided since late Cretaceous (Sengor and Yilmaz, 1981; Karig and Kozlu, 1990; Kozlu, 1987; Robertson and Dixon, 1984). The boundary between African and Anatolian plates is marked by Cyprus-Misis-Andırın trend along which transtensional regime has been dominant since late Pliocene. As a result of this extension, intracontinental basaltic volcanics were erupted along the lineament of the left lateral Yumurtalık fault in southern Turkey (Figure 1) (Kozlu, 1987; Kelling et al., 1987; Karig and Kozlu, 1990; Parlak et al., 1997). These volcanic rocks rest on the Late Pliocene-Quaternary continental sediments and are intercalated with the Quaternary terrace-conglomerates in the Misis-Andırın basin (Kozlu, 1987). The Plio-Quaternary alkali-olivine basalts are often intercalated with agglomerates and tuffs. They show microlitic-porphyric, ophitic and sub-ophitic textures. The alkali basalts are represented by euhedral olivine (Fo84-79) phenocrysts with variable grain size of 0.3-5.5 mm, laths of plagioclase (An66-58) with a grain size of 0.5-3 mm and anhedral clinopyroxenes (Ca46-48, Mg39-41, Fe11-13) with the grain size of 0.4-0.8 mm. The groundmass is commonly composed of microliths of plagioclase (An44-63) and clinopyroxene (Ca55-51, Mg38-43, Fe5-7).

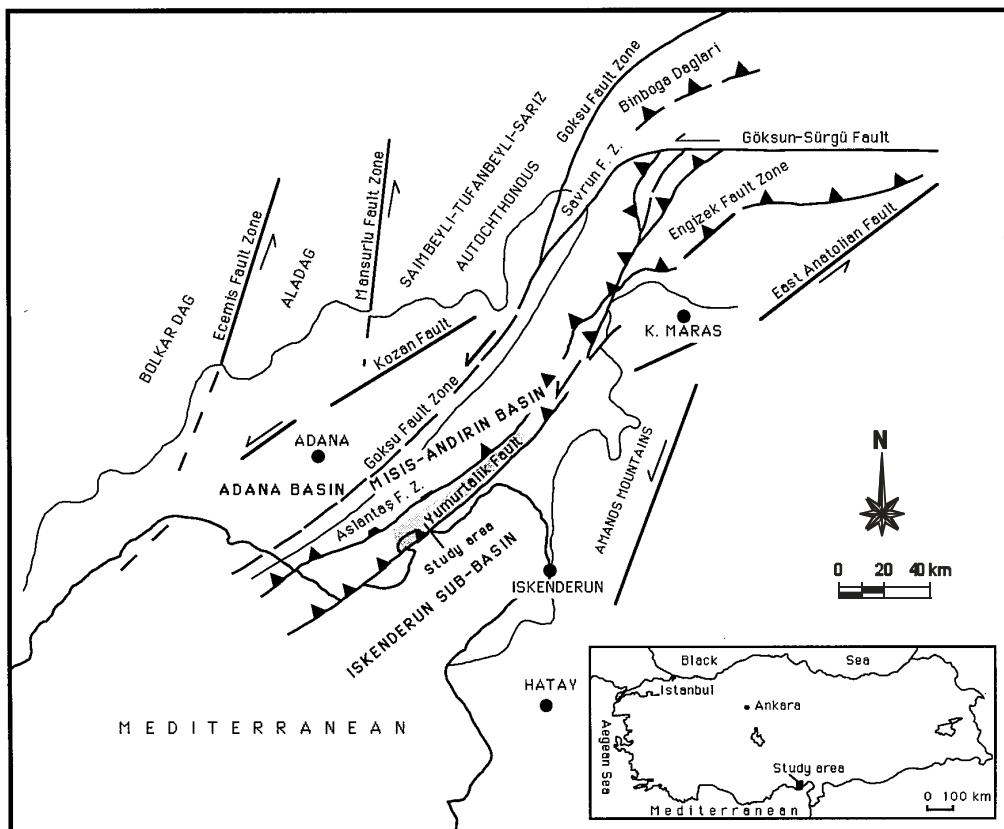


Figure 1: The main tectonic units in Adana, Misis-Andırın and İskenderun region in southern Turkey (from Kozlu, 1987).

Şekil 1: Adana, Misis-Andırın ve İskenderun bölgelerindeki ana tektonik hatlar (Kozlu, 1987'den alınmıştır).

