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Adakite-Like Intrusive Rocks From the Bozüyük Area (NW Turkey)

Bozüyük Civarının Adakit Benzeri Magmatik Kayaçları (KB Türkiye)

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ABSTRACT

We have discovered a felsic intrusive unit (the Karaköy granite; 125±4.2 M.A.), which was emplaced into the Triassic metamorphic rocks of the Sakarya Zone as small stocks and dikes in the north of the Bozüyük Town of NW Turkey. This area is close to the İzmir-Ankara Suture which is the remnant of northern branch of Neo-Tethys Ocean. The Karaköy granitic rocks are composed of equigranular leuco granites, granodiorites, tonalites and their hypabyssal equivalents. They are represented by peraluminous and low-K rocks, displaying high SiO2, Al2O3, Na2O, Sr, and low K2O, MgO, Yb and Y. They exhibit negative Nb-Ta anomalies similar to the subduction related magmas. By contrast, lack of negative Eu anomaly and presence of high Sr/Y and low K2O/Na2O ratios are likely to the adakite-like magmas and/or Archaean TTG's. In the light of the findings obtained from this study, we conclude that there was an active north-dipping subduction zone within the northern Neo-Tethys Ocean during the Early Cretaceous, and adakite-like intrusive rocks derived possibly from the melting of basaltic topmost layer of the subducted slab.

Keywords**:** Adakite, Bozüyük, Granite, Lower Cretaceous, Petrology, Slab-melting.

ÖZ

KB Türkiye'de Bozüyük İlçesi kuzeyindeki alanlarda Sakarya zonunun Triyas yaşlı metamorfik kayaları içerisine yerleşmiş felsic bir intrüzif birim (Karaköy graniti, 125±4.2 My) keşfedilmiştir. Bu alan Neo-Tetis okyanusu kuzey kolunun kalıntılarını temsil eden İzmir-Ankara kenet kuşağına yakındır. Karaköy granitik kayaları granüler dokulu löko granitler, granodiyorit, tonalit ve bunların hipabisal eşdeğerlerinden oluşur. Bunlar peralümina'lı düşük potasyumlu olup, yüksek SiO2, Al2O3, Na2O, Sr ve düşük K2O, MgO, Yb ve Y içeriklidirler. Yitim ile ilişkili magmalara benzer şekilde negatif Nb-Ta anomalisi sergilerler. Fakat, yitim ile ilişkili magmaların aksine, negatif Eu anomalisi göstermezler ve adakit benzeri magmalara ve/veya Arkeen Tonalit-Tronjemit-Granit (TTG) serilerine benzer şekilde yüksek Sr/Y ve düşük K2O/Na2O oranlarına sahiptirler. Bu çalışmada elde edilen bulgular ışığında biz, Alt Kretase döneminde, Neo-Tetis okyanusu içinde, kuzey yönlü bir yitimin varlığı ve adakit-benzeri intrüzif kayaların olasılıkla dalan levhanın en üst bazaltik kesiminin ergimesinden türemiş olduğu sonucuna ulaşmış bulunmaktayız.

Anahtar Kelimeler*:* *Adakit, Bozüyük, Granit, Alt Kretase, Petroloji, Dilim ergimesi*

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INTRODUCTION

In most of the tectonic evolution models for NW Anatolia (i.e., Şengör and Yılmaz 1981; Okay and Tüysüz 1999), the early Cretaceous has been regarded as widening period of oceanic crust of the northern Neo-Tethys. In contrast, some recent studies show occurrence of subduction-accretion complexes (Okay et al., 2006; Tüysüz and Tekin, 2007) and obducted ophiolite slabs (Okay et al., 2006; Akbayram et al., 2009) during the Early Cretaceous, indicating the convergence within the oceanic realm. We present here, the first document on the occurrence of an orogenic magmatic activity accompanying this tectonic development.

The study area covers the northern part of the Bozüyük town at the south of Bilecik province of NW Turkey (Figs 1a, b). In this area, granitic plutonic rocks displaying the adakite-(and/or TTG) like geochemistry emplaced into the Triassic metamorphic rocks (the Karakaya complex; Okay et al., 1990). We have mapped these granitic rocks in detail, and studied its petrographical aspects together with their geochemical nature, in some extends. Here, we first introduce preliminary petrological features of the early Cretaceous adakitic rocks which were produced possibly by the slab-melting mechanism.

GEOLOGICAL SETTING

The Karaköy granite crops out near the Bozüyük town, between the Bilecik and Eskişehir provinces as three small stocks intruded into the Triassic metamorphic rocks (Kayacı, 2008; Figs 1a, b). They occupy nearly 2 km^2 area. This region is close to the northern boundary of the İzmir-Ankara suture zone, which has been regarded as the remnant of the northern branch of the Neo-Tethys Ocean (Şengör and Yılmaz, 1981; Okay and Tüysüz, 1999). At the base of the region, there are two different metamorphic units that tectonically amalgamated before the Liassic transgression (Yılmaz, 1981; Yılmaz et al., 1997). One of the metamorphic units is the Söğüt metagranite (Yılmaz, 1981) which is Carboniferous in age (295±5 Ma, Çoğulu et al., 1965). The other unit is formed from the metabasite, metapelite and metatuff association (the Nilüfer unit; Okay et al., 1990) which is Triassic in age. Both metamorphic units are unconformably overlain by a thick Mesozoic sedimentary succession in the northern part of the study area (Altınlı, 1975; Yılmaz, 1981; Altıner et al., 1992).

