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Post-Collisional Magmatism on the Northern Margin of the Taurides and its Geological Implications: Geology and Petrology of the Yahyalı-Karamadazı Granitoid

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Abstract: The Karamadazı Granitoid (Yahyalı-Kayseri) is a typical example of bimodal magmatism on the northern margin of the Eastern Tauride belt. The Karamadazı Granitoid intrudes the Palaeozoic-Mesozoic Yahyalı metamorphic rocks and is unconformably overlain by Upper Maastrichtian clastics. It consists of granodiorite-quartz diorite as the main intrusive phase, and includes leucogranites and aplitic dykes in its marginal parts. Samples from the Karamadazı Granitoid are calc-alkaline and calcic in character. The granodiorites are mainly metaluminous, whereas leucogranites and aplites are weakly peraluminous in nature. Plots of major-element oxides against SiO_2 indicate a poor fractionation trend for the granodiorites. The leucogranites represent highly fractionated end-members.

The Karamadazı Granitoid displays I-type characteristics based on geochemical and mineralogical compositions. LIL elements are enriched compared to the HFS elements and spider-diagram patterns are similar to those of upper continental crust rocks. The geochemical data also imply that the Karamadazı Granitoid is composed of two distinct magmas, derived from different sources that have undergone limited differentiation. Whatever the sources were, the magmas have interacted with the upper continental crust. On tectono-magmatic discrimination diagrams, the granodiorites plot in the arc region, while leucogranites plot in the triple-junction of the arc, syn-collisional and within-plate fields and thus can be classified as post-collisional granitoids.

Geochemical comparison of the Karamadazı Granitoid with several H-type post-collisional granitoids from the northern Tauride margin (Horoz Granitoid) and central Anatolia (Yozgat, Ekecikdağ, and Terlemez granitoids) indicates clear similarities among these granitoids. This suggests that the granitoids are comparable not only in age, formation and emplacement processes, but also in the tectonic processes which led to their formation.

Key Words: Karamadazı Granitoid, Geochemistry, Granodiorite, Leucogranite, Eastern Tauride Belt, Central Turkey

Toros Birliklerinin Kuzey Kenarında Çarpışma Sonrası Magmatizma ve Jeolojik Anlamı: Yahyalı-Karamadazı Granitoyidi'nin Jeolojisi ve Petrolojisi

Özet: Kayseri-Yahyalı yöresindeki Karamadazı Granitoyidi, Doğu Toros Kuşağının kuzey kenarında yer alan bimodal magmatizmaya tipik bir örnektir. Granitoyid Paleozoyik-Mezozoyik yaşlı Yahyalı Metamorfitlerini sıcak dokanaklarla keser ve geç Maastriştiyen yaşlı birimlerle uyumsuz olarak örtülür. Granitik kütlede, dokanağa yakın kesimde ana intrüsif fazı oluşturan granodiyorit/kuvars diyorit dış kesimlerde ise aplitik dayklar tarafından kesilmiş lökogranitler yer almaktadır. Karamadazı Granitoyidi'nde jeokimyasal olarak incelenen kayaçların tümü kalk-alkalen karakterde olup kalsik özellikler sunmaktadırlar. Granodiyoritler belirgin olarak metalüminli, granit ve aplitler ise zayıf peralüminlidir. Majör element oksitlerinin SiO_2'ye göre davranışı granodiyoritlerde zayıf bir fraksiyonel kristallenmeye işaret etmektedir. Granitler ise ileri derecede fraksiyonlaşmış uç ürünleri temsil etmektedir.

Karamadazı Granitoyidi kayaçları jeokimyasal ve mineralojik bileşimlerine göre genelde I-tipi özellikler gösterirler. İncelenen örneklerin tümünde LIL elementleri HFS elementlerine göre zenginleşme gösterir ve kayaçların örümcek diyagramlarındaki iz element desenleri, genelde üst kabuk granitoyitlerine benzer. Jeokimyasal verilere göre, Karamadazı sokulumunun farklı kaynaklardan türemiş ve kendi içinde sınırlı olarak ayrımlaşmış iki farklı magmanın ürünlerini içerdiği öne sürülebilir. Kökenleri ne olursa olsun granitoyidi oluşturan magmalar üst kabuk ile yoğun etkileşmişlerdir. Tektono-magmatik ayırtlama diyagramlarında granodiyoritler daha çok yay alanında yer alırken lökogranitler yay-çarpışma-levha içi granit üçlü kesişme noktasında yoğunlaşırlar. Ancak bunların bölgedeki Geç Kretase yaşlı ofiyolitleri kesmeleri, ofiyolit yerleşmesi sonrasında sokulum yaptıklarını, dolayısı ile "çarpışma sonrası granitoyitler" olarak sınıflanabileceklerine işaret etmektedir.

Karamadazı Granitoyidi, Toros kuzey kenarı (Horoz Granitoyidi) ve Orta Anadolu'daki (Yozgat, Ekecikdağ, Terlemez granitoyitleri) bazı H-tipi çarpışma-sonrası granitoyitler ile jeokimyasal özellikleri bakımından karşılaştırıldığında bunların çok belirgin benzerlikler sundukları görülmektedir. Bu benzeşme, sadece granitlerin oluşum ve yerleşim süreçlerinde ve yaşlarında değil aynı zamanda bunların oluşumlarına yol açan tektonik süreçlerde de benzerlikler olduğunu ortaya koymaktadır.

Anahtar Sözcükler: Karamadazı Granitoyidi, Jeokimya, Granodiyorit, Lökogranit, Doğu Toros Kuşağı, Orta Türkiye

Introduction

Interpretation of the geodynamic evolution of central Anatolia during and after the Alpine Orogeny can be achieved through an understanding of the magmatism and conditions of magma genesis in the region. Previous work in central Anatolia was mainly focused on the granitoids in the Central Anatolian Crystalline Complex (CACC, Göncüoğlu *et al.* 1991, 1995-1996), and important conclusions on the Alpine evolution of this region were drawn. Generally accepted tectonic settings suggested in those studies were collisional/post-collisional (Göncüoğlu & Türeli 1994; Akıman *et al.* 1993; Erler & Göncüoğlu 1996; Boztuğ 1998, 2000; Aydın *et al.* 1998; Yalınız *et al.* 1999) and/or magmatic arc (Görür *et al.* 1984; Kadıoğlu & Güleç 1996). However, the investigation of coeval magmatism, origins and tectonic setting of magmatic rocks along the northern margin of the Taurides, and assessment of suggested models for the CACC are necessary in order to evaluate the tectonic evolution of the region as a whole.

Formation of limited granitic rocks along the northern margin of the Taurides has been linked to the evolution of an ocean called the "*Inner Tauride Oceanic Belt*" or "*Intra Tauride*" (Görür *et al.* 1984; Dilek *et al.* 1999). Of these granitoids, the Horoz Granitoid is the only one previously studied in the central Taurides (Çalapkulu 1980; Çevikbaş & Öztunalı 1991; Çevikbaş *et al.* 1995).

The present study aims to determine the petrogenesis and tectonic setting of the Karamadazı Granitoid using geochemical data. Results of this study cannot be used only to elucidate the missing parts in the geodynamic evolution of the area, but also to establish similarities or differences between the magmatism along the northern edge of the Taurides, and also the widespread Late Cretaceous magmatism in central Anatolia.

Therefore, the Karamadazı Granitoid (Figure 1) located about 25 km northwest of the town of Yahyalı (Kayseri) was sampled, and these samples analyzed by XRF in the laboratories of the Washington State University (USA) Department of Geology, and Keele University, School of Earth Sciences and Geography (U.K.).

Field Geology

Previous work in the Karamadazı area was generally concerned with the stratigraphic-tectonic features of the region (Baykal 1944; Okay 1954; Abdüsselamoğlu 1962; Özgül 1976; Göncüoğlu *et al.* 1991). Studies on the Karamadazı granitoid, however, have been concerned mainly with aspects of economic and mining geology (Blumenthal 1941, 1944; Önay 1952; Oygür *et al.* 1978; Oygür 1986; Ulakoğlu 1983; Kuşcu *et al.* 2000). Those studies generally outlined the geological features of skarns around the Karamadazı Granitoid, and described the styles, reserves and grades of iron mineralization in the region. Data on the Karamadazı Granitoid are limited to petrographic observations, and no data are available on the geochemical characteristics, tectonic setting or petrogenesis of the granitoid.

Granitic rocks of the Karamadazı region are located in an area where various rock groups of Palaeozoic-Mesozoic age are exposed. The area was referred to as the "Siyah Aladağ Permo-Carboniferous limestone field" by Blumenthal (1941, 1944), the "Yahyalı Sequence" by Tekeli *et al.* (1981), "Palaeozoic Rocks" by Ulakoğlu (1983), and the "Yahyalı Metamorphics" by Göncüoğlu *et al.* (1991, 1992). According to Göncüoğlu *et al.* (1991, 1992), these rocks are lower grade metamorphic equivalents of Niğde Massif rocks along the southern margin of the CACC.