ANALYTICAL METHOD

Fourteen samples of the alkali-olivine basalts were employed for REE, Sr and Nd isotopic compositions. Sr and Rb concentrations were determined by XRF spectrometer on glass beads fused from ignited powders to which $\text{Li}_2\text{B}_4\text{O}_7$ was added (1:5), in a gold-platinum crucible at 1150°C . REE, Sm and Nd concentrations were measured by ICP-AES with an analytical error $\pm 5\text{-}10\%$ in the Mineralogy Department at Geneva University (Voldet, 1993). Sr and Nd were isolated from the same sample dissolution by using HF+HNO₃ method of Hart and Brooks (1974). 500 mg powder of each sample was loaded into a 15 ml teflon bomb capsule. 4 ml of concentrated HF and 0.5 ml of concentrated HNO₃ were added, and the bomb was sealed in an aluminum jacket at 200°C for 5 hours. Then the HF and HNO₃ were evaporated to

dryness. Dissolution was further assured and HF was eliminated by evaporating twice with 1 ml 6M HCl at 130°C . The samples were then dissolved in 1 ml of 2.5M HCl, centrifuged, and the solution was loaded on column for separation of Sr and Nd. Sr and Nd isotopic ratios were determined at the University of Geneva on a 7-collectors Finnigan MAT 262 thermal ionization mass spectrometer with extended geometry and stigmatic focusing. The data are recalculated with reference to the following standards, namely Eimer and Amend $^{87}\text{Sr}/^{86}\text{Sr}=0.7080$ and La Jolla standard $^{143}\text{Nd}/^{144}\text{Nd}=0.511835$. Sr and Nd isotopic ratios were corrected for mass fractionation assuming $^{86}\text{Sr}/^{88}\text{Sr}=0.1194$ and $^{146}\text{Nd}/^{144}\text{Nd}=0.721903$, respectively. The mean value of the standards are for Eimer and Amend $^{87}\text{Sr}/^{86}\text{Sr}=0.708001\pm 06$ (2σ) and for La Jolla $^{143}\text{Nd}/^{144}\text{Nd}=0.511797\pm 04$ (2σ) during the period of data acquisition.

GEOCHEMISTRY

Major and trace element

Major and trace element (including REE) concentrations of the basaltic rocks are shown in Table 1. As is realized from the results of major element analysis, the reported values of the Loss On Ignition (LOI) are minus (-). 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 volatile content (Ragland, 1989). Variations of the major oxides are plotted against SiO_2 as differentiation index in Figure 2. It is apparent that two different suites are present in the study area. First group is represented by low SiO_2 (43.78-46.74 %), Al_2O_3 (14.41-16.23 %) and high TiO_2 (2.5-2.84 %), MgO (7.31-9.45 %), CaO (7.8-10.29 %), FeO (11.34-13.23 %), P_2O_5 (0.71-1.0 %), MnO (0.17-0.18 %), K_2O (1.41-2.56 %). Whereas the second group is characterized by high SiO_2 (48.27-48.67 %), Al_2O_3 (15.99-16.23 %) and low TiO_2 (2.36-2.48 %), MgO (5.95-6.01 %), CaO (9.69-9.72 %), FeO (12.38-12.65 %), P_2O_5 (0.39-0.43 %), MnO (0.16-0.17 %), K_2O (0.87-0.94 %). Despite the difference in terms of major element contents, all the basaltic rocks are characterized by alkali basalts in the Nb/Y versus Zr/TiO_2 diagram of Winchester and Floyd (1977) (Figure 3). The alkaline affinity of these basaltic suites has also been proved in terms of plagioclase and clinopyroxene mineral chemistry (Parlak et al., 1997).

Incompatible elements are those most likely to be transposed by melts and other fluids passing through the mantle. Therefore, these elements are most likely to preserve evidence of 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 in Figure 4 together with OIB and MORB. It is clearly seen that the studied samples have similar trace element patterns compared to OIB in general. The samples with high SiO_2 have lower LILE (Rb , Sr) and HFSE (Nb , La , Ce , Pr , Nd , Sm , Zr , Eu) than the samples with low SiO_2 .

Chondrite-normalized REE patterns of the alkali basalts are shown in Figure 5. All the samples are represented by LREE enrichment and the distinction between two groups can be summarized as (i) high LREE content of the samples with low SiO_2 (La : 30.8-40.9 ppm) compared to the samples with high SiO_2 (La : 16.1-18.5 ppm) and (ii) more fractionated REE patterns of the former (La/Yb_n = 14.2-21.6 and Gd/Yb_n = 2.4-4.1) compared to the latter (La/Yb_n 6.4-9.5 and Gd/Yb_n = 2-2.9), respectively. Cullers and Graf (1984) stated that LREE enrichment, no Eu anomaly and the ratios of $\text{Eu}/\text{Sm}=0.31-0.35$ are characteristic features of ocean island and continental alkali basalts.