All of the outcrops of the Karaköy granite form the elongated, nearly east-west trending, semi-elliptical and stock-like intrusive masses (Fig 1b). Narrow (app. 50 m) contact metamorphic aureoles were developed along the contacts between the granitic bodies and the metamorphic country rocks. Thin (app. 2-5m) granite porphyry dikes cut the granitic bodies. The Karaköy granite is dated radiometrically as 125 ± 4.2 Ma (whole rock, K-Ar).

RESULTS

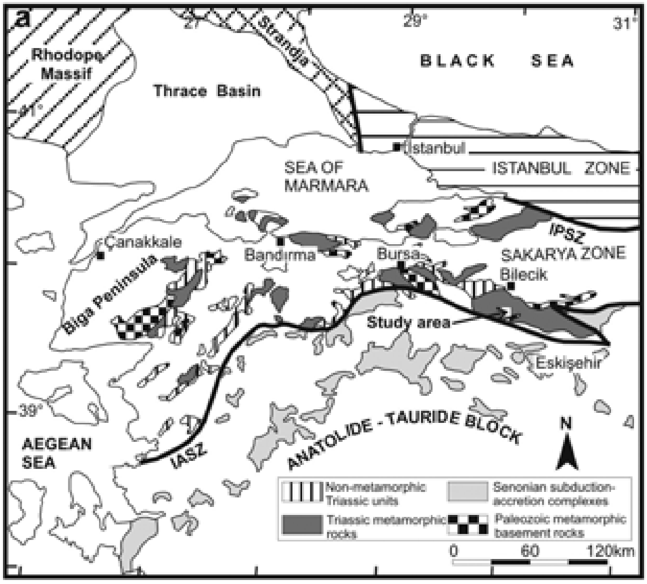
Petrography

The Karaköy granitic rocks range from leucogranodiorite to granite, petrographically. The contacts between leucogranodiorite and granite are generally gradual.

The granites are medium to fine grained with the hypidiomorphic inequigranular and/or microgranular texture. Granitic samples are comprised mainly from plagioclase ($An_{12-25)}$ + quartz + K.Feldspar + muscovite + opaque minerals + apatite. Rare epidote, chlorite, calcite and zoisite are the alteration products. The most significant petrographic features of the unit are lack of the mafic minerals (such as biotite, hornblende etc.) and very rare amount of opaque minerals (i.e. iron oxides) (Fig 2a). Porphyry samples are recognized by their highly (holocrystalline) porphyritic textures (Fig 2b). Mineralogical composition of the porphyries is the same as the granitic samples. Modal mineralogical compositions and the textural features of the Karaköy granite are briefly outlined in Table 1.

Geochemistry

Major, trace and REE compositions of the Karaköy granite are presented in Table 2 (see Genç and Tüysüz, 2010 for the the analytical