The area is bounded by strike-slip faults with normal components on the east and west (Ecemiş Fault zone), and by the Kayseri Plain to the north (Figure 1). In previous work (Ulakoğlu 1983), the host rocks were considered to be continuous sequence of Precambrian to

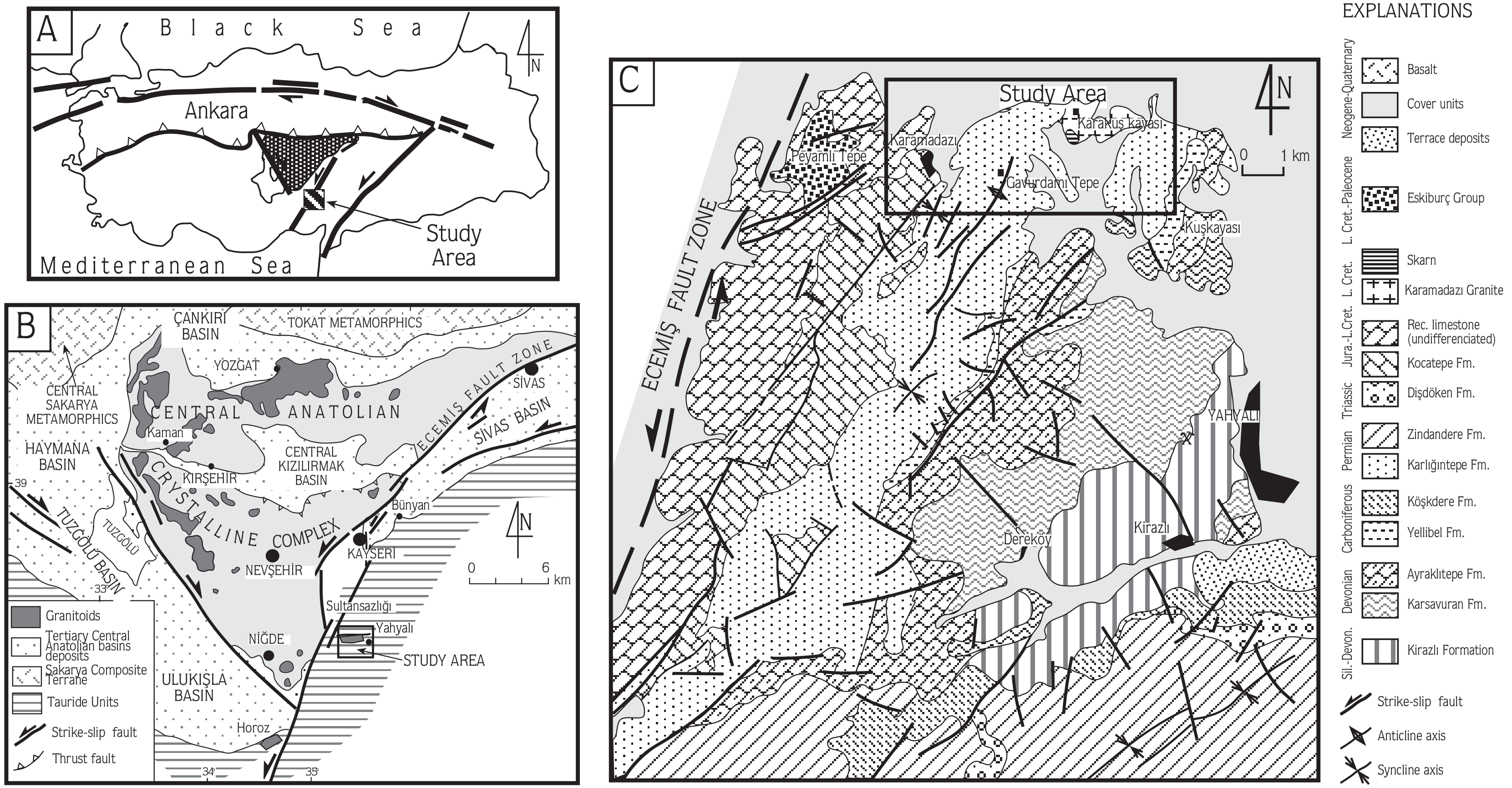

Figure 1. **(a)** Simplified map showing the approximate position of the CACC; **(b)** geological map of the CACC and; **(c)** geological map of the Yahyalı region (simplified from Ayhan & Lengeranlı 1986).

Permian age with several discontinuities. Ulakoğlu (1983) suggested that the basal metamorphic rocks of the area are of Precambrian age, followed by low-grade metamorphic rocks (Karacatepe Formation) of Cambrian age. It has been shown by Göncüoğlu *et al.* (2000) that this part of the succession is equivalent to Silurian siliciclastic rocks of the central Taurides. These rocks are overlain by coral limestones of the Çalmardı Formation (Devonian), Ağcaşar Formation (Carboniferous) and Akbaş Formation (Permian) (Figure 1). These are unconformably overlain by Lower Triassic reddish clastics (Dişdöken Formation, Ayhan & Lengeranlı 1986) and are followed by Middle-Upper Triassic to Lower Cretaceous recrystallized limestones and dolomites. Based on new data, the Yahyalı Metamorphics are Early Palaeozoic-Late Mesozoic in age, and represent a paraautochthonous nappe overlain by an allochthonous peridotite nappe (Tekeli 1980; Göncüoğlu *et al.* 1991).

The stratigraphically lowest observable parts of the region are metamorphosed to greenschist facies (Ayhan & Lengeranlı 1986; Göncüoğlu *et al.* 1991). The uppermost unit in the sequence is the Akbaş Formation (Ulakoğlu 1983), represented by various limestones and ortho-quartzite lenses. These rocks also host well-developed skarn zones. The extent of skarnization and recrystallization associated with metasomatism during granitoid intrusion is particularly observed wherever limestones of the Akbaş Formation are cut by the Karamadazı Granitoid. The contacts between recrystallized limestones, the Akbaş Formation and the Karamadazı Granitoid are usually deformed, and the intensity of deformation increases from south to north. Limestones are intensely folded due to this deformation. Folds are better observed in Jurassic-Lower Cretaceous grey-beige, banded dolomitic limestones. The Karamadazı Granitoid is cut by younger basaltic rocks in the eastern part of the study area.

Granitic rocks also cut the Jurassic-Lower Cretaceous recrystallized and dolomitic limestones to the northwest of Karamadazı Village (Figures 1 & 2). At Peyamlı Tepe, to the southwest of this location, pebbles of the basal conglomerates of the non-metamorphosed upper Maastrichtian sequence are mainly derived from the Karamadazı Granitoid (Göncüoğlu *et al.* 1991). Therefore, it is evident that the emplacement of Karamadazı Granitoid took place during the post-Early Cretaceous–pre-late Maastrichtian period. This obviously confirms that the Karamadazı Granitoid is coeval with magmatism in the CACC.

Karamadazı Granitoid

The felsic-intermediate plutonic rocks cropping out in the area between Karamadazı (Çubuklu) Village to the west and Yularıköy to the east have been termed the "*Karamadazı Granite*" in previous studies (Ulakoğlu 1983). Due to presence of granodioritic/quartz dioritic rocks as well as granites (sensu stricto), following Streckeisen (1976), the unit is here named the "Karamadazı Granitoid". The unit is generally observed as stocks and as conformable bodies along the margins of limestones. Oygür *et al.* (1978) and Oygür (1986) suggested that the granitic rocks are more or less zoned from Yularıköy (to the east) towards Karamadazı Village (to the west) as granite, granodiorite, and quartz diorite. Also, Ağar & Kıtay (1962) mentioned the presence of dioritic rocks from drill holes in an open-pit mine. Such a regional zoning is not confirmed in the field, but the granitoid has been separated into two main units (Figure 2) on the basis of petrographical and geochemical analyses. Petrographical and geochemical analyses have shown that the rocks are mainly aplitic, granitic, granodioritic, or quartz monzonitic in composition. Of these, aplites cut across granite, granodiorite, and quartz monzonites where exposed. However, the more mafic rocks (granodiorites and quartz monzonites) are found in the southern part of the area close to skarns, while leucogranites and aplites (from here on leucogranites) are observed in the outer parts. The monzonitic to dioritic rocks occur mainly as rounded enclaves within the granodiorites, whereas the leucogranites have smaller and fewer enclaves. The enclaves are usually 5 cm to 50 cm in diameter and are cut by later aplite dikes. The enclaves are not altered much compared to the granite and contain about 1-cm-long hornblende crystals.

The northern margin of the Karamadazı Granitoid is bounded by an approximately E–W-trending and steeply dipping (*c.* 70°) normal fault (Figure 2). The downthrown northern part is unconformably overlain by younger sediments of the Kayseri Plain (Figure 2). Karamadazı Granitoid is intensely altered due to faulting in the eastern part (Kuşcu *et al.* 2000) and is cut by aplitic

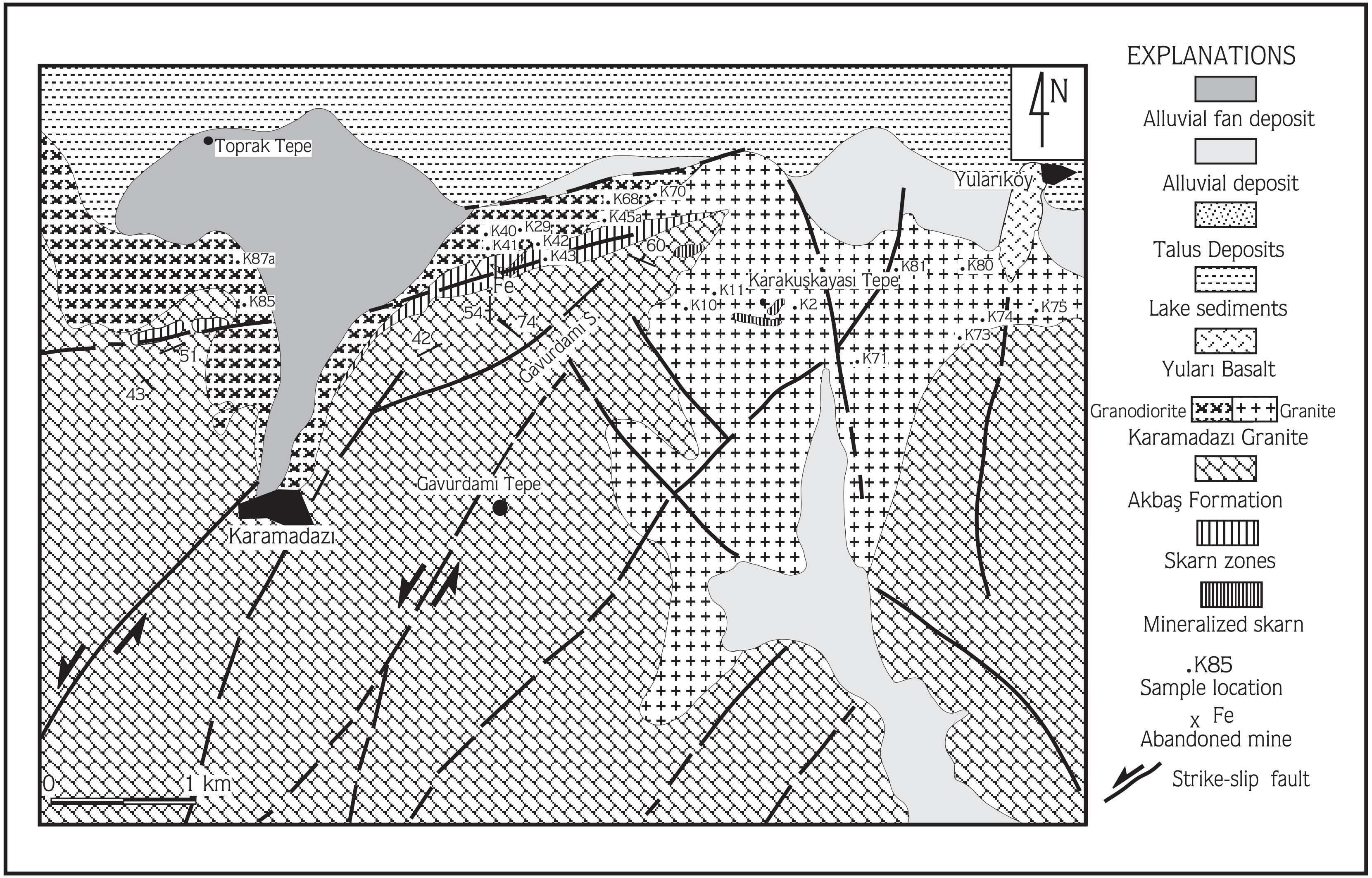

Figure 2. Geological map of the Karamadazı area.

and pegmatitic dykes. Aplite dykes are more common than pegmatitic ones and are observed along two main trends (N40º-50ºW and N50º-60ºW). These dykes are also cut by N-S trending aplitic dykes.