The distinction of these alkaline basalts with regard to Primitive mantle-normalized incompatible trace element variations and chondrite-normalized REE patterns suggest that these basaltic rocks are derived: (i) from mantle sources of different compositions (White et al., 1979; Humpris and Thompson, 1983), (ii) from a single parental magma by fractional crystallization (Yoder and Tilley, 1962; O'Hara, 1968; Presnall et al., 1978), (iii) from the same source under different conditions (i.e., at different depths and different degrees of partial melting) (White et al., 1979). These points will be reconsidered in discussion section of the paper.

Table 1: Major-trace element (REE) analyses of the alkaline rocks in southern Turkey.
 Çizelge 1: Güney Türkiye'deki alkalen kayaçların ana-iz element analizleri.

Elements	Sample Numbers													
	OP-1	OP-2	OP-3	OP-4	OP-5	OP-6	OP-7	OP-8	OP-9	OP-10	OP-11	OP-12	OP-13	OP-14
SiO ₂	43.82	43.83	44.14	43.78	43.96	46.74	48.49	48.35	48.27	48.67	44.25	44.04	44.26	44.25
TiO ₂	2,84	2,80	2,70	2,83	2,84	2,50	2,45	2,36	2,46	2,48	2,82	2,81	2,78	2,81
Al ₂ O ₃	14,50	14,46	14,42	14,41	14,47	16,23	16,07	16,23	15,99	15,99	14,96	14,90	15,02	14,91
FeO	13,20	13,12	12,86	13,20	13,20	11,34	12,57	12,38	12,61	12,65	13,23	13,01	13,10	13,06
MnO	0,18	0,18	0,18	0,18	0,18	0,18	0,17	0,16	0,16	0,16	0,18	0,18	0,18	0,17
MgO	9,33	9,37	9,17	9,43	9,45	7,31	5,95	5,95	5,99	6,01	8,55	8,66	8,99	8,98
CaO	9,43	9,31	9,91	9,35	9,42	7,80	9,72	9,69	9,70	9,69	10,24	10,10	10,29	10,14
Na ₂ O	4,26	4,56	4,24	4,35	4,32	5,19	3,56	3,38	3,53	3,46	3,58	3,66	3,69	3,83
K ₂ O	1,72	1,68	1,66	1,56	1,61	2,56	0,91	0,87	0,94	0,92	1,41	1,43	1,45	1,49
P ₂ O ₅	1,00	0,99	0,95	1,00	0,98	0,71	0,43	0,39	0,42	0,43	0,88	0,90	0,86	0,91
LOI	-0,45	-0,39	-0,42	-0,48	-0,58	-0,35	-0,33	-0,32	-0,36	-0,50	-0,46	-0,57	-0,58	-0,68
Total	99,83	99,91	99,81	99,61	99,88	100,20	100,00	99,44	99,71	99,97	99,64	99,10	100,03	99,86
Ba	474	493	461	460	455	401	332	323	337	345	437	446	436	437
Ni	178	187	179	244	177	120	37	36	37	38	144	148	147	150
V	185	180	186	191	189	153	227	230	235	228	210	203	200	205