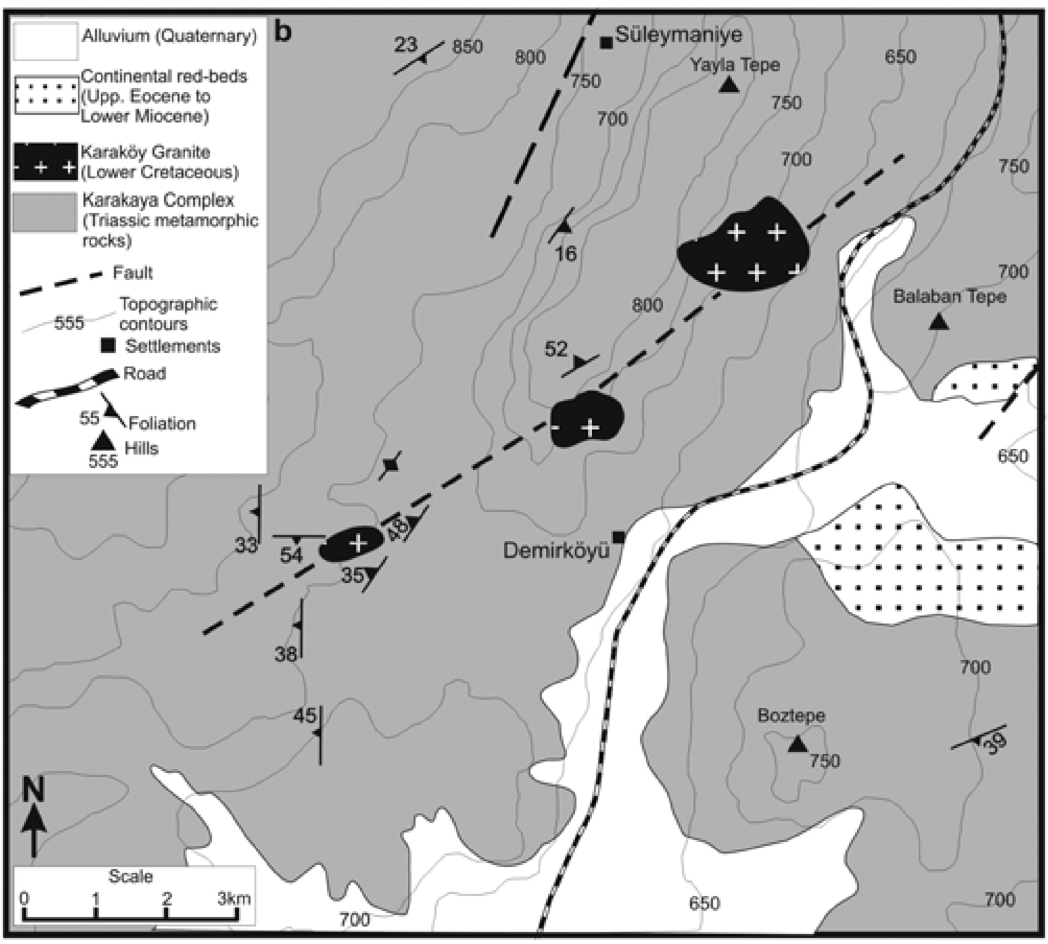


Figure 1a. Main tectonic subdivisions of the NW Anatolia and location of the study area (IPSZ: Intra-Pontide Suture Zone, IASZ: İzmir-Ankara Suture Zone). 1b: Simplified geology map of the Karaköy granite and its surroundings.

Şekil 1a. KB Anadolu'nun tektonik asbölümleri ve inceleme alanının yeri (IPSZ: İntra-Pontid Sütur Zonu, IASZ: İzmir-Ankara Sütur Zonu). 1b. Karaköy graniti ve çevresinin sadeleştirilmiş jeoloji haritası.

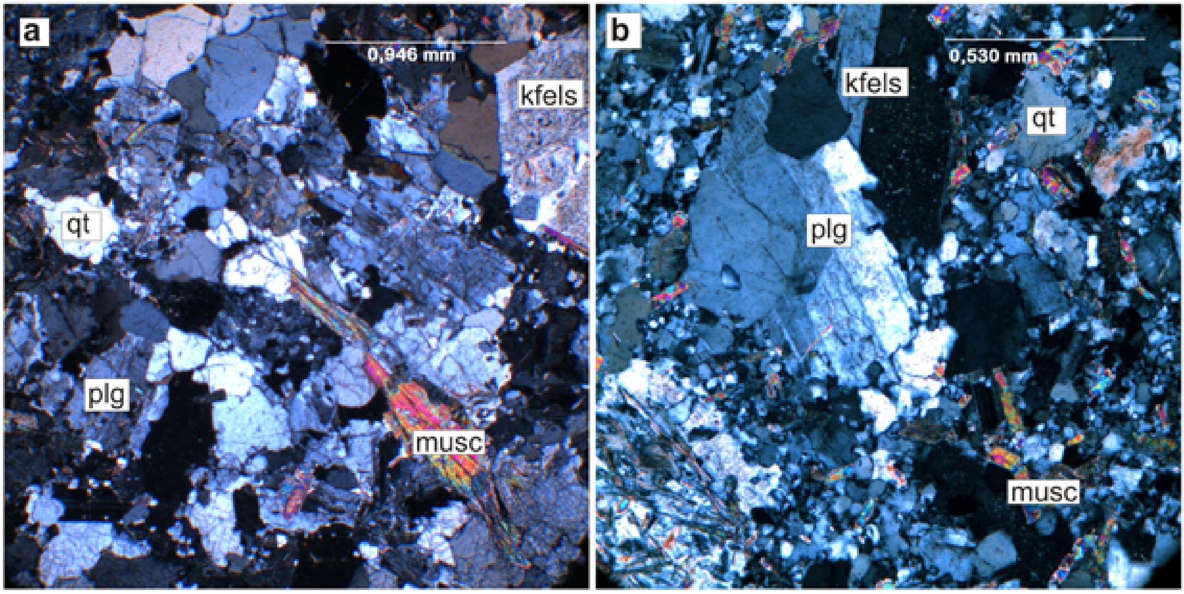


Figure 2a. Photomicrograph from the granitic rocks displaying the inequigranular texture (crossed nicols; plg: plagioclase, kfels: K-feldspar, qt: quartz, musc: muscovite), **2b:** Photomicrograph from the porphyry rocks showing the porphyritic texture with microgranular groundmass (crossed nicols; abbreviations are the same as the Fig 2a).

Şekil 2a. Farklı tane boylu granüler doku sergileyen granitik kayaçlardan birinin polarizan mikroskop görüntüsü (çapraz nikol; plg: plajioklas, kfels: alkali feldispat, qt: kuvars, musc: muskovit), 2b: Mikrogranüler matriksli ve porfirik dokulu porfir kayaçlarından birinin polarizan mikroskoptaki görünümü (çapraz nikol, kısaltmalar Şekil 2a ile aynıdır).

Table 1. Modal mineralogical compositions and textural features of the Karaköy granite (* denotes the secondary minerals).

Çizelge 1. Karaköy granitinin modal mineral bileşimleri ve dokusal özellikleri (ikincil mineralleri göstermektedir).*

Modal mineralogical composition (mean %)	Rock Types	
	Granites	**Granit Porphyries**
Quartz	35-40	40-42
Plagioclase	40-45	40-43
K.Feldspar	7-15	8-10
Muscovite	4-10	4-6
Opaques	0-2	1-2
Apatite	Rare	Rare
Calcite	0-1	-
Epidote (pistachite)	0-3	-
Epidote (allanite)	Rare	-
Epidote* (zoisite)	0-3	-
Sericite*	0-3	0-2
Textures	Sub-idiomorphic granular, graphic-granophyric; pertites in K.Feldpars, zoning in plagioclases	Highly Porphyritic, secondary cataclastic