Skarnization processes have caused many mineralogical and textural changes within the original plutonic rocks and have formed endoskarns. Plagioclases and mafic minerals are mainly altered to epidote, and intense silicification is apparent within the skarnized plutonic rocks. Blastomylonitic-porphyroclastic textures as well as cataclastic-granoblastic textures in samples from near the fault zones indicate cataclastic deformation followed by the emplacement of the granitoid.

Leucogranitic rocks mainly consist of K-feldspar, plagioclase, biotite, quartz, and titanite as an accessory mineral. Granodiorites contain hornblende and apatite. Enclaves within the granitoid contain hornblende as a major mafic mineral and secondary epidote. A summary of petrographic characteristics of rock units within Karamadazı Granitoid are given in Table 1, and more detailed petrography was presented by Kuşcu *et al.* (2000).

Geochemistry and Petrogenesis

Nineteen samples from the Karamadazı Granitoid were analyzed for major and trace elements. Seven samples of granodiorite, eleven samples of leucogranite, and one enclave sample were analysed, and the geochemical data for these samples are presented in Table 2.

The mafic components of the Karamadazı Granitoid are presented in Figure 3a (Cox *et al.* 1979), and the majority of these samples plot in the granodiorite-quartz diorite fields. It is evident that the Karamadazı Granitoid comprises two distinct subgroups based on the SiO_2-Zr/TiO_2 diagram of Winchester & Floyd (1977), and samples are classified as granite and granodiorite-diorite (Figure 3b). The mafic microgranular enclave within the granodiorite plots in the diorite field due to its lower silica content.

All samples from the Karamadazı Granitoid are classified as subalkaline on a TAS diagram (Figure 4a) (Irvine & Baragar 1971), and calc-alkaline on an AFM diagram (Figure 4b). The highly differentiated nature of the leucogranites is clearly seen on this diagram.

Molecular A/CNK ($Al_2O_3/CaO+Na_2O+K_2O$) ratios of the samples are generally less than 1.10 except for two samples from the granodiorite subgroup. This ratio varies between 0.76 and 1.20 (Figure 4c). According to these values, the granodiorites are generally metaluminous but some samples are slightly peraluminous. The A/CNK ratio of the leucogranites is around 1.00 and they plot on the metaluminous-peraluminous boundary. The enclave sample plots with granodiorites on this diagram. A/CNK ratios greater than 1.10 are interpreted as alkali leaching and related alteration of mica minerals, while ratios less than 1.10 are related to carbonization of the rocks (Kuşcu *et al.* 2000). The collection and analyses of samples from near the skarn zones reveal the effects of metasomatic processes that facilitated these exchanges

Table 1. Summary of petrographic characteristics of the Karamadazı Granitoid.

Sample No	Mineral Content	Texture	Rock Name
K-71	quartz-K-feldspar (kaolinized)-plagioclase (sericitized)-biotite-titanite	porphyritic	granite
K-74	quartz-K-feldspar-plagioclase-biotite-titanite	porphyritic, myrmekitic	granite
K-80	quartz-K-feldspar-plagioclase-biotite	porphyritic, perthitic	granite
K-81	quartz-K-feldspar-plagioclase-biotite	porphyritic, perthitic	granite
K-40	plagioclase (zoned)-amphibole-biotite-K-feldspar (zoned)-quartz	porphyritic	granodiorite
K-41	plagioclase (sericitized)-amphibole-biotite-K-feldspar (kaolinized, as megacrysts)-quartz	porphyritic-corona	granodiorite
K-44	plagioclase-amphibole-biotite (chloritized)-K-feldspar-quartz-titanite-apatite	porphyritic-corona	granodiorite
K-45	plagioclase-amphibole-biotite-K-feldspar-quartz-titanite-apatite	Equigranular	granodiorite
K-43	quartz-K-feldspar-biotite	equigranular, micrographic-myrmekitic	aplite
K45 (enclave)	plagioclase-amphibole-K-feldspar-quartz-apatite-epidote	equigranular	diorite

Table 2. Representative whole-rock analyses and CIPW norms for the Karamadazı granodiorite (◆), granite (◊), granitoid enclave (●) and aplite dykes (■).

SAMPLE	K29	K40	K41	K87A	K68	K70	K85	K74	K81	K11	K71	K75	K80	K45a	K 2	K10	K42	K43	K73
Symbol	◆	◆	◆	◆	◆	◆	◆	◊	◊	◊	◊	◊	◊	●	■	■	■	■	■
SiO_2	61,89	63,41	62,48	61,09	64,21	64,53	63,99	77,38	77,05	78,04	79,88	77,94	77,59	55,47	77,03	77,82	75,67	76,77	76,68
Al_2O_3	20,25	18,00	17,73	16,73	17,64	16,73	18,28	12,40	12,68	12,48	12,11	12,3	11,98	17,89	12,61	12,20	13,36	12,53	12,63
TiO_2	0,54	0,57	0,62	0,69	0,58	0,57	0,65	0,03	0,08	0,07	0,11	0,09	0,14	1,03	0,08	0,07	0,13	0,10	0,08
FeO	2,03	2,17	2,60	5,34	4,09	2,33	4,69	0,65	0,62	0,28	0,16	0,63	0,93	6,61	0,53	0,43	0,82	0,71	0,95
MnO	0,08	0,07	0,08	0,08	0,08	0,07	0,06	0,02	0,02	0,03	0,01	0,03	0,03	0,1	0,01	0,02	0,01	0,01	0,01
CaO	4,95	6,43	6,62	4,78	3,76	6,19	4,47	0,61	0,65	0,63	0,45	0,66	0,76	3,94	1,02	0,83	1,09	0,68	0,58
MgO	0,73	2,46	2,88	3,43	2,17	2,50	2,81	0,00	0,15	0,00	0,00	0,00	0,07	6,63	0,03	0,00	0,26	0,08	0,05
K_2O	0,14	0,21	0,24	5,33	3,10	0,19	1,25	4,74	4,80	3,74	3,36	3,58	3,36	4,6	4,68	4,27	4,65	5,12	4,97
Na_2O	8,24	5,91	5,81	0,48	3,59	5,87	3,60	3,62	3,66	4,54	4,66	4,72	4,33	1,83	3,45	3,80	3,52	3,36	3,60
P_2O_5	0,20	0,21	0,23	0,22	0,22	0,21	0,24	0,02	0,02	0,01	0,01	0,02	0,04	0,31	0,02	0,01	0,03	0,01	0,01
Total	99,05	99,44	100,76	100,05	99,44	99,19	100,04	99,47	99,73	100,21	100,06	100,25	99,55	99,45	99,46	99,44	99,54	99,37	99,56
Ba	54	166	171	248	530	129	424	82	68	47	76	55	164	543	175	15	170	99	21
Rb	5	4	4	15	117	5	30	194	237	236	210	198	187	53	107	198	142	189	193
Sr	861	1290	1227	783	542	1218	556	49	39	19	22	25	53	876	88	18	183	91	20
Ga	16	16	16	15	16	15	20	11	15	13	13	13	12	17	12	13	14	13	16
Nb	19	16	15	11	19	17	14	12	24	24	17	18	15	23	29	47	21	21	36
Zr	182	171	183	154	189	177	157	68	49	57	56	43	71	160	62	59	66	65	59
Y	12	15	16	14	21	15	18	7	5	8	7	7	7	23	13	15	11	9	9
Th	17	11	10	10	11	14	8	39	20	31	32	41	34	4	34	26	36	39	29
Ni	9	11	14	17	8	11	8	5	4	5	5	7	6	17	4	4	4	4	4
Cr	14	19	28	53	17	25	18	0	3	17	20	20	21	35	0	0	0	1	0
V	32	81	83	108	81	74	104	6	10	11	1	8	9	132	0	3	7	3	2
Cu	6	4	4	15	104	7	4	3	2	0	0	0	0	28	1	4	3	9	1
Pb	0	0	2	2	2	0	2	7	6	5	6	5	6	0	5	7	6	4	8
Zn	9	16	21	70	40	14	27	7	3	14	17	16	23	46	8	4	7	5	5
La	28	16	33	38	35	35	23	23	17	11	1	16	15	36	27	13	48	35	25
Ce	50	55	45	73	61	66	76	21	29	24	0	26	15	59	47	52	63	59	48
Q	1,93	11,63	10,06	9,86	17,27	13,87	21,08	36,57	35,43	37,45	41,20	37,20	39,39	0	36,66	37,63	34,27	35,78	34,84
Or	0,84	1,25	1,43	2,90	18,48	1,14	7,41	28,19	28,47	26,90	27,36	27,93	25,82	11,03	27,84	25,40	27,64	30,48	29,53
Ab	70,45	50,34	49,57	45,99	30,58	50,12	30,49	30,76	31,02	31,67	28,19	30,27	28,63	39,63	29,32	32,30	29,90	28,58	30,56
An	18,04	22,11	21,77	20,70	18,81	18,91	22,23	3,05	3,24	3,13	2,22	3,28	3,80	23,16	5,09	3,60	5,44	3,40	2,89
C	0	0	0	0	1,53	0	2,86	0,19	0,27	0,25	0,70	0,09	0,37	0	0	0,29	0,54	0,21	0,26
Di	5,74	8,14	9,24	2,91	0	9,84	0	0	0	0	0	0	0	8,62	0	0,49	0	0	0
Hy	1,97	5,44	6,72	16,29	12,21	5,03	14,69	1,17	1,42	0,45	0,13	1,06	1,72	12,75	0,94	0,45	1,96	1,37	1,77
Ol	0	0	0	0	0	0	0	0	0	0	0	0	0	2,83	0	0	0	0	0
Il	1,04	1,09	1,19	1,34	1,11	1,09	1,24	0,06	0,16	0,13	0,21	0,17	0,27	1,99	0,15	0,14	0,25	0,19	0,15