Cr	259	262	254	270	255	146	167	185	173	176	239	239	240	237
Nb	60	53	59	58	58	60	23	25	23	23	42	44	44	44
Zr	233	228	231	230	233	331	148	143	150	149	179	181	181	186
Y	28	27	26	27	21	24	23	24	23	23	25	24	22	29
Sr	1040	1019	1030	1040	1045	875	510	532	517	512	946	965	944	936
Rb	19	20	20	22	21	34	13	13	13	13	12	13	12	13
La	37,8	38,5	37,1	35,8	39,2	40,9	16,1	16,7	18,5	17,1	31,3	30,9	31,8	30,8
Ce	77,7	78,9	76,5	74,0	80,3	77,9	33,0	37,1	40,5	37,4	65,1	62,9	66,9	63,7
Pr	9,4	9,6	9,5	9,2	10,1	8,4	4,5	4,9	4,8	4,5	7,6	7,2	7,7	7,1
Nd	37,6	38,1	36,6	36,2	39,0	33,5	18,2	20,0	21,8	20,4	31,1	31,1	32,1	30,5
Sm	8,0	8,2	7,9	8,0	8,1	7,0	4,3	4,9	5,4	5,3	6,9	7,1	6,8	6,3
Eu	2,5	2,6	2,5	2,5	2,6	2,2	1,5	1,7	1,8	1,7	2,2	2,3	2,2	2,1
Gd	6,0	6,4	6,3	6,7	6,5	5,8	4,4	4,6	4,9	4,4	5,4	5,2	5,4	5,5
Dy	4,7	4,6	4,6	4,6	4,8	4,9	3,7	3,9	4,2	4,1	4,5	4,7	4,4	4,2
Ho	0,8	0,8	0,8	0,9	0,9	0,9	0,7	0,7	0,8	0,7	0,8	0,8	0,8	0,8
Er	1,8	1,9	2,1	2,1	2,1	2,5	1,9	2,0	2,0	1,9	2,0	1,9	2,1	2,0
Tm	0,2	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,2	0,3	0,3	0,3	0,3	0,2
Yb	1,3	1,3	1,3	1,8	1,3	1,8	1,8	1,4	1,4	1,4	1,3	1,8	1,4	1,3
Lu	0,2	0,2	0,2	0,3	0,2	0,3	0,3	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Ce/Y	2,8	2,9	2,9	2,7	3,8	3,2	1,4	1,5	1,8	1,6	2,6	2,6	3,0	2,2
Ce/Zr	0,3	0,3	0,3	0,3	0,3	0,2	0,2	0,3	0,3	0,3	0,4	0,3	0,4	0,3
La/Ba	0,1	0,1	0,1	0,1	0,1	0,1	0,0	0,1	0,1	0,0	0,1	0,1	0,1	0,1
La/Nb	0,6	0,7	0,6	0,6	0,7	0,7	0,7	0,7	0,8	0,7	0,7	0,7	0,7	0,7
La/Zr	0,2	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,2
Y/Nb	0,5	0,5	0,4	0,5	0,4	0,4	1,0	1,0	1,0	1,0	0,6	0,5	0,5	0,7
Ba/Ce	6,1	6,2	6,0	6,2	5,7	5,1	10,1	8,7	8,3	9,2	6,7	7,1	6,5	6,9
Zr/Nb	3,9	4,3	3,9	4,0	4,0	5,5	6,4	5,7	6,5	6,5	4,3	4,1	4,1	4,2
Zr/Ba	0,5	0,5	0,5	0,5	0,5	0,8	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
Sr/Pr	110,6	106,1	108,4	113,0	103,5	104,2	113,3	108,6	107,7	113,8	124,5	134,0	122,6	131,8
K ₂ O/P ₂ O ₅	1,7	1,7	1,7	1,6	1,6	3,6	2,1	2,2	2,2	2,1	1,6	1,6	1,7	1,6
Al ₂ O ₃ /CaO	1,5	1,6	1,5	1,5	1,5	2,1	1,7	1,7	1,6	1,7	1,5	1,5	1,5	1,5
Al ₂ O ₃ /TiO ₂	5,1	5,2	5,3	5,1	5,1	6,5	6,6	6,9	6,5	6,4	5,3	5,4	5,3	5,3