Table 2. Major, trace and rare earth element contents of the Karaköy granite (Fe2O3*: total iron oxide, LOI: loss of ignition).
Çizelge 2. Karaköy granitinin ana, iz ve nadir toprak elementleri içeriği (Fe2O3: toplam demir oksit, LOI: ateşte kayıp).*

	K2	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**	**K11**	**K12**	**TS2**
SiO2	72.28	72.76	71.95	71.53	71.70	71.48	72.19	71.67	72.11	72.30
Al2O3	15.77	15.52	15.21	16.02	15.37	15.34	15.80	15.83	16.18	15.90
Fe2O3*	1.41	1.51	1.32	1.27	1.20	1.62	1.15	1.33	1.37	1.09
MgO	0.43	0.37	0.42	0.39	0.32	0.45	0.39	0.43	0.41	0.39
CaO	1.39	1.04	1.45	1.76	1.95	2.19	1.85	1.75	1.62	1.44
Na2O	6.53	5.62	6.65	6.49	6.01	6.08	6.19	6.51	6.51	7.00
K2O	0.84	1.17	1.01	0.88	0.93	0.89	0.90	0.92	0.87	0.83
TiO2	0.13	0.12	0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.14
P2O5	0.06	0.05	0.04	0.05	0.05	0.05	0.04	0.05	0.04	0.03
MnO	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.03	
Cr2O3	0.002	0.002	0.005	0.001	0.002	0.002	0.001	0.001	0.002	
LOI	1.17	1.91	2.15	1.48	2.50	1.77	1.39	1.37	0.74	0.83
Total	100.03	100.08	100.34	100.01	100.16	100.00	100.02	99.99	100.00	99.96
Sc	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	
Mo	1.20	1.60	1.50	1.20	1.20	1.60	0.90	1.00	1.50	
Cu	4.00	6.30	4.70	5.00	3.30	5.80	2.90	4.00	5.40	
Pb	8.80	16.00	12.40	23.30	9.30	78.30	15.70	36.20	13.60	
Zn	39.00	22.00	35.00	29.00	15.00	23.00	19.00	24.00	28.00	
Ni	5.60	5.60	5.20	5.80	6.20	6.50	4.20	5.70	6.70	
Ba	101.00	157.20	128.10	127.40	96.20	100.90	97.00	104.90	102.90	
Co	1.80	1.80	1.70	2.10	1.40	2.00	1.50	1.90	2.20	
Cs	1.10	1.60	1.40	1.00	2.90	1.30	1.80	1.00	1.40	
Ga	18.80	18.60	18.20	19.40	18.30	19.30	18.20	19.10	19.80	
Hf	2.30	2.40	2.20	2.60	2.20	2.20	2.30	2.20	2.90	
Nb	1.10	1.10	1.00	0.90	0.90	1.10	0.80	0.80	0.90	
Rb	14.80	17.50	18.90	14.30	14.10	13.30	12.30	14.40	13.80	
Sr	550.90	387.30	328.70	537.70	380.30	620.60	536.40	502.10	634.00	
Ta	0.10	0.10	0.10	0.10	0.10	0.20	0.10	0.10	0.10	
Th	0.90	0.80	0.70	0.90	0.80	0.80	0.90	0.40	1.00	
U	0.60	0.60	0.80	0.70	1.00	0.60	0.60	0.60	0.80	
V	18.00	16.00	11.00	13.00	9.00	13.00	14.00	16.00	13.00	
Zr	73.00	63.20	64.70	76.60	61.30	66.00	70.20	70.00	88.00	
Y	2.80	3.30	2.90	3.20	3.00	3.30	3.00	3.10	3.10	
La	2.30	3.30	2.80	3.20	3.00	2.90	3.20	3.40	2.90	
Ce	5.40	7.90	7.20	7.80	7.50	7.20	7.30	7.90	6.50	
Pr	0.79	1.07	0.99	1.08	1.09	0.97	1.05	1.09	0.92	
Nd	3.10	4.70	4.40	4.70	4.60	4.40	4.40	4.50	3.80	
Sm	1.10	1.50	1.30	1.40	1.40	1.10	1.30	1.40	1.10	
Eu	0.37	0.36	0.33	0.40	0.41	0.39	0.36	0.42	0.41	
Gd	1.00	1.20	1.14	1.11	1.20	1.13	1.21	1.18	1.05	
Tb	0.14	0.15	0.17	0.15	0.16	0.16	0.16	0.15	0.16	

	K2	K5	K6	K7	K8	K9	K10	K11	K12	TS2
Dy	0.60	0.66	0.68	0.71	0.70	0.62	0.64	0.78	0.78	
Ho	0.09	0.09	0.09	0.11	0.10	0.11	0.09	0.09	0.10	
Er	0.22	0.25	0.21	0.23	0.27	0.29	0.25	0.27	0.27	
Yb	0.22	0.21	0.16	0.22	0.17	0.19	0.15	0.19	0.19	
Lu	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03	