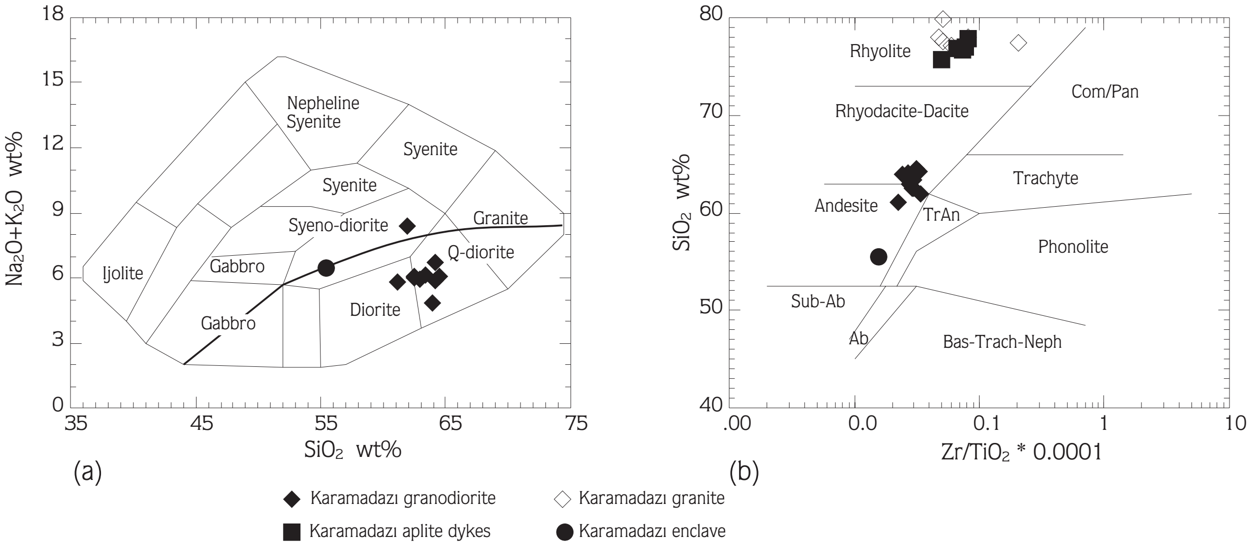

Figure 3. Geochemical discrimination diagrams for Karamadazı Granitoid, enclaves and aplites: **(a)** total alkali-silica (Na_2O+K_2O vs SiO_2) diagram, after Cox *et al.* (1979) and **(b)** SiO_2 vs Zr/TiO_2 discrimination diagram, after Winchester & Floyd (1977).

between the carbonate and plutonic rocks. These effects are also evident from variations of Ca and alkalis on Harker diagrams. According to Peacock (1931) indices (Figure 4d), all samples except the enclave sample plot in the calcic granite field. The presence of two subgroups within the Karamadazı Granitoid is apparent on these diagrams.

Harker-type diagrams and variation diagrams for major and trace elements are employed in order to compare rock units within the Karamadazı Granitoid (Figure 5). The most striking aspect on Harker-type diagrams when employing SiO_2 or relatively immobile Zr as a differentiation index is the presence of two subgroups within the Karamadazı Granitoid. Based on these diagrams, the Karamadazı Granitoid consists of two chemically different intrusive bodies, which are not co-magmatic and not related via fractionation. The first group comprises granodiorites that show limited variation in silica content. However, negative correlation of major elements such as Al_2O_3, MgO, and TiO_2, and positive correlation of some trace elements such as Th, Rb, and Ba against SiO_2, suggest a weak fractionation within this group. Lack of obvious trends of K_2O, Na_2O, and CaO against SiO_2 is probably related to an alteration effect, as mentioned above. Similar conclusions can be drawn for diagrams where Zr is used as the differentiation index (Figure 5). The granodiorites are depleted in Rb, and this depletion is related to the alteration and element mobility in K-feldspars (Table 2).

Leucogranites, the second subgroup of the Karamadazı Granitoid, plot as highly differentiated end members on these diagrams and do not display a within-group fractionation. The absence of compositions intermediate between the granodiorites and leucogranites was not result of a selective sampling strategy.

Based on molar $Al_2O_3/(CaO+Na_2O+K_2O)$ ratios (Figure 4c), Na_2O content (greater than 3.2 % except one sample), high normative diopside and low normative corundum (<1%) (Chappel & White 1974) (Table 2), common mafic microgranular enclaves (MME), and K-feldspar megacryst contents, the Karamadazı Granitoid granodiorites are classified as “hybrid-late orogenic” granitoids (Barbarin 1990). The leucogranites, on the other hand, are similar to highly differentiated granites derived from the upper crust (C-type granites).

The Karamadazı Granitoid subgroups exhibit distinct patterns on ORG-normalized (Pearce *et al.* 1984) spider-diagrams. Both groups generally show enrichment in HFS and LIL elements, positive anomalies in Th and Rb, and a negative anomaly in Ba (Figure 6a). Compared to the granodiorites, the leucogranites are relatively enriched in K and Rb, and depleted in Ba and Zr. The distinct Ba (and partly Ce in granites) anomaly in the Karamadazı samples

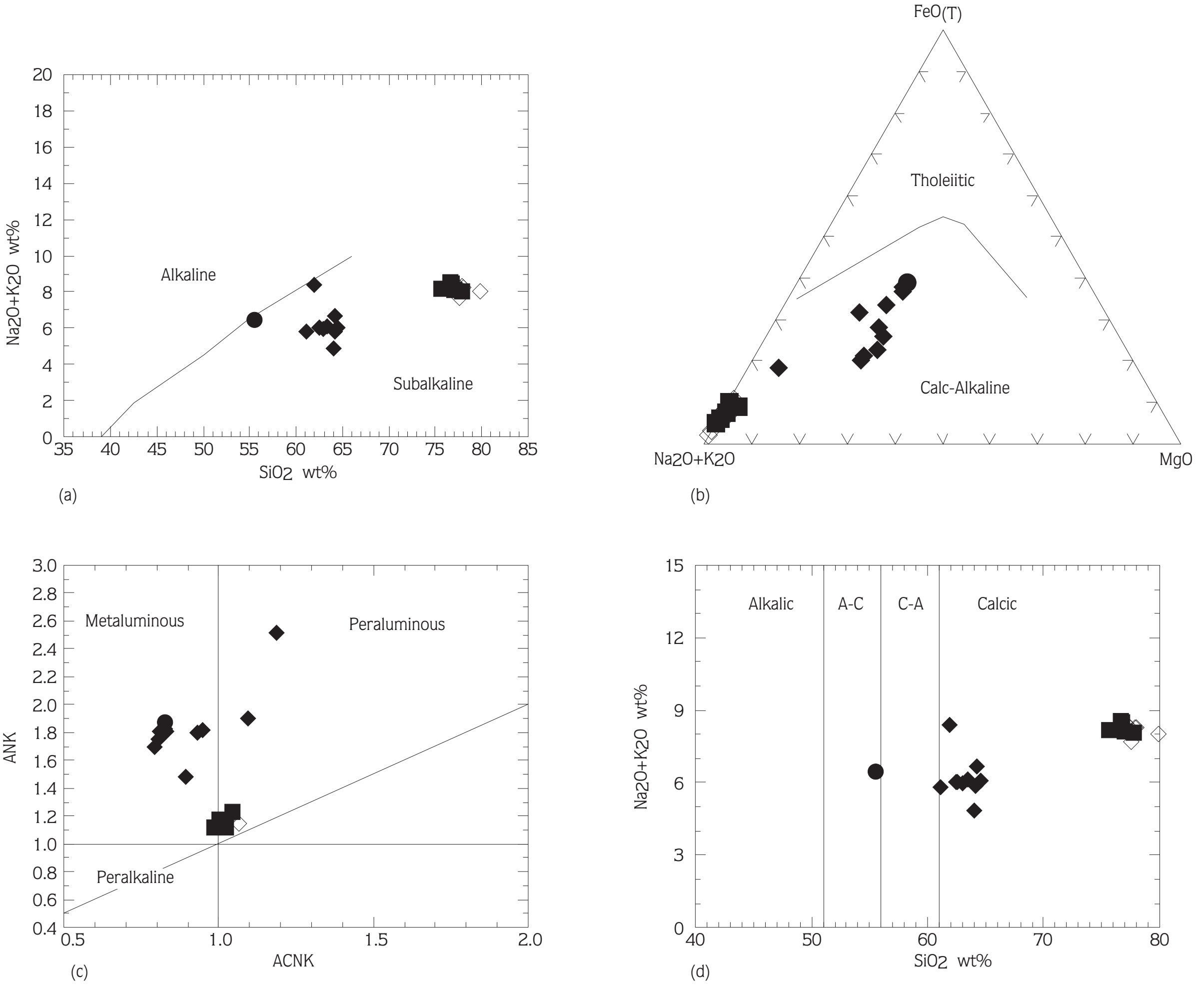

Figure 4. Geochemical discrimination diagrams for Karamadazı Granitoid, enclaves and aplites: **(a)** total alkali-silica and **(b)** Na_2O+K_2O - $FeO_{(T)}$ - MgO (AFM) diagrams, after Irvine & Baragar (1971); **(c)** $Al_2O_3+Na_2O+K_2O$ vs $Al_2O_3+CaO+Na_2O+K_2O$ diagram, after Maniar & Piccoli (1989) and; **(d)** total alkali-silica diagram, after Peacock (1931).

is ascribed to a larger fractionation of K-feldspar and hornblende (the main depositories for Ba and Ce) (Bonin 1990; Rollinson 1994), suggesting lower water pressures and/or shallower emplacement depths. On the other hand, distinct positive Rb and Th anomalies suggest a crustal origin.