Sr-Nd Isotope

The Sr- and Nd-isotopic ratios of the alkali-olivine basalts are given in Table 2. The isotopic ratio of the (⁸⁷Sr/⁸⁶Sr) is low (ranging from 0.703081 to 0.703920) whereas the ¹⁴³Nd/¹⁴⁴Nd ratio is high (ranging from 0.512601 to 0.512986) and the ^eNd is between

-0.7 and +6.8 (see Table 2). Figure 6a shows a plot of the (⁸⁷Sr/⁸⁶Sr) and ^eNd for the alkali-olivine basalts. In this diagram all the samples, except one (OP-5 = -0.7), plot almost within the present-day OIB field defined by Hart and Staudigel (1989) and are comparable with the Siberian Flood Basalt Province (DePaolo and Wasserburg, 1979; Sharma et al., 1991).

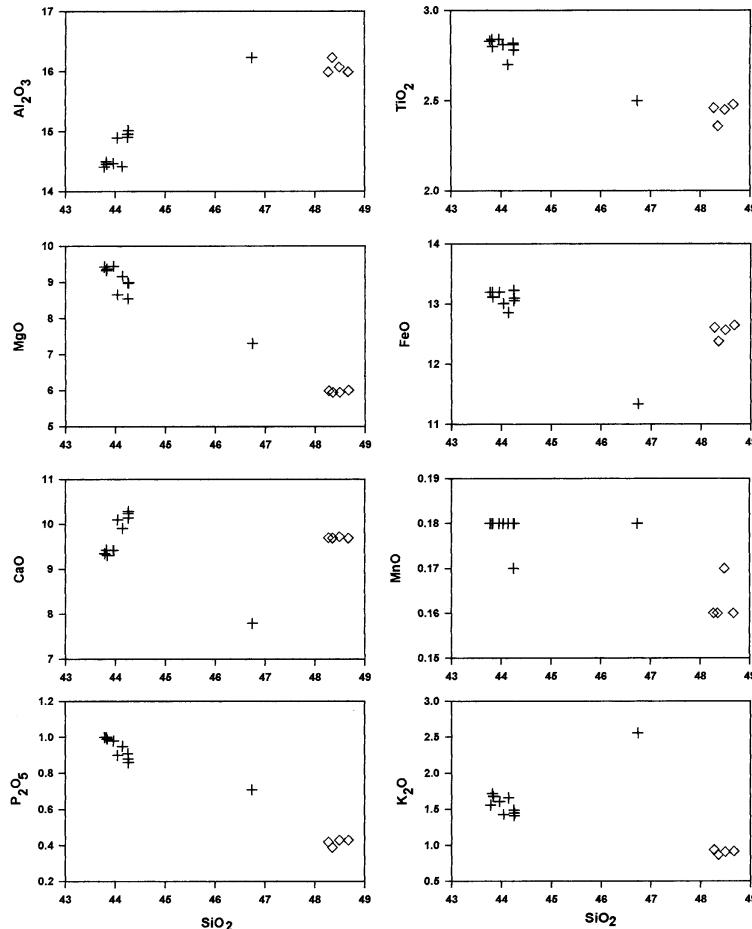


Figure 2: Plots of the major oxides versus SiO_2 , showing the difference for two groups of rocks (+ is low silica and ◊ is high silica samples).

Sekil 2: Çalışma alanındaki bazaltların ana oksitler ve SiO_2 Harker diyagramı (+ düşük silisyumlu, ◊ yüksek silisyumlu numuneleri göstermektedir).

Table 2: Sr-Nd isotope data for the alkali basalts in southern Turkey
Çizelge 2: Güney Türkiye'deki alkalen bazaltların Sr-Nd izotop oranları.

Sample No	Rb	Sr	$^{87}\text{Rb}/^{86}\text{Sr}$	$(^{87}\text{Sr}/^{86}\text{Sr})_{\text{m}}$	$(^{\text{E}}\text{Sr})$	Sm	Nd	$^{147}\text{Sm}/^{144}\text{Nd}$	$(^{143}\text{Nd}/^{144}\text{Nd})_{\text{m}}$	$(^{\text{E}}\text{Nd})$
OP-1	19	1040	0,052798	0,703081 ± 09	-20,133	8,0	37,6	0,128723	0,512891 ± 09	4,948
OP-2	20	1019	0,056722	0,703137 ± 08	-19,340	8,2	38,1	0,130210	0,512900 ± 04	5,124
OP-3	20	1030	0,056117	0,703335 ± 10	-16,529	7,9	36,6	0,130587	0,512891 ± 03	4,948
OP-4	22	1040	0,061135	0,703105 ± 10	-19,795	8,0	36,2	0,133702	0,512902 ± 03	5,162
OP-5	21	1045	0,058077	0,703082 ± 06	-20,121	8,1	39,0	0,125654	0,512601 ± 05	-0,708
OP-6	34	875	0,112297	0,703256 ± 08	-17,667	7,0	33,5	0,126418	0,512986 ± 14	6,802
OP-7	13	510	0,073667	0,703920 ± 08	-8,230	4,3	18,2	0,142940	0,512757 ± 03	2,332
OP-8	13	532	0,070620	0,703887 ± 09	-8,698	4,9	20,0	0,148225	0,512675 ± 07	0,731
OP-9	13	517	0,072669	0,703913 ± 09	-8,329	5,4	21,8	2,442407	0,512721 ± 04	1,189
OP-10	13	512	0,073379	0,703916 ± 10	-8,287	5,3	20,4	2,328679	0,512751 ± 03	1,796
OP-11	12	946	0,036660	0,703150 ± 09	-19,149	6,9	31,1	0,134228	0,512885 ± 03	4,830
OP-12	13	965	0,038933	0,703227 ± 08	-18,057	7,1	31,1	0,138119	0,512881 ± 03	4,751
OP-13	12	944	0,036737	0,703180 ± 07	-18,723	6,8	32,1	0,128162	0,512896 ± 05	5,046
OP-14	13	936	0,040139	0,703176 ± 08	-18,781	6,3	30,5	0,124967	0,512893 ± 04	4,988