Table 2 continued

	TS5	TS6	TS7	TS8	TS9	TS10	TS11	TS12
SiO2	72.90	71.60	71.90	71.60	71.90	71.20	71.80	72.60
Al2O3	15.60	14.90	15.60	15.50	15.50	15.50	15.60	15.80
Fe2O3	1.11	1.12	1.09	1.03	1.25	1.24	1.16	1.26
MgO	0.32	0.40	0.37	0.33	0.41	0.60	0.39	0.35
CaO	1.08	1.67	1.84	2.08	2.23	2.35	1.82	1.70
Na2O	6.00	7.16	6.92	6.41	6.45	6.34	6.88	6.47
K2O	1.23	1.04	0.90	0.97	0.95	0.94	0.93	0.90
TiO2	0.15	0.12	0.13	0.10	0.16	0.14	0.13	0.12
P2O5	0.05	0.04	0.04	0.04	0.04	0.06	0.04	0.04
MnO		0.03					0.02	0.04
Cr2O3								
LOI	1.53	1.80	1.18	1.93	1.12	1.52	1.13	0.73
Total	99.97	99.87	99.97	99.99	100.01	99.89	99.90	100.01

methods). SiO_2 and MgO contents of the samples range from 71.20 to 72.90% wt and from 0.32 to 0.43% wt, respectively. All the samples are sodium-rich in character (Na_2O=5.62 - 7.16 % wt). Potassium contents are in between 0.83 and 1.23% wt. The SiO_2 versus K_2O distribution indicates that it is similar to low-K magma series. Alumina saturation index (ASI) varies from 1.00 to 1.28, implying its peraluminous character.

The Karaköy granite is classified as granite and trondhjemite (Figs 3 and 4). The samples are characterized by significant enrichment in LREE over HREE [$(La/Yb)_N$ = 7.05–14.38] (Fig 5). They exhibit weakly negative and no negative Eu anomalies, resulting the crude or weakly concave MREE patterns (Fig 5). Their $(Eu/Eu^*)_N$ values vary from 0.82 to 1.08.

The Karaköy granite samples display relative enrichment in large ion lithophile elements (LILE) and depletion in high field strength elements (Nb, Ta) together with the positive peaks in Pb and negative anomalies in Ti on the N-Type MORB-normalized multi element diagram (Fig 6).

DISCUSSION AND CONCLUSIONS

N-MORB normalized multi-element patterns for the Karaköy granite samples indicate clearly that they are closely similar to the volcanic arc granites (i.e. Pearce et al., 1984). The significant negative Ta and Nb anomalies, positive peaks in Pb and negative anomalies in Ti are collectively support this conclusion (Fig 6). The samples fall into the volcanic arc granite field (not shown here) on the classical tectonic discrimination plots designed for the granitic rocks (i.e. Rb-Hf-Ta: Harris et al., 1986; Rb vs Y+Nb: Pearce et al., 1984).

Karaköy granites have high Na_2O (5.62-7.16 % wt) and Sr (380-634 ppm), and low MgO (0.32-

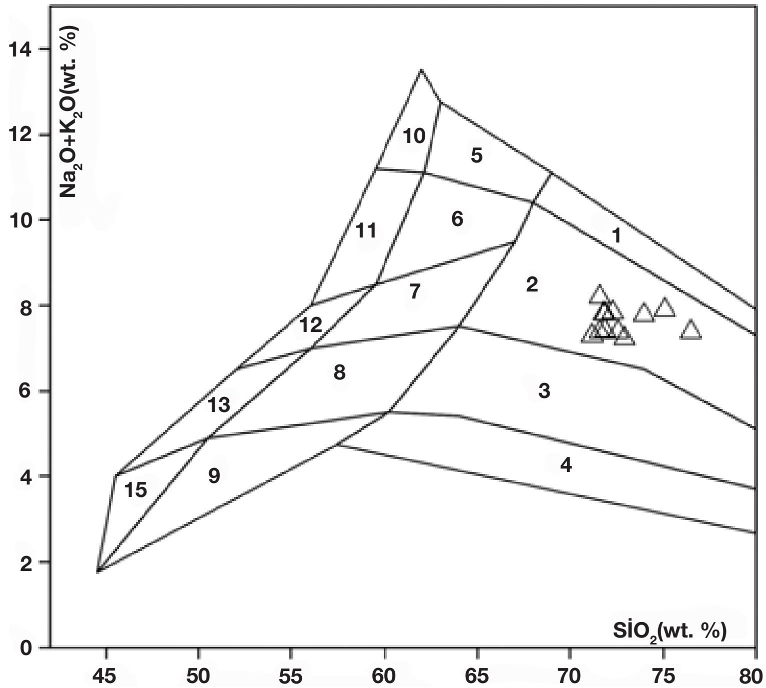


Figure 3. Total alkali-silica variation diagram (Middlemost, 1994) for the Karaköy granite (1: alkali feldspar granite, 2: granite, 3: granodiyorite, 4: tonalite, 5: alkali feldspar quartz syenite, 6: quartz syenite, 7: quartz monzonite, 8: quartz monzodiorite, 9: quartz diorite, 10: alkali feldspar syenite, 11: syenite, 12: monzonite, 13: monzodiorite, 14: diorite/gabbro).

Şekil 3. Karaköy granitinin toplam alkalilere karşı silika diyagramında sınıflandırılması (Middlemost, 1994) (1: alkali feldispat granit, 2: granit, 3: granodiyorit, 4: tonalit, 5: alkali feldspat kuvars siyenit, 6: kuvars siyenit, 7: kuvars monzonit, 8: kuvars monzodiyorit, 9: kuvars diyorit, 10: alkali feldispat siyenit, 11: siyenit, 12: monzonit, 13: monzodiyorit, 14: diyorit/gabro).

