Tr. J. of Earth Sciences
6 (1997) 65-76
© TÜBİTAK

Post-Collisional A-Type Magmatism in the Central Anatolian Crystalline Complex: Petrology of the İdiş Dağı Intrusives (Avanos, Turkey)

M. Cemal GÖNCÜOĞLU
ODTÜ Jeoloji Mühendisliği Bölümü, Ankara-TURKEY
Serhat KÖKSAL
İller Bankası Genel Müdürlüğü, Ankara-TURKEY
P. A. FLOYD
Department of Earth Sciences, Keele University, Staffordshire, ST5 5BG, U.K.

Received: 17 / 12 / 1996; accepted: 9 / 7 / 1997

Abstract: The İdiş Dağı Igneous Complex (IIC) is one of the late-stage plutonic bodies within the Central Anatolian Crystalline Complex (CACC) which intrudes the Paleozoic-Mesozoic metamorphic basement and late Cretaceous granitoids. Uppermost Cretaceous (?)-Lower Paleocene olistostromal volcaniclastic rocks represent the oldest cover on the IIC.

Petrographic and geochemical data indicate that the IIC mainly comprises quartz syenite with well-defined alkaline and peralkaline oversaturated trends. The analyzed samples show humped patterns on chondrite- and ORG-normalized spidergrams with peaks at Rb, Th, and Ce, and also negative Nb anomalies. These features are similar to patterns considered typical of post-collisional A_2 -type granitoids produced by crustal anatexis. A post-collision setting is also suggested by the distribution of data over different fields in chemically-based tectonic discrimination diagrams employing Nb, Y and Rb. These characteristics are consistent with geochemical data from other CACC granitoids and the regional geology.

The late-orogenic plutonic rocks of the CACC (granites and syenites) represent the melt products of continental crust during post-collisional uplift. This event followed crustal thickening that was related to the southward emplacement of ophiolitic nappes during the closure of the İzmir-Ankara-Erzincan Ocean.

Orta Anadolu Kristalen Kompleksinde Çarpışma Sonrası A-Tipi Magmatizma: İdiş Dağı Sokulumunun Petrolojisi (Avanos, Turkey)

Özet: Paleozoyik-Mezozoyik metamorfik temele ve Geç Kretase granitoyidlerine sokulum yapan İdiş Dağı Magmatik Kompleksi (İMK), Orta Anadolu Kristalen Kompleksi (OAKK)'ndeki geç-evre plutonitlerinden biridir. En Üst Kretase (?)-Alt Paleosen olistostromal volkaniklastik kayaçlar İMK üzerindeki en yaşlı örtüyü temsil eder.

Petrografik ve jeokimyasal veriler İMK'nin genelde belirgin alkalen ve aşırı doygun peralkalen trende sahip kuvars siyenitleri içerdiğini göstermektedir. Kimyasal analizi yapılan örnekler, kondirit ve okyanus sırtı granitoyidleriyle normalize edilmiş örümcek diyagramlarında Rb, Th, Ce'da pozitif Nb'da negatif anomaliye sahip inişli çıkışlı bir şekil göstermiştir. Bu özellikler kıtasal ergimeyle oluşan çarpışma sonrası A_2 -tipi granitoyidlerinin tipik şekillerine benzemektedir. Çarpışma sonrası oluşum, verilerin, Nb, Y ve Rb elementlerini içeren değişik kimyasal temelli tektonik ayrım grafiklerindeki değişik alanlara dağılımıyla da desteklenmektedir. Bu özellikler diğer OAKK granitoyidlerinin verileriyle uyumludur.

OAKK'nin geç-orojenik plutonik kayaçları (granitler ve syenitler) çarpışma sonu yükselim sırasında kıtasal kabuğun ergime ürünlerini temsil eder. Bu olay, İzmir-Ankara-Erzincan Okyanusu'nun kapanışı sırasında ofiyolit naplarının güneye doğru yerleşimiyle bağlantılı olan kıtasal kalınlaşmayı takip etmiştir.

Introduction

In spite of copious geological work in Central Anatolia, there are still problematic features in our understanding of the geological evolution of plutonic rocks in this and surrounding regions. The present research is aimed towards gaining and understanding of the geological and petrological characteristics of the syenitic intrusives of the İdiş Dağı-Avanos area, as we consider this to be one of the key regions of Central Anatolia (Figure 1).