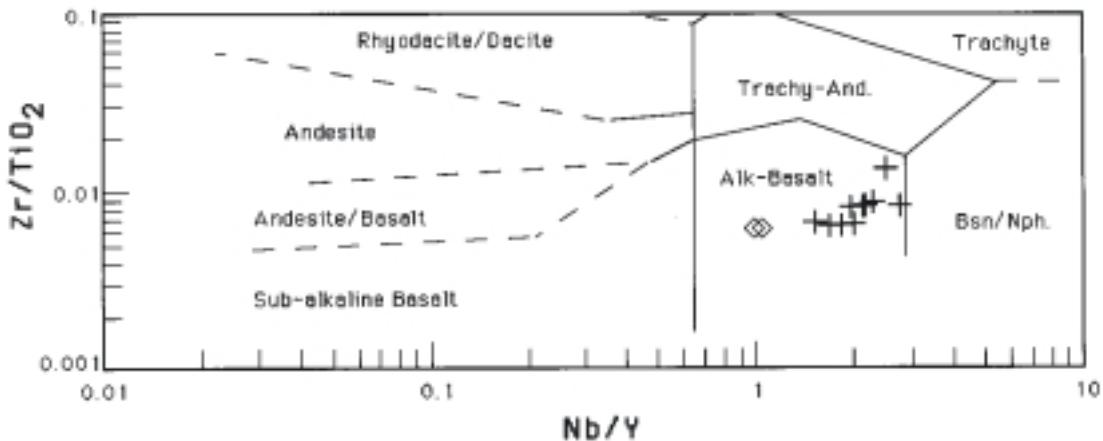


Figure 3: Zr/TiO_2 versus Nb/Y diagram (after Winchester and Floyd, 1977) showing the alkaline affinity of the two different Plio-Quaternary basalts in the study area.

Şekil 3: Çalışma alanındaki Pliyo-Kuvatner bazaltlarının Zr/TiO_2 - Nb/Y diyagramı (Winchester and Floyd, 1977).

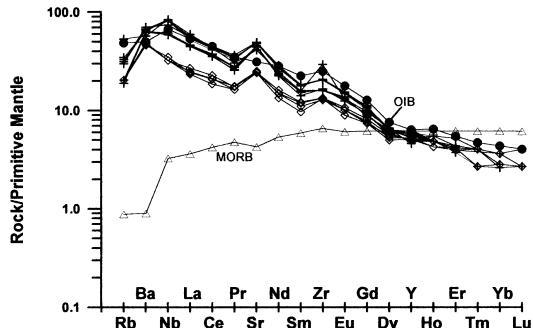


Figure 4: Primitive mantle normalized trace element patterns of the samples (normalizing values are from Sun and McDonough, 1989).

Şekil 4: Örneklerin İlksel mantoya göre normalize edilmiş spider diyagramı (normalize değerler Sun ve McDonough, 1989'dan alınmıştır).

The source similarity of the OIB and the continental basalts is well constrained in ^{87}Nd versus ^{87}Sr diagram (see Figure 6b). The alkali-olivine basalt samples plot within the overlapping field of the OIB and the Continental basalt (see Figure 6b). Plots of Ba/Ce vs $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{143}\text{Nd}/^{144}\text{Nd}$ in Figure 7a and b suggest that alkaline basalts in the study area are close to the primitive mantle values. The data presented here, therefore, indicate an asthenospheric mantle as a major source for the basaltic volcanism in this region. Carlson et al. (1981) and DePaolo (1988) also pointed out the similar features for the Columbia River Basalts.

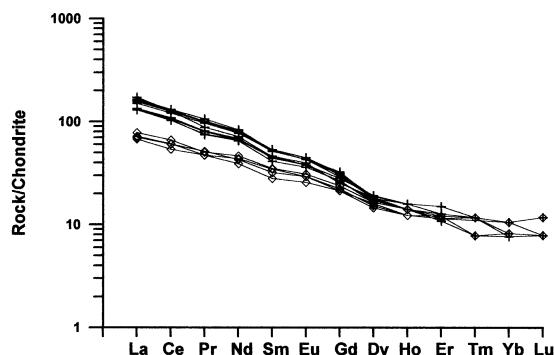


Figure 5: Chondrite-normalized REE abundance in alkali basalts (normalizing values are from Sun and McDonough, 1989).

Şekil 5: Alkali bazaltlarının kondrite göre normalize edilmiş REE içerikleri (normalize değerler Sun ve McDonough, 1989'dan alınmıştır).