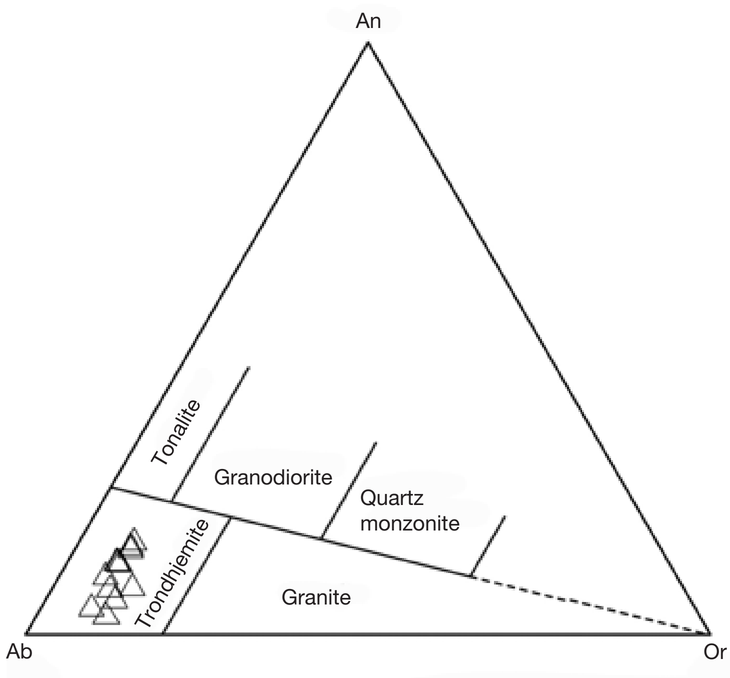


Figure 4. An-Ab-Or classification diagram for the Karaköy granite (O'Connor, 1965).

Şekil 4. Karaköy graniti için An-Ab-Or sınıflama diyagramı (O'Connor, 1965).

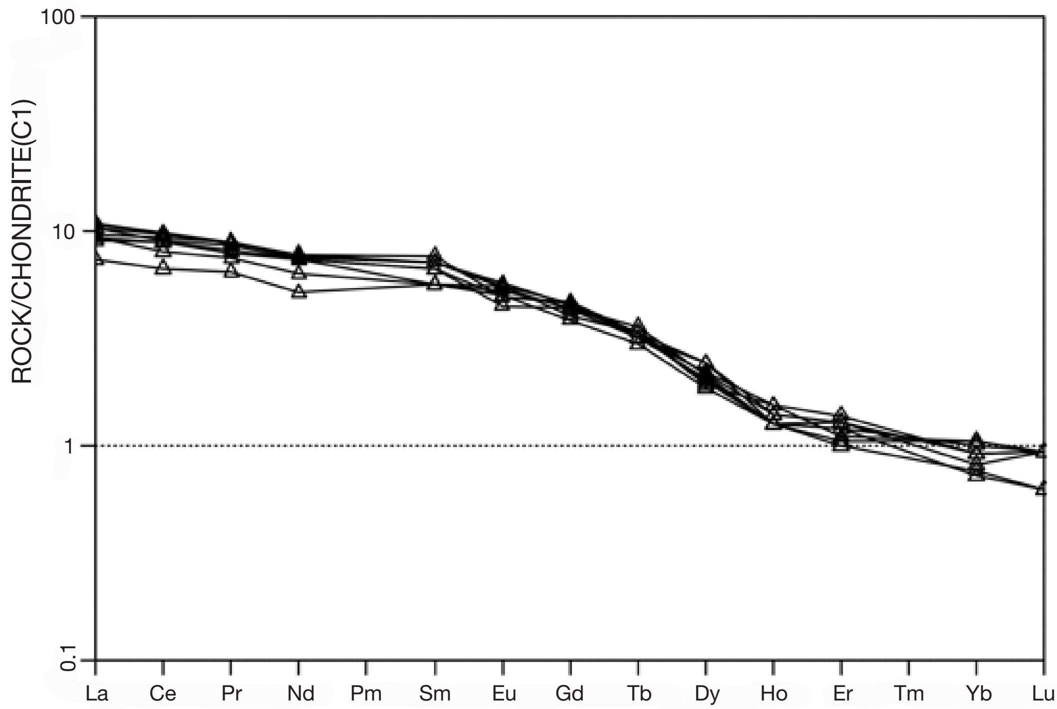


Figure 5. Chondrite-normalized REE distribution diagram for the Karaköy granite (normalizing values are after Boynton, 1984).

Şekil 5. Karaköy granitinin kondrite normalize edilmiş nadir toprak element dağılım diyagramı (normalizasyon değerleri Boynton, 1984'dan alınmıştır).