Previous work relating to the syenitic rocks in the Central Anatolian Crystalline Complex (CACC; Göncüoğlu et al., 1991) is limited and mainly restricted to the petrography and/or major element geochemistry (Aydın, 1985; Lünel, 1985; Lünel and Akıman, 1986; Bayhan and Tolluoğlu, 1987; Tolluoğlu 1993; Akıman and Boztuğ, 1993). More detailed petrogenetic work by Özkan (1987), who studied the alkaline rocks in the Hayriye (Kayseri) area, suggested that the Atdere foid syenite may have formed by partial melting of the residue after the formation of I-type granitoids. In a complementary work, Özkan and Erkan (1994) suggested that the foid syenite probably derived from an originally undersaturated and potassic melt which then fractionated towards a Na-rich sodalite-nepheline syenitic composition. According to Bayhan (1987), however, the Cefalıkdağ and Baranedağ plutons around Kaman (Kırşehir) can be differentiated into subalkaline and alkaline groups of cafemic associations showing meta-aluminous characteristics. The alkaline rocks are of synitic composition and resemble A-type granitoids, formed by differential partial melting of a source that includes both crust and mantle material. Bayhan (1988), on the other hand, noticed that the syenitoids in the Bayındır-Akpınar area to the northeast of Kaman were formed from different magmas derived from different source materials, and were not fractionated from a single parent magma. Göncüoğlu et al. (1993a), in discussing the geodynamic setting of Central Anatolian Plutonics, suggested that late-stage alkaline magmatism in CACC (which is mainly represented by syenitoids) should be interpreted as post-collisional and related to thermal relaxation and extension of the thickened crust.

The age of the plutonic rocks in the CACC is another important issue that is in contention. Ayan (1963) made the first geochronological study in the CACC and proposed that the age of intrusion of Ba-