DISCUSSION

In this section, petrogenesis of the alkaline basalts will be discussed in detail. Most mantle-derived magmas have K_2O/P_2O_5 ratio of 2 or less (Basaltic Volcanism Study Project, 1981). Crustal assimilation and/or apatite fractionation can result in elevated K_2O/P_2O_5 ratios, as observed in the Colombia River Basalts (Carlson and Hart, 1988). The K_2O/P_2O_5 ratio of the samples are between 1.6 and 2.2 (except one-3.6) and the small variations in the ratios of the selected

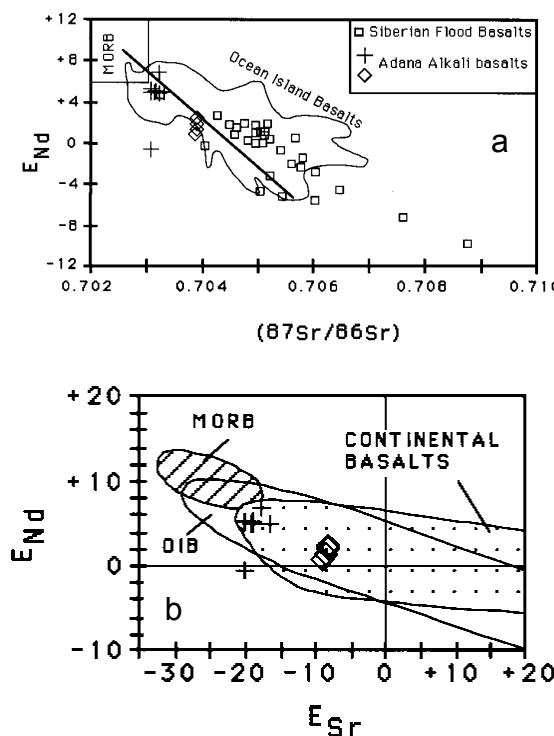


Figure 6: (a) Plot of the ϵ_{Nd} and $^{87}\text{Sr}/^{86}\text{Sr}$. Most of the alkali-olivine basalts in the study area cluster in the field of OIB and are also well correlated with the Siberian Flood basalts (Sharma et al., 1991; De Paolo and Wasserburg, 1979). Fields of the MORB and OIB are from Hart and Staudigel (1989) (b) ϵ_{Nd} and ϵ_{Sr} diagram for alkali-olivine basalts from southern Turkey. Our samples fall in the overlapping field of OIB and Continental basalts (fields the MORB, OIB and Continental basalts are from Chauvel and Jahn, 1984).

Şekil 6: (a) ϵ_{Nd} ve $^{87}\text{Sr}/^{86}\text{Sr}$ diyagramı. MORB ve OIB'ların alanları Hart ve Staudigel (1989)'dan alınmıştır (b) Alkali olivinli bazaltların ϵ_{Nd} ve ϵ_{Sr} diyagramları. (MORB, OIB ve Continental bazalt alanları Chauvel ve Jahn (1984)'ten alınmıştır).

incompatible trace elements ($Zr/Nb=3.88-6.52$, $Zr/Ba=0.41-0.83$, $Y/Nb=0.36-1$, $Ce/Zr=0.22-0.37$ and $La/Zr=0.11-0.18$) (see Table 1) suggest that the crustal contamination is not significant for the studied volcanic rocks along the African-Anatolian plate boundary. The studied samples have fairly large range for Ni (36-244 ppm) and Cr (146-270 ppm).

High silica samples have low Ni (36-120 ppm) and Cr (146-185 ppm) contents, compared to low silica samples that have high Ni (144-244

ppm) and Cr (237-270 ppm) respectively. This suggests that olivine and pyroxene fractionation played important role whereas plagioclase fractionation does not (absence of Eu anomaly) in affecting the compositions of the alkaline basalts in the study area.

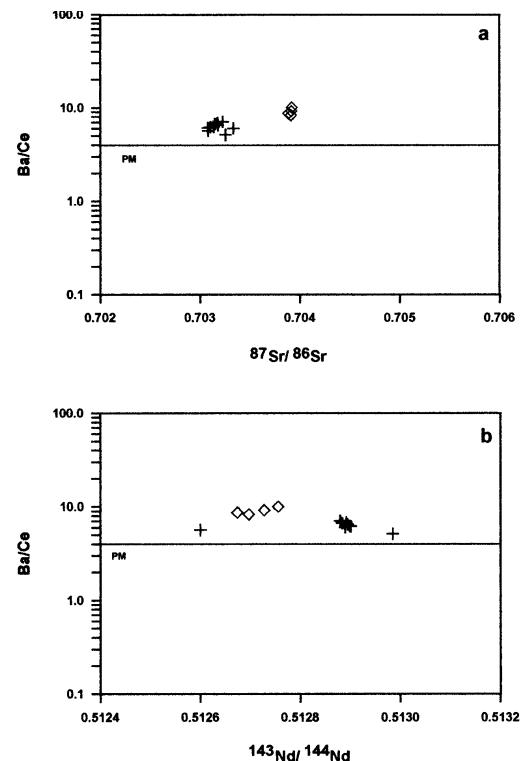


Figure 7: Plots of (a) Ba/Ce versus Sr and (b) Ba/Ce versus Nd isotopic composition for the alkaline rocks in the study area. (Primitive mantle line (PM) is from Halliday et al., 1995).