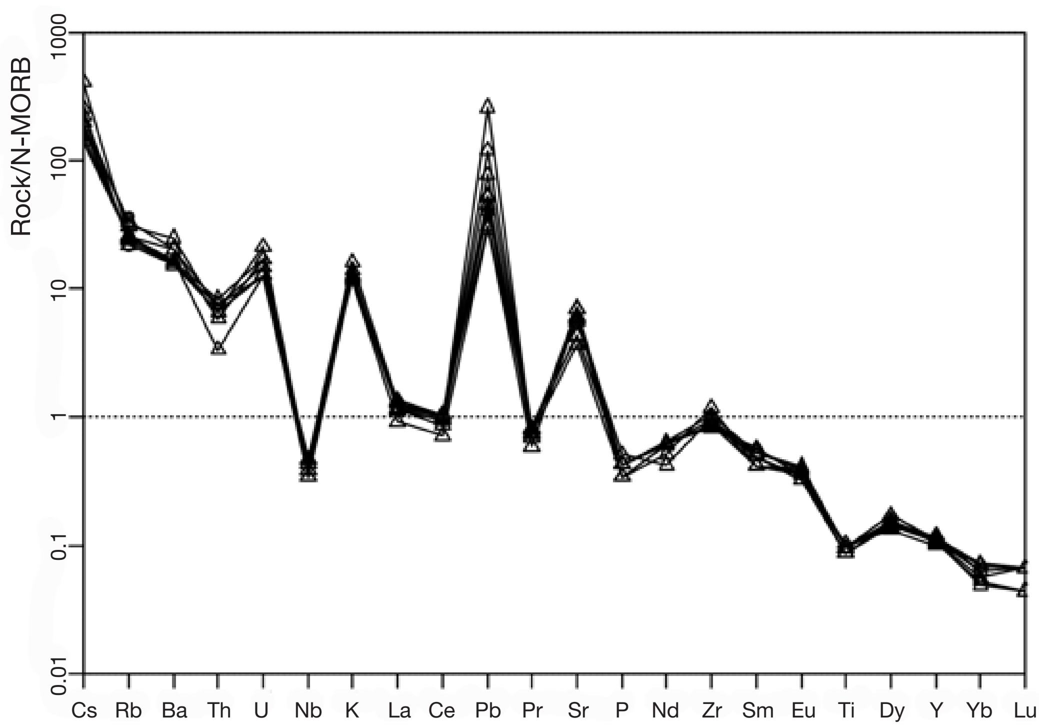


Figure 6. N-MORB normalized multi element variations diagram for the Karaköy granite (normalizing values are after Sun and McDonough, 1989).

Şekil 6. Karaköy granitinin N-MORB'a normalize edilmiş çoklu element dağılım diyagramı (normalizasyon değerleri Sun and McDonough, 1989'dan alınmıştır).

0.6 % wt) and Y (2.8-3.3 ppm) contents. Its high SiO_2 (>56 % wt), Al_2O_3 (> 15 % wt) and low Fe/Mg, La/Yb (10.45-21.33; av. 16.19) and K_2O/Na_2O (~0.15) ratios; lower HFSE contents, and lack of negative Eu anomalies collectively indicate that the Karaköy granites display "Adakite-like (especially high silica adakite, Martin et al., 2005) and/or TTG (Archean Tonalite-Trondhemite-Granite)-like" geochemistry (Defant and Drummond, 1990; Martin, 1999; Martin et al., 2005). Distributions of the samples on the O'Connor (1965) diagram (see Fig 4), and Sr versus Y plot (Fig 7), which is a classical discrimination for adakites (Defant and Drummond, 1990), are also support its Adakitic and TTG affinity. It is further supported by the HREE depletions of the Karaköy granite samples on the chondrite-normalized diagram (see Fig 5), together with its high Sr/Y ratios and low Y and Yb suggesting the garnet retainment in the magma source (Defant and Drummond, 1990; Atherton and Petford, 1993; Rapp and Watson, 1995; Rapp et al., 1999, 2003; Martin, 1999). Additionally, the weak (or crude) concave MREE patterns observed in the Karaköy granite samples are commonly attributed the presence of residual amphibole in the source (e.g. Gromet & Silver, 1987; Wang et al, 2006).

Three major models have been proposed for the origin of adakites and/or TTG's; a) partial melting of the (young and hot) subducted slab (Defant and Drummond, 1990), b) partial melting of the thickened mafic arc crust or melting of delaminated mafic (metabasaltic) lower crust (c.f. Atherton and Petford, 1993, Xu et al., 2002; Martin et al., 2005), c) high pressure differentiation and fractional crystallization (FC), and crustal assimilation and fractional crystallization (AFC) of mantle derive mafic melts (e.g. Castillo et al, 1999; Müntener et al, 2001; Macpherson et al, 2006; Richards and Kerrich, 2007; Gao et al, 2011). The first model fits well to our case. The evidences supporting this idea are as follows: 1) There is no geological and petrological record indicating the arc magmatic suites and thickened arc crust in the NW Anatolia during the Early Cretaceous, 2) there was no crustal thinning caused by the asthenospheric upwelling and related partial melting of the mafic lower crust as indicated by lack of the volcanic rocks with asthenospheric signature (i.e. OIB), 3) Geochemical data do not support the generation via FC. When we compare the data given by Gao et al (in press) for the adakite-like magmas generated by the FC processes of the mafic melts, we propose that our geochemical data is distinctly different. For example, the K2O contents for the Karaköy granites are low and the Na2O is quite high. Our Sr/Y ratios for the Karaköy granites are very high with respect to those of the FC-related adakite-like suites (c.f. Gao et al, in press). Beside these, the Sr/Y ratios of the Karaköy granite range from 113 to 204, unlikely to the FC-related adakite-like rocks (c.f. Gao et al, in press). Whereas the trend of Sr/Y from the typical adakite field to the typical arc region is clear for FC-generated adakite-like rocks, the Sr/Y values are constrained within only "Adakite field" for the Karaköy granite (see Fig 7). Therefore, we propose that "adakite- and/or TTG-like" geochemistry of the Karaköy granite may be indicative for partial melting of uppermost basaltic part (Defant and Drummond, 1990; Rapp 1995; Rapp and Watson, 1995) of a northward subducting oceanic slab during the Early Cretaceous. The subduction polarity is estimated by the areal distribution of the granitic stocks. They form a roughly E-W trend within the metamorphic rocks, which constitutes the basement of the Sakarya Zone, the northern continental margin of the northern branch of Neo-Tethys (Şengör and Yılmaz, 1981).