Compared to lower and upper crustal values (Figure 6a), both subgroups are quite distinct from the lower crustal patterns. The leucogranites are enriched in LIL elements (except Ba), and depleted in HFS elements relative to upper crust. The granodiorites are depleted in LIL elements compared to the lower crust, while they are similar in terms of HFS elements.

Therefore, regardless of their source area, the Karamadazı granodiorites closely interacted with the upper crust, while the leucogranites were probably derived from the upper crust, and are highly differentiated.

Chemical Discrimination of the Tectonic Environment

Tectono-magmatic discrimination diagrams (Pearce *et al.* 1984) have been used in order to identify the tectonic setting of the Karamadazı Granitoid (Figure 7). These diagrams not only distinguish various tectonic settings for

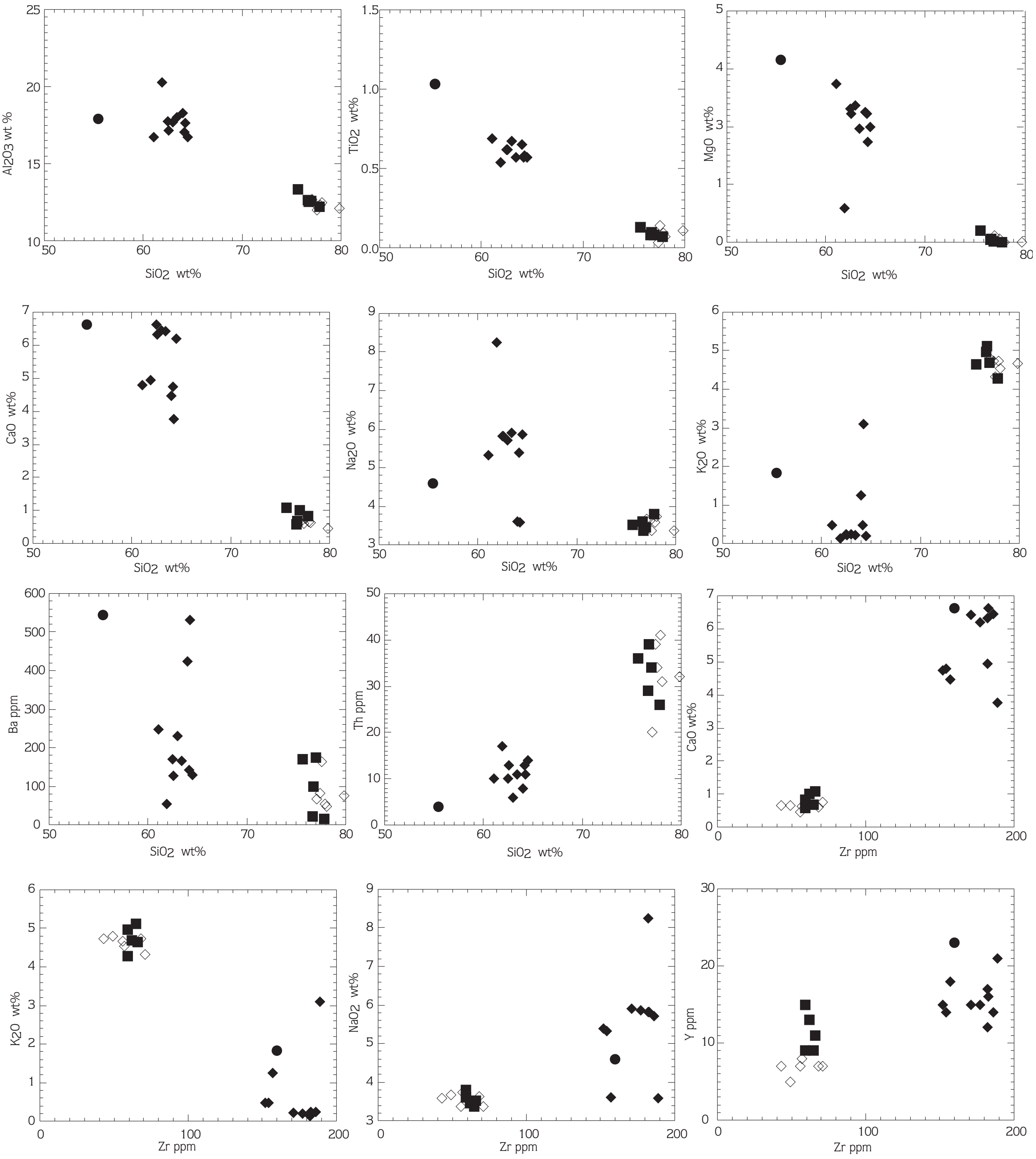

Figure 5. Harker-type diagrams involving SiO_2 and Zr as differentiation indices for classification of the Karamadazı Granitoid, enclaves and aplites.

granitoids, but also reflect operative magmatic processes, and, thus, are widely accepted for use in tectono-magmatic discrimination.

In order to interpret a possible tectonic setting, we first compared the ORG-normalized trace-element distribution of the Karamadazı Granitoid (Figure 6a) with

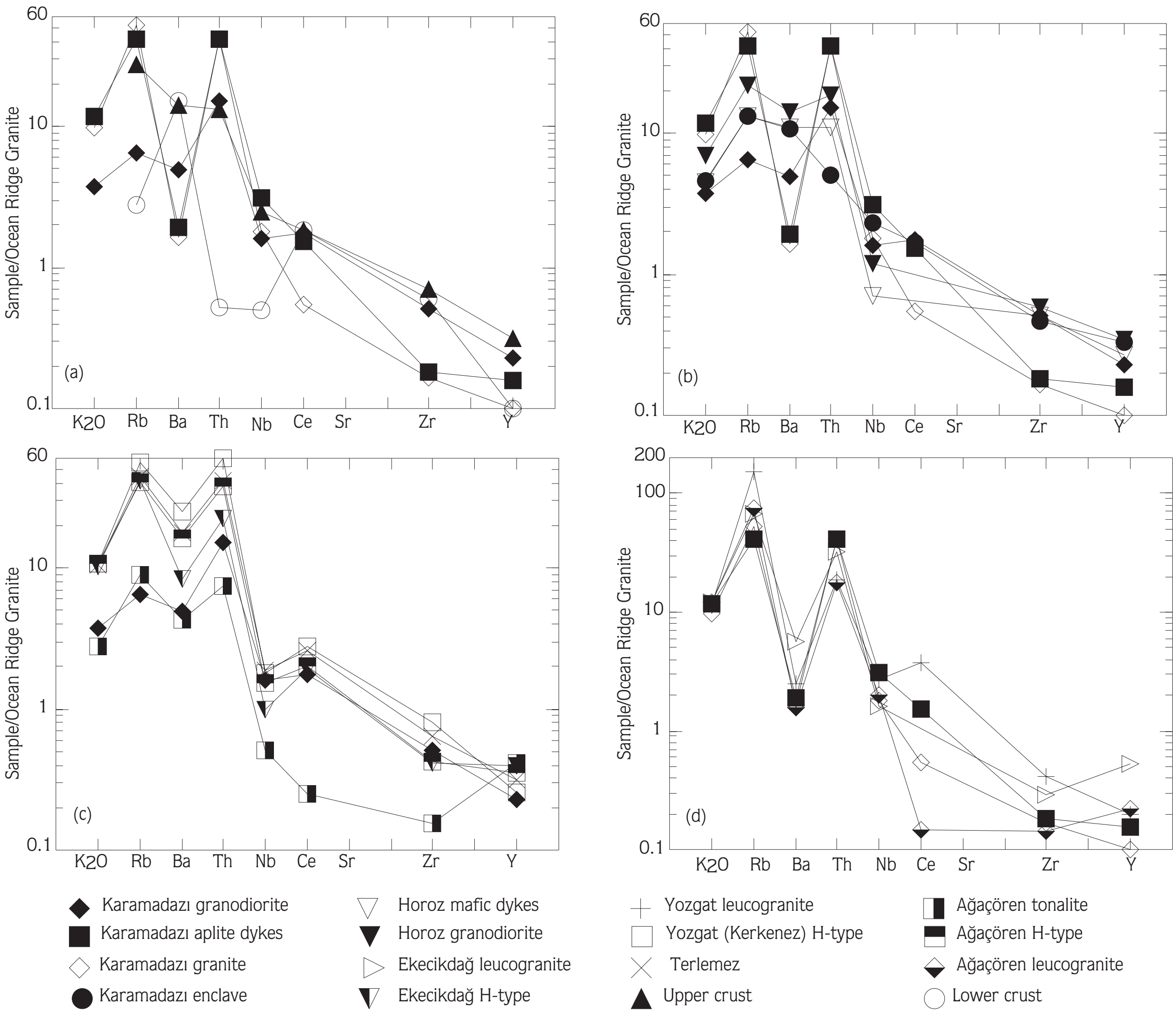

Figure 6. Multi-element diagrams normalized against ocean ridge granite (ORG), after Pearce *et al.* (1984) in comparison to: **(a)** lower and upper crust; **(b)** Horoz Pluton; **(c)** various H-type Central Anatolian Granitoids (CAG) and; **(d)** various CAG leucogranites.

the spider-diagrams of granitic rocks from better-constrained tectonic settings reported in Pearce *et al.* (1984). A close comparison of these easily rules out the possibility of ocean-ridge and within-plate natures for the studied samples (relative enrichment of LIL relative to HFS and depletion in HFS elements, steep Th to Nb slopes). Conversely, subduction-related (VAG-type) and collision-related (syn- and post-COLG types) granitoids display patterns similar to those of the Karamadazı Granitoid, but it is not possible to distinguish between these two main tectonic settings.