Şekil 7: Çalışma alanındaki alkali bazaltlar için (a) Ba/Ce-Sr ve (b) Ba/Ce-Nd diyagramları. (İlkSEL manto çizgisi (PM) Halliday ve dig. (1995)'ten alınmıştır).

Fitton et al. (1988 and 1991) used Ce/Y vs. Zr/Nb and La/Ba vs. La/Nb diagrams respectively, to demonstrate chemical differences between the basalts of the Basin and Range and those of the Transition zone and the Sierran Province. They demonstrated that the basalts from Basin and Range province are similar to OIB and interpreted these basalts as originating within the asthenosphere. The ratios of these selected incompatible trace elements ($Ce/Y=1.4-3.8$, $Zr/Nb=3.9-6.5$, $La/Ba=0.05-0.1$, and $La/Nb=0.6-0.8$) indicate that the alkali basalts in the study area plot within the field of OIB (Figure 8) defined by Fitton et al. (1988 and

1991). Following these diagrams, it is suggested that the basaltic rocks were originated from asthenospheric mantle as a result of thinning of the lithosphere. Ratios of some incompatible elements such as La/Nb (0.6-0.8), Sr/Pr (107-134), Zr/Ba (0.4-0.5), Ce/Zr (0.2-0.3) suggest relatively uniform mantle source for the alkaline rocks in the study area. The differences in terms of their chondrite normalized REE and primitive mantle normalized incompatible trace element patterns suggest that they were originated from the same source under different conditions, such as different depths and different degrees of partial melting. Low ratios of $\text{Al}_2\text{O}_3/\text{TiO}_2$ (5.1-6.9), fractionated HREE ($\text{Gd}/\text{Yb}_n=2-4.1$) and LREE ($\text{La}/\text{Yb}_n=6.4-21.6$) all suggest the high proportion of garnet in the residual phase during melting in the mantle source.

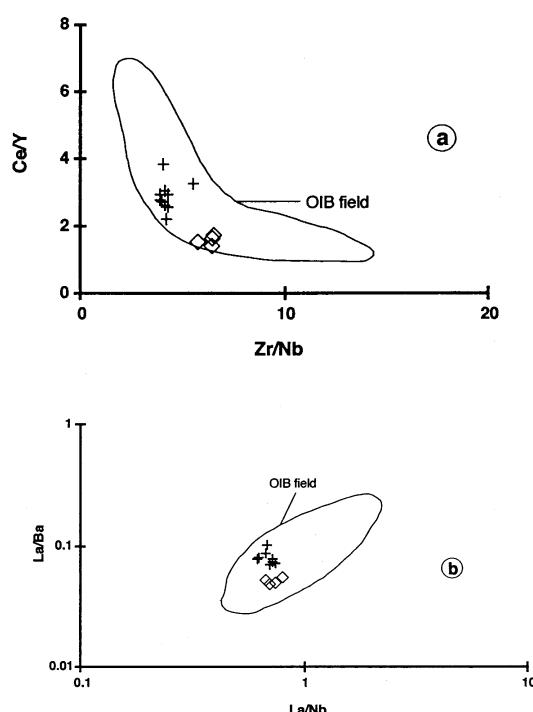


Figure 8: (a) Ce/Y vs. Zr/Nb and (b) La/Ba vs. La/Nb diagrams for the alkali basalts in the study area (the field of OIB from Fitton et al., 1988 and 1991).

Şekil 8: Alkali bazaltlar için (a) Ce/Y-Zr/Nb ve (b) La/Ba-La/Nb diyagramları (Okyanus adası bazaltlarının alanı Fitton ve diğ. (1988 ve 1991)'den alınmıştır).

CONCLUSION

The alkaline rocks in the study area are geochemically similar to those in OIB in terms of the REE patterns and the ratios of some incompatible trace elements such as Zr/Ba, Ba/Nb, Ba/La, Zr/Nb. These intracontinental alkaline basalts resemble the alkali basalts of Basin and Range province (Fitton et al., 1991) that are interpreted as being derived from asthenospheric mantle source.

The volcanic activity in the study area occurred within the transtensional zones of the NE-SW trending Yumurtalık strike-slip fault system. These NE-SW trending sinistral strike-slip fault systems controlling this volcanism have resulted from the continuous compressional tectonic regime at the Kahramanmaraş triple junction (southern Turkey) where the collision of the African-Arabian and Anatolian plates occurs. The strike-slip related transtensional deformation along the African-Anatolian plate boundary might be the reason for decompressional partial melting of the asthenospheric material (White and McKenzie, 1989), as basaltic lavas along this NE-SW lineament in southern Turkey.

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