Although the early Cretaceous is widely known to be a silent period in terms of tectonic activity in NW Turkey (c.f. Şengör and Yılmaz, 1981), some recent data contradict with this view. For example, occurrence of Lower Cretaceous (88 to 108 Ma) blueschists has been reported from Bursa - Eskişehir region (Okay et al., 1998; Okay and Kelley, 1994; Harris et al., 1994). Similarly, some older blueschists (120-65 Ma; Çoğulu and Krummenacher, 1967; Kulaksız and Phillip, 1985) were reported from the eastern part of the Tavşanlı zone. These ages indicating the early Cretaceous (120-108 Ma) may have been disregarded in the tectonic evolution models. Presence of these blueschists together with our coeval adakitic magmatism may be attributed to a subduction zone during the early

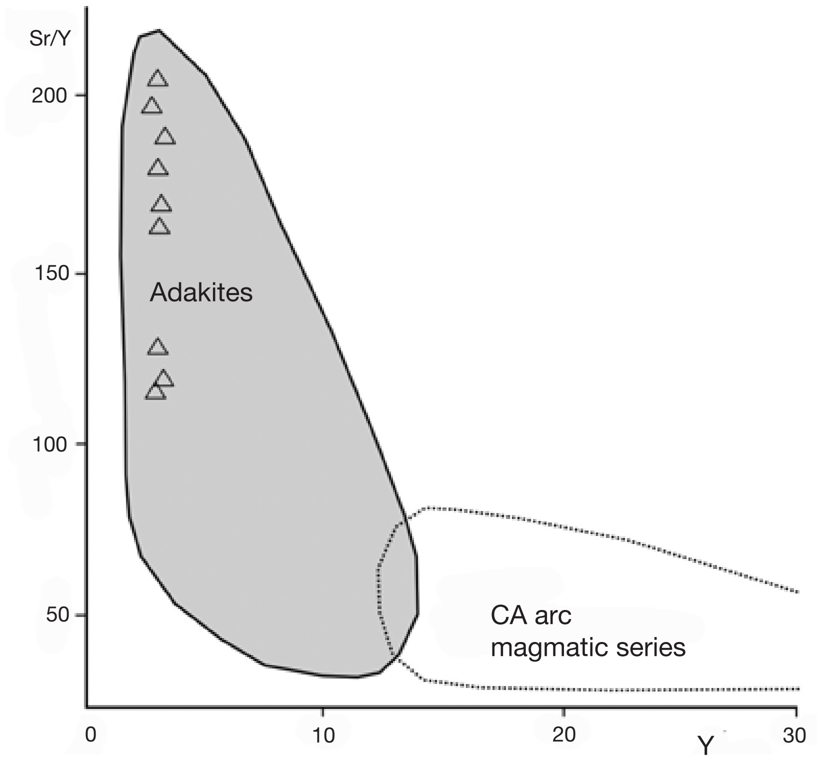


Figure 7. Sr versus Y diagram (Defant and Drummond, 1990) for the Karaköy granite.
Şekil 7. Karaköy graniti için Sr'a karşı Y diyagramı (Defant and Drummond, 1990).

Cretaceous. Okay et al. (1998) had already insinuated to this evolutionary scheme in their study (see their p. 293, Fig 9a).

In the light of our data, we think that this subduction should be started at least 124 Ma, during the Aptian. This result is further supported by the available fossil and radiometric age data. For example, Tüysüz and Tekin (2007) obtained the radiolarian data from the Central part of the İzmir-Ankara-Erzincan suture, indicating the northern branch of the Neo-Tethys Ocean was consumed by northward subduction(s) during the beginning of the Late Valanginian-Early Barremian to Campanian period. Radiometric ages from HP/LT metamorphic rocks of Central Pontides (i.e. eclogite and mica schists of the Domuzdağ complex) vary from 124 ± 9 to 104.3 ± 4.8 Ma (av. 105 Ma; Rb-Sr and Ar-Ar. Okay et al., 2006) are also support the presence of a subduction within the northern Neo-Tethys during the early Cretaceous time (see Fig 14a by Okay et al., 2006).

Tüysüz (1999) found out the early Cretaceous volcanic chain (the Sada volcanic belt; see his Fig 8) that existed in the Intra-Pontide Ocean which was occupied an area between the western Pontides and the Sakarya Zone. More recently Akbayram et al. (2009) have reported from the Armutlu peninsula and its surroundings that the Intra-Pontide Ocean was consumed totally during the Early Cretaceous (138-111 Ma). These geological data document the occurrence of the orogenic events which occurred during the early Cretaceous in the Intra-Pontide Ocean. It indicates clearly that the similar orogenic events were formed simultaneously within the northern Neo-Tethys and Intra-Pontide Ocean.

Considering our findings and the evaluations outlined above; the following conclusions may be drawn;

a) In the northern part of the Bozüyük area, there are some leucogranitic rocks which are early Cretaceous in age, emplaced into the Triassic metamorphic rocks of the Sakarya Zone. They display adakitic and/or TTG-like geochemical affinity.

b) They were derived possibly from the slab-melting events due to the subduction that occurred during the early Cretaceous period within the northern Neo-Tethys Ocean.

c) Lower Cretaceous is the critical period for the geological evolution of the northern Neo-Tethyan oceanic realm in which a northerly subduction was initiated.

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