To interpret the tectonic setting of the Karamadazı Granitoid, we also plotted our data on trace-element discrimination diagrams (Figure 7). With the exception of sample K-10, the granitoids plot in the VAG+Syn-COLG area of Pearce *et al.* (1984) on the Nb-Y diagram (Figure 7a). This result conforms to the trace-element patterns mentioned above. However, VAG and Syn-COLG cannot be differentiated on this diagram. Thus, our samples were also plotted on the Rb vs (Y+Nb) diagram (Pearce *et al.* 1984) (Figure 7b). All the granodiorite samples plot in the VAG field, while the leucogranites, due to their

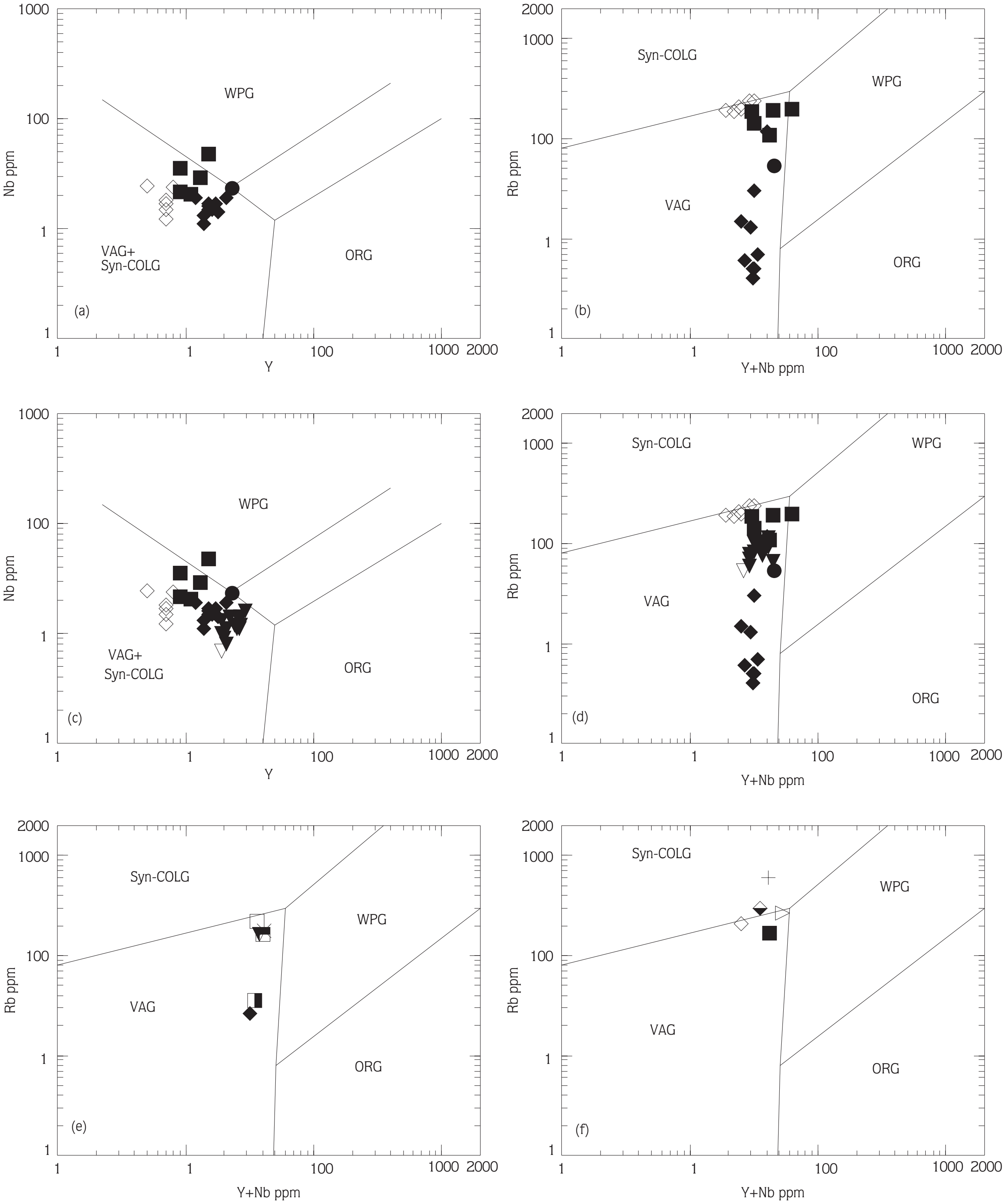

Figure 6. Tectonic discrimination diagrams, after Pearce *et al.* (1984) for **(a-b)** Karamadazı Granitoid; **(c-d)** Karamadazı Granitoid and Horoz Pluton samples; **(d)** Karamadazı and other H-type CAG granitoids and; **(f)** Karamadazı and CAG leucogranites. Symbols as in Figure 6.

higher Rb content, plot around the triple junction of the Syn-COLG, VAG and WPG fields. The VAG signature of the granodiorites might suggest an arc environment. However, Pearce *et al.* (1984) suggested that granites formed in a post-collisional extensional setting may display geochemical characteristics similar to VAG if they are related to calc-alkaline magmas derived from the upper mantle. Moreover, almost fixed values of Y and Nb against Rb can be due to alteration of hornblendes. Therefore, it is questionable to accept a VAG setting based only on the Rb vs Y+Nb diagram. However, during post-collisional uplift and at the roots of the arcs, melting may be initiated in the lower crust and similar products can be obtained via complex melting or mixing, with fractional crystallization processes involved in both. Hence, Pearce (1996) interpreted the granitoids that plot at the WPG–syn-COLG–VAG intersection as post-collisional. Similarly, using and comparing the well-constrained, post-collisional Adamello (Italy), Oman and Chile granitoids with the Dogneca granitoids, Nicolescu & Cornell (1999) interpreted the Fe-skarn Dogneca (Romania) granitoids as post-collisional. Thus, in such cases, regional geological data rather than geochemical diagrams are more reliable, and should be used for tectonic-environment discrimination.

Since the Karamadazı Granitoid cuts across the Upper Cretaceous ophiolites, the granitoids must have intruded after ophiolite emplacement, or after crustal thickening ceased; this is further evidence for a post-collisional origin of the granitoids.

Correlation with the Central Anatolian and Northern Tauride Granitoids

Current studies suggest that the Central Anatolian Granitoids formed from hybrid magmas of mantle origin which were later contaminated by continental crust, therefore having both I- and S-type characteristics (see Aydın *et al.* 1998 for details). The Karamadazı Granitoid and Horoz Pluton in central Taurides, on the other hand, originally formed in the same tectonic setting, then reached their present geographic position due to pos-Eocene left-lateral movement along the Ecemiş Fault. According to Çevikbaş *et al.* (1995), the Horoz Pluton is a hybrid-type granitoid, whereas quartz-monzodioritic mafic dykes and MME represent the mafic component of the physically and chemically mixed magmas; the granodiorites crystallized from the hybrid magma.

Spider diagram patterns of the Karamadazı Granitoid samples are compared to the Horoz Pluton samples in Figure 6b. Dioritic mafic dyke and MME patterns of the Horoz Pluton match the MME sample of the Karamadazı Granitoid, with only some differences in Th and Nb. Therefore, the mafic phase of the hybrid system can be regarded as near-identical for both plutons.

Although spider diagrams of the granodiorites in both plutons reveal similar patterns, the Karamadazı Granitoid is less enriched in LIL elements, implying lower degrees of differentiation. There is no composition in the Horoz Pluton that is equivalent to those of the leucogranites of the Karamadazı Granitoid.

The Karamadazı granodiorite spider patterns are generally comparable to the H-type members of the Ekecikdağ (Türeli *et al.* 1993), Yozgat (Erler & Göncüoğlu 1996), and Ağaçören (Kadıoğlu & Güleç 1996) members of Central Anatolian Granitoids (CAG) (Figure 6c). Although HFS-element abundances and overall patterns are similar, the Karamadazı granodiorites are slightly depleted in LIL elements compared to the H-type CAG. With the exception of the HFS elements, the leucocratic members have comparable spider-diagram patterns (Figure 6d).

In a broader sense, comparable spider diagram patterns of the Karamadazı granodiorites and H-type granitoids in the CAG and the northern margin of the Taurides, and of Karamadazı leucogranites and leucogranites in the CAG suggest a similarity in their petrogenesis.

In order to compare probable tectonic settings of the Karamadazı Granitoid with the northern Tauride margin (Horoz Pluton) and CAG granitoids, trace-element data of these granitoids were plotted on Pearce *et al.* (1984) diagrams (Figures 7c & d). The Karamadazı Granitoid and Horoz Pluton samples plot close to the WPG field and in the VAG+Syn-COLG field. All samples except the Karamadazı granodiorites cluster around the VAG–WPG–syn-COLG triple junction, and therefore can be regarded as post-collisional, as was the Horoz Pluton (Çevikbaş *et al.* 1995).

A comparison of the Karamadazı Granitoid with different intrusive bodies in CAG is given in Figures 7e &

f. Previous geological and geochemical studies of tectonic-environment discrimination in central Anatolia do not indicate a VAG signature (Türeli *et al.* 1993; Akıman *et al.* 1993; Boztuğ *et al.* 1994; Erler & Bayhan 1995; Erler & Göncüoğlu 1996; Aydın *et al.* 1998; Boztuğ 1998, 2000). Those studies indicated two main tectonic settings for the CAG as syn-collisional and post-collisional.

Compared to H-type CAG, the Karamadazı granodiorites plot with the Ağaçören tonalites, and due to lower Rb values, both plutons are classified as VAG (Figure 7e). Low Rb contents are related to alteration and alkali-element mobility, as previously mentioned. These samples would plot close to VAG–Syn-COLG–WPG triple junction if the skarnification and related alteration processes (sericitization) had not acted on the granitoids. Other H-type granitoids in central Anatolia, however, plot at VAG–WPG–syn-COLG triple junction. Both the Karamadazı and the CAG leucogranites cluster around the VAG–WPG–syn-COLG triple junction (Figure 7f). Therefore, they can be classified as post-COLG as proposed by Pearce (1996).

Based on petrological data, it can be concluded that the Karamadazı Granitoid, as a typical member of northern Tauride margin granitoid together with the Horoz Pluton, is genetically comparable to the CAG, and formed in a similar tectonic setting.

Regional Geological Constraints

Granitic magmatism in northern Tauride margin units, including the Karamadazı Granitoid and Horoz Pluton, and some granitoids within the CACC, have been accepted as Late Cretaceous-Middle Eocene arc magmatics on the basis of Oktay's (1982) interpretation without the support of reliable petrological data. This assumption was then adopted in subsequent regional geological models (Görür & Şengör 1986; Görür *et al.* 1984, 1998; Çevikbaş & Öztunalı 1991, 1992; Baş *et al.* 1986, 1992; Whitney & Dilek 1997). Based on that assumption, those authors suggested that a distinct "*Inner Tauride Ocean*" operated between the Central Anatolian Crystalline Complex (Kırşehir Block of Görür *et al.* 1984) and the Menderes-Tauride Platform. Bi-polar subduction of the Inner Tauride oceanic plate gave way to arc plutonism, represented by granitic rocks both to the N (Central Anatolian Crystalline Complex) and S (northern edge of the Menderes-Tauride Platform).

Studies on the petrogenesis of granitic rocks in the region (Göncüoğlu 1986; Göncüoğlu *et al.* 1991; Türeli *et al.* 1993; Göncüoğlu & Türeli 1994; Çevikbaş *et al.* 1995; Kuşcu & Erler 1998; Boztuğ 2000) advocated a collisional–post-collisional character for this Late Cretaceous magmatism in the region.

According to Göncüoğlu *et al.* (1991, 1992) the CACC represents what was the northern part of the Tauride-Anatolide Platform during the Mesozoic times that faced the Neotethyan İzmir-Ankara branch. Closure of this ocean due to the northward subduction of its oceanic lithosphere in the Late Cretaceous caused tectonic emplacement of ophiolite nappes and passive margin units on the passive platform-margin to the south. A piece of platform (the present CACC) was thickened, buried and metamorphosed during this process. S-type syn-collisional granitoids in the CACC formed during this period (Akıman *et al.* 1993; Türeli *et al.* 1993; Erler & Göncüoğlu 1996). The tectonically telescoped Tauride-Anatolide margin experienced a period of rapid exhumation in the Late Cretaceous (Göncüoğlu *et al.* 2000). Melting of the upper mantle and lower crust occurred in response to lithospheric attenuation and rapid uplift. Fractional crystallization and assimilation of I-type and hybrid magmas related to complex fractional mixing and mingling processes, not yet explained thoroughly, produced granitic bodies (defined as CAG) with a wide range of compositions (Aydın *et al.* 1998; Boztuğ 1998; Aydın *et al.* 2001). These granitoids typically cluster in the post-COLG field on tectonic discrimination diagrams. A supra-crustal expression of this Late Cretaceous post-collisional extension event is the development of latest Cretaceous extensional basins in central Anatolia (Göncüoğlu *et al.* 1991, 1993; Dirik *et al.* 1999; Çemen *et al.* 1999). The Ulukışla basin is the most important of these, and separates the CACC and Tauride units (Figure 1).

The Karamadazı Granitoid and Horoz Pluton to the west are located within the Tauride units to the south of the Ulukışla basin. Petrologic characteristics, ages and tectonic settings of these plutons are parallel to those in the CACC as discussed above. Consequently, in the light of aforementioned geologic constraints, granitic magmatism along the northern Tauride margin is considered to be a product of Late Cretaceous extensional regime.

Results

The Karamadazı Granitoid is located to the north of a tectonic unit traditionally known as the Taurides, or as the Menderes-Tauride Platform of Görür *et al.* (1998). It is a composite granitic body and consists of granodioritic and leucogranitic subgroups, which are calc-alkaline in character. Based on the geochemical and petrographic data, the peraluminous leucogranites represent a highly fractionated end-member derived from an upper crustal magma, while the main metaluminous granodioritic part of the pluton is fractionated from a hybrid magma and is post-collisional in character. MME within the granodiorites are thought to represent the mafic component of the hybrid system.

The Karamadazı Granitoid and Horoz Pluton (located just to the west of Karamadazı Granitoid) occur in the same tectonic setting and have near-identical geochemical features. Moreover, the leucogranitic and granodioritic parts of the Karamadazı Granitoid display geochemical features identical to those of the leucogranites and the relatively well studied H-type granitoids (Yozgat, Ekecikdağ, Ağaçören) of the CACC, respectively. Furthermore, the above mentioned granitoids very probably formed in the same tectonic setting as granitoids in other parts of the world (e.g., Adamello, Querigut, Oman and Chile granitoids; Pearce *et al.* 1984) identified as post-COLG on tectonic discrimination diagrams.

In the light of these similarities, we suggest that the granites within the "*Tauride Platform*" units, which supposedly have a distinct geological history (e.g. Görür *et al.* 1998; Dilek *et al.* 1996, 1999), and the CACC units formed during the same Late Cretaceous regional compression and subsequent extension events.

If this suggestion is confirmed with more detailed petrologic data, the absence of oceanic crust between the CACC and Taurides during the Mesozoic, and hence of arc magmatism due to subduction until the Late Cretaceous, will be verified. Such a situation would signify the existence of these units as different parts of the thickened continental-margin system (*Tauride-Anatolide Platform*).

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References

ABDÜLSSELAMOĞLU, Ş. 1962. *Geology of Eastern Taurides between Kayseri-Adana.* General Directorate of Mineral Research and Exploration (MTA) Report No: **3264** [in Turkish, unpublished].

AĞAR, Ü. & KITAY, R. 1962. *Geology and Reserve of the Özkoyuncu Magnetite Occurrence in Kayseri-Yahyalı-Karamadazı Area.* General Directorate of Mineral Research and Exploration (MTA) Report No: **2886** [in Turkish, unpublished].

AKIMAN, O., ERLER, A., GÖNCÜOĞLU, M.C., GÜLEÇ, N., GEVEN, A., TÜRELİ, T.K. & KADIOĞLU, Y.K. 1993. Geochemical characteristics of granitoids along the western margin of the Central Anatolian Crystalline Complex and their tectonic implications. *Geological Journal* **28**, 371-382.

AYDIN, N., GÖNCÜOĞLU, M.C. & ERLER, A. 1998. Latest Cretaceous magmatism in the Central Anatolian Crystalline Complex: brief review of field, petrographic and geochemical features. *Turkish Journal of Earth Sciences* **7**, 259-268.

AYDIN, N., GÖNCÜOĞLU, M.C. & ERLER, A. 2001. A review of magmatism in Central Anatolia during the Mesozoic post-collisional period. *International Geology Review* **44**, 695-710.

AYHAN, A. & LENGERANLI, Y. 1986. Tectonostratigraphic Characteristics of the Area between Yahyalı and Demirkazık (Aladağlar Region). *Jeoloji Mühendisliği* **27**, 31-45 [in Turkish with English abstract].

BARBARIN, B. 1990. Granitoids: main petrogenetic classifications in relation to origin and tectonic setting. *Geological Journal* **25**, 227-238.

BAŞ, H., AYHAN, A. & ATABEY, E. 1986. Some petrologic and geochemical characteristics of the Ulukışla-Çamardı (Niğde) volcanics. *Jeoloji Mühendisliği* **26**, 27-34 [in Turkish with English abstract].

BAŞ, H., POYRAZ, N. & JUNG, D. 1992. Petrography and geochemistry of the Ulukışla-Çamardı magmatics. *Geological Bulletin of Turkey* **35**, 71-89 [in Turkish with English abstract].

BAYKAL, F. 1944. *Geological Characteristics of the Taurides between Malatya and Kayseri.* General Directorate of Mineral Research and Exploration (MTA) Report No: **1703** [in Turkish, unpublished].

BLUMENTHAL, M. 1941. *A General Review of the Geology of the Taurides between Niğde and Adana.* General Directorate of Mineral Research and Exploration (MTA) Publications Vol B. No. **6**, 48 p [in Turkish].

BLUMENTHAL, M. 1944. Permocarboniferous of the Taurides between Kayseri and Malatya. *General Directorate of Mineral Research and Exploration (MTA) Bulletin* **1/31**, 105-118 [in Turkish with English abstract].

BONIN, B. 1990. From orogenic to anorogenic settings: evolution of granitoid suits after a major orogenesis. *Geological Journal* **25**, 261-270.

BOZTUĞ, D. 1998. Post-collisional central Anatolian alkaline plutonism, Turkey. *Turkish Journal of Earth Sciences* **7**, 145-165.

BOZTUĞ, D. 2000. S-I-A-type intrusive associations: geodynamic significance of synchronism between metamorphism and magmatism in central Anatolia, Turkey. *In*: BOZKURT, E., WINCHESTER, J.A. & PIPER, J.D.A. (eds), *Tectonics and Magmatism in Turkey and the Surrounding Area.* Geological Society, London, Special Publications **173**, 407-424.

BOZTUĞ, D., YILMAZ, S. & KESKİN, Y. 1994. Petrochemistry and petrogenesis of the eastern part of the Kösedağ Pluton (Suşehri, NE Sivas) in Central-Eastern Anatolian alkaline province. *Geological Bulletin of Turkey* **37**, 1-14 [in Turkish with English abstract].

ÇALAPKULU, F. 1980. Geologic investigation of Horoz Granodiorite. *Geological Bulletin of Turkey* **23**, 59-69 [in Turkish with English abstract].

ÇEMEN, İ. GÖNCÜOĞLU, M.C. & DIRİK, K. 1999. Structural evolution of the Tuzgölü Basin in central Anatolia, Turkey. *Journal of Geology* **107**, 693-706.

ÇEVİKBAŞ, A. & ÖZTUNALI, Ö. 1991. Mineral deposits of Ulukışla-Çamardı (Niğde) basin. *Jeoloji Mühendisliği* **39**, 22-40 [in Turkish with English abstract].

ÇEVİKBAŞ, A. & ÖZTUNALI, Ö. 1992. Geology of the Ulukışla-Çamardı (Niğde) basin. *General Directorate of Mineral Research and Exploration (MTA) Bulletin* **114**, 155-172 [in Turkish with English abstract].

ÇEVİKBAŞ, A., BOZTUĞ, D., DEMİRKOL, C., YILMAZ, S., AKYILDIZ, M., AÇLAN, M., DEMİR, Ö. & TAŞ, R. 1995. Mineralogical and geochemical evidence for equilibrium hybrid system in the formation of Horoz Pluton (Ulukışla-Niğde). *Geological Bulletin of Turkey* **10**, 62-77 [in Turkish with English abstract].

CHAPPEL, B.W. & WHITE, A.J.R. 1974. Two contrasting granite types: expanded abstract. *Pacific Geology* **8**, 173-174.

COX, K.G., BELL, J.D. & PANKHURST, R.J. 1979. *The Interpretation of Igneous Rocks*. George Allen and Unwin, London.

DILEK, Y., HACKER, B.R. & MILLER, J.S. 1996. Structure and geochronology of the Inner-Tauride Belt, south-central Turkey, and its tectonic evolution. *Geological Society America Abstracts* **28**, A369.

DILEK, Y., WHITNEY, D.L. & TEKELİ, O. 1999. Links between tectonic processes and landscape morphology in an Alpine collision zone, South-Central Turkey. *Zeitschrift für Geomorphologie N.F.* **118**, 147-164.

DIRİK, K., GÖNCÜOĞLU, M.C. & KOZLU, H. 1999. Stratigraphy and pre-Miocene tectonic evolution of the southwestern part of the Sivas Basin, Central Anatolia, Turkey. *Geological Journal* **34**, 303-319.

ERLER, A. & BAYHAN, H. 1995. Problems and a general evaluation of central Anatolian granitoids. *Hacettepe University, Earth Sciences* **17**, 49-67 [in Turkish with English abstract].

ERLER, A. & GÖNCÜOĞLU, M.C. 1996. Geologic and tectonic setting of the Yozgat Batholith, northern Central Anatolian Crystalline Complex, Turkey. *International Geology Review* **38**, 714-726.

GÖNCÜOĞLU, M.C. 1986. Geochronologic age data from the southern part of the Central Anatolian Massif. *General Directorate of Mineral Research and Exploration (MTA) Bulletin* **105/106**, 111-124 [in Turkish with English abstract].

GÖNCÜOĞLU, M.C. & TÜRELİ, K. 1994. Alpine collisional-type granitoids from western Central Anatolian Crystalline Complex, Turkey. *Journal of the Kocaeli University, Earth Sciences Section* **1**, 39-46.

GÖNCÜOĞLU, M.C., DIRİK, K. & KOZLU, H. 1995-1996. Characteristics of pre-Alpine and Alpine Terranes in Turkey: Explanatory notes to the terrane map of Turkey: *Annales Geologique de Pays Hellenique* **37**, 515-536.

GÖNCÜOĞLU, M.C., TOPRAK, V., KUŞCU, İ., ERLER, A. & OLGUN, E. 1991. *Geology of the Western part of the Central Anatolian Massif, Part 1: Southern Part.* Turkish Petroleum Corporation (TPAO) Project Report No. **2909** [in Turkish, unpublished].

GÖNCÜOĞLU, M.C., ERLER, A., TOPRAK, V., YALINIZ, K., OLGUN, E. & ROJAY, B. 1992. *Geology of the Western Part of Central Anatolian Massif, Part 2: Central Region.* Turkish Petroleum Corporation (TPAO) Project Report No. **3155** [in Turkish, unpublished].

GÖNCÜOĞLU, M.C., ERLER, A., TOPRAK, G.M.V., OLGUN, E., YALINIZ K., KUŞCU, İ., KÖKSAL S. & DIRİK, K. 1993. *Geology of the Central Part of Central Anatolian Massif, Part 3: Geologic Evolution of the Tertiary Central Kızılırmak Basin.* Turkish Petroleum Corporation (TPAO) Project Report No. **3313** [in Turkish, unpublished].

GÖNCÜOĞLU, M.C., TEKELİ, O. & ÇEMEN, İ. 2000. Exhumation of Niğde Massif, southern Central Anatolian Crystalline Complex. *International Earth Science Colloquim on the Agean Region, 25-29 September 2000, Dokuz Eylül University, İzmir, Turkey, Abstracts,* p. 141.

GÖRÜR, N. & ŞENGÖR, A.M.C. 1986. *Geology of the Central Anatolian Basins along the Geotravers Region.* Türkiye 1. Jeotravers Projesi, Workshop. TÜBİTAK, TBAG-Temel Bilimler, 36 p [in Turkish with English abstract].

GÖRÜR, N., OKTAY, F., SEYMEN, İ. & ŞENGÖR, A.M.C. 1984. Paleotectonic evolution of the Tuzgölü basin complex, central Turkey: sedimentary record of a Neo-Tethyan closure *In*: DIXON, J.E. & ROBERTSON, A.H.F. (eds), *The Geological Evolution of the Eastern Mediterranean.* Geological Society, London, Special Publications **17**, 467-482.

GÖRÜR, N., TÜYSÜZ, O. & ŞENGÖR, A.M.C. 1998. Tectonic evolution of the Central Anatolian basins. *International Geology Review* 40, 831-850.

IRVINE, I.C. & BARAGAR, W.R.A. 1971. A guide to chemical classification of the common volcanic rocks. *Canadian Journal of Earth Sciences* 8, 523-548.

KADIOĞLU, Y. K. & GÜLEÇ, N. 1996. Mafic microgranular enclaves and interaction between felsic and mafic magmas in the Ağaçören Intrusive Suite: evidence for petrographic features and mineral chemistry. *International Geological Review* 38, 854-867.

KUŞCU, İ. & ERLER, A. 1998. Mineralizations in a collisional related setting: Central Anatolian Crystalline Complex, Turkey. *International Geology Review* 40, 552-565.

KUŞCU, İ., GENÇALIOĞLU-KUŞCU, G., GÖNCÜOĞLU, M.C. & MEINERT, L.D. 2000. *Orta Anadolu Kristalen Karmaşığı'nda Yeralan Granitoyidler ve Skarn Yataklarının Kökensel Birlikteliklerinin Magmatik Petrojenez ile İlişkilendirilmesi.* TÜBİTAK Project NO: YDABÇAG-198Y098, 146 p [in Turkish, unpublished].

MANIAR, P. D. & PICCOLI, P.M. 1989. Tectonic discrimination of granitoids. *Geological Society of America Bulletin* 101, 635-643.

NICOLESCU, Ş.T. & CORNELL, D.H. 1999. P-T conditions during skarn formation in the Ocna de Fier ore district, Romania. *Mineralium Deposita* 34, 730-742.

OKAY, A.C. 1954. *Geology of the Region Between Kayseri, Niğde and Tuzgölü.* General Directorate of Mineral Research and Exploration (MTA) Report No. 2252 [in Turkish, unpublished].

OKTAY, F.Y. 1982. Stratigraphy and geologic evolution of the Ulukışla and its surroundings. *Geological Bulletin of Turkey* 25, 15-23 [in Turkish with English abstract].

OYGÜR, V. 1986. Geology and formation of the Karamadazı (Yahyalı-Kayseri) contact metasomatic magnetite deposit. *Jeoloji Mühendisliği* 27, 1-9 [in Turkish with English abstract].

OYGÜR, V., YURT, M.Z., YURT, F. & SARI, İ. 1978. *Geological Report on the Kayseri-Yahyalı-Karamadazı and Kovalı Iron-ore Deposits.* General Directorate of Mineral Research and Exploration (MTA) Report No: 6609 [in Turkish, unpublished].

ÖNAY, T.Ş. 1952. *Report on Mining Geology of the Magnetite Deposit Belonging to Mustafa Koyuncu in Kayseri-Develi-Yahyalı.* General Directorate of Mineral Research and Exploration (MTA) Report No: 1984 [in Turkish, unpublished].

ÖZGÜL, N. 1976. *Some basic aspects of the Taurides. Geological Bulletin of Turkey* 19, 65-78 [in Turkish with English abstract].

PEACOCK, M.A. 1931. Classification of igneous rock series. *Journal of Geology* 39, 54-67.

PEARCE, J.A. 1996. Sources and settings of granitic rocks. *Episodes* 19, 120-125.

PEARCE, J.A., HARRIS, N.B.W. & TINDLE, A.G. 1984. Trace-element discrimination diagrams for the tectonic interpretation of granitic rocks. *Journal of Petrology* 25, 956-983.

ROLLINSON, H. 1994. *Using Geochemical Data: Evaluation, Presentation, Interpretation.* Longman Scientific and Technical, New York.

STRECKEISEN, A. 1976. To each plutonic rock its proper name. *Earth Science Reviews* 12, 1-33.

TEKELI, O. 1980. Structural evolution of the Aladağlar in Taurides. *Geological Bulletin of Turkey* 23, 11-14 [in Turkish with English abstract].

TEKELİ, O., AKSAYA, A., EVREN, İ., IŞIK, A. & ÜRGÜN, B.M. 1981. *Taurides Ophiolite Projects-Aladağ Project Report.* General Directorate of Mineral Research and Exploration (MTA) Report No: 6976 [in Turkish, unpublished].

TÜRELİ, T.K., GÖNCÜOĞLU, M.C. & AKIMAN, O. 1993. Petrology and genesis of the Ekecikdağ Granitoid (western part of Central Anatolian Crystalline Complex). *General Directorate of Mineral Research and Exploration (MTA) Bulletin* 115, 15-28 [in Turkish with English abstract].

ULAKOĞLU, S. 1983. Geology of the Karamadazı Granitoid and its surroundings. *Jeoloji Mühendisliği* 17, 69-78 [in Turkish with English abstract].

WINCHESTER, J.A. & FLOYD, P.A. 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. *Chemical Geology* 20, 325-343.

WHITNEY, D.L. & DILEK, Y. 1997. Core complex development in central Anatolia. *Geology* 25, 1023-1026.

YALINIZ, M.K., AYDIN, N.S., GÖNCÜOĞLU, M.C. & PARLAK, O. 1999. Terlemez quartz monzonite of Central Anatolia (Aksaray-Sarıkaraman): age, petrogenesis and geotectonic implications for ophiolite emplacement. *Geological Journal* 34, 233-242.

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