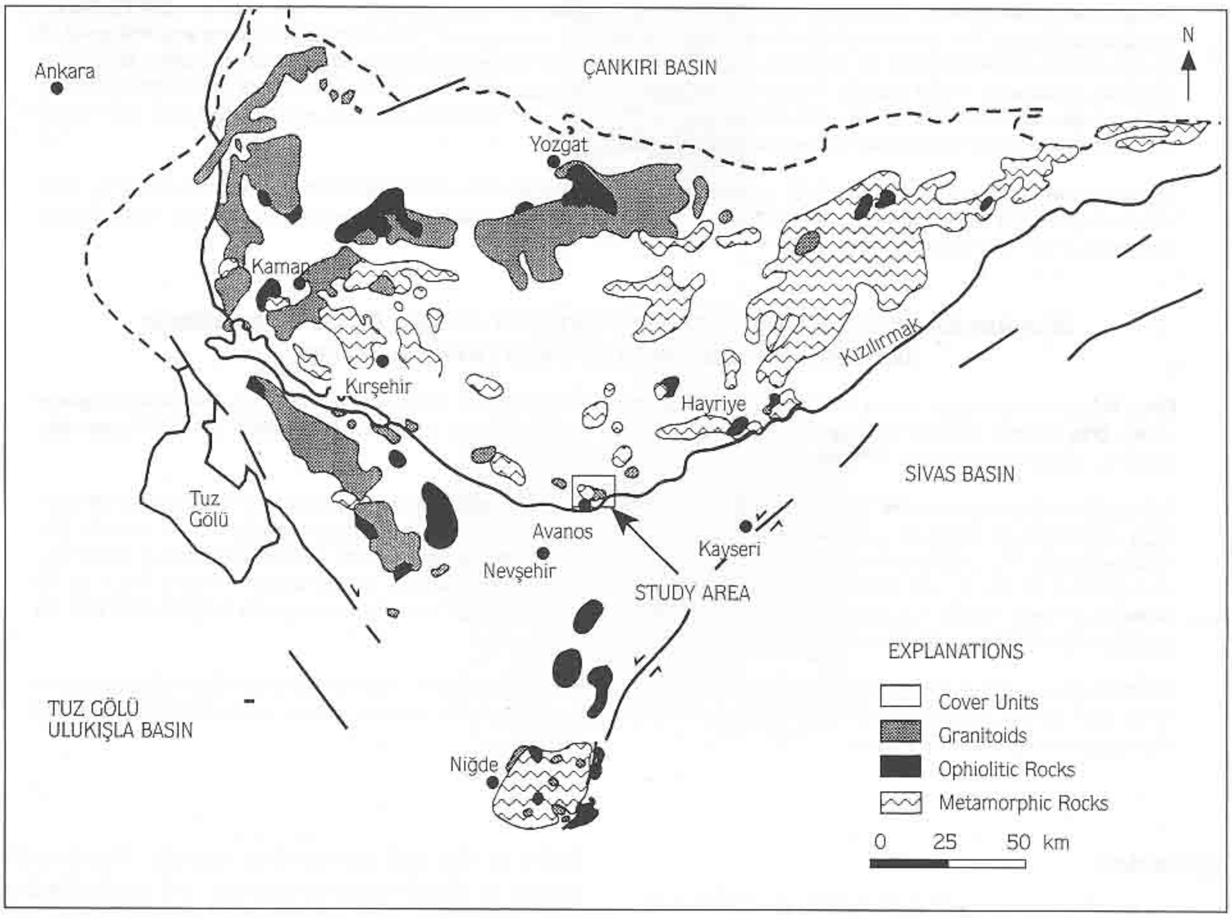

Figure 1. Generalized geological map of the Central Anatolian Crystalline Complex and the location of Idiş Dağı Igneous Complex.

ranedağ monzonitic granite was 54 Ma (total Pb method). Later, Ataman (1972) calculated a 71 ± 1 Ma isochron age for the Cefalıkdağ granitic rocks (Rb/Sr method). This age was assumed by Erkan and Ataman (1981), who used K/Ar mineral dating method and obtained similar ages (69-74Ma), to be an intrusion/cooling age for these intrusive rocks. Göncüoğlu (1986), using both Rb/Sr and K/Ar methods, determined the crystallization age of the Üçkapılı Granitoid to be 95 ± 11 Ma, with a cooling age of 77.8 ± 1.2 Ma. Kuruç (1990) calculated an isochron age of 85.1 ± 3.6 Ma (Rb/Sr whole rock method) for syenitic rocks in the Kaman region, whereas Güleç (1994) obtained an intrusion age of the Ağaçören granitoid of 110 ± 14 Ma (Rb/Sr method).

The above short review of previous work clearly shows that there is not yet a consensus on the petrogenesis, age and geodynamic interpretation of the syenitic intrusives of Central Anatolia. It is further evident that the spatial and temporal relationship of the syenitic rocks around Kırşehir (Lünel, 1985; Lünel and Akıman, 1986; Bayhan, 1987, 1988; Bayhan and Tolluoğlu, 1987; Erler et al., 1991; Tolluoğlu, 1993), Nevşehir (Aydın, 1985), Kayseri (Özkan, 1987; Özkan and Erkan, 1994) and to some extent in sivas (Boztuğ et al., 1994) and Niğde (Çevikbaş et al., 1995) have not been investigated sufficiently to determine if their apparently varying characters can be genetically related or not.

To overcome some of these shortcomings the present work has mainly focused on the geological and geochemical properties of the syenitic rocks from the central part of the CACC (Figure 1).

Regional Geological Setting

The study area is located in the central part of the CACC (Figures 1 and 2) which represents (together with the Menderes Massif in the west) the metamorphosed and telescoped northern passive margin of the Tauride-Anatolide Platform facing the Izmir-Ankara-Erzincan (IAE) branch of the Alpide northern Neotethys ocean. The CACC displays typical features of a collisional belt formed during the closure of the IAE (Göncüoğlu et al., 1991) and is essentially composed of three main units: (a) Central Anatolian Metamorphics (comprising the Gümüşler, Kaleboynu and Aşığediği Metamorphics; Göncüoğlu, 1977, Göncüoğlu et al., 1991), over which are thrust (b) the Central Anatolian Ophiolites: both of which are intruded by (c) the Central Anatolian Granitoids (Akıman et al., 1993). The IIC of this study is one of the plutonic complexes, composed of granitic and syenitic rocks, that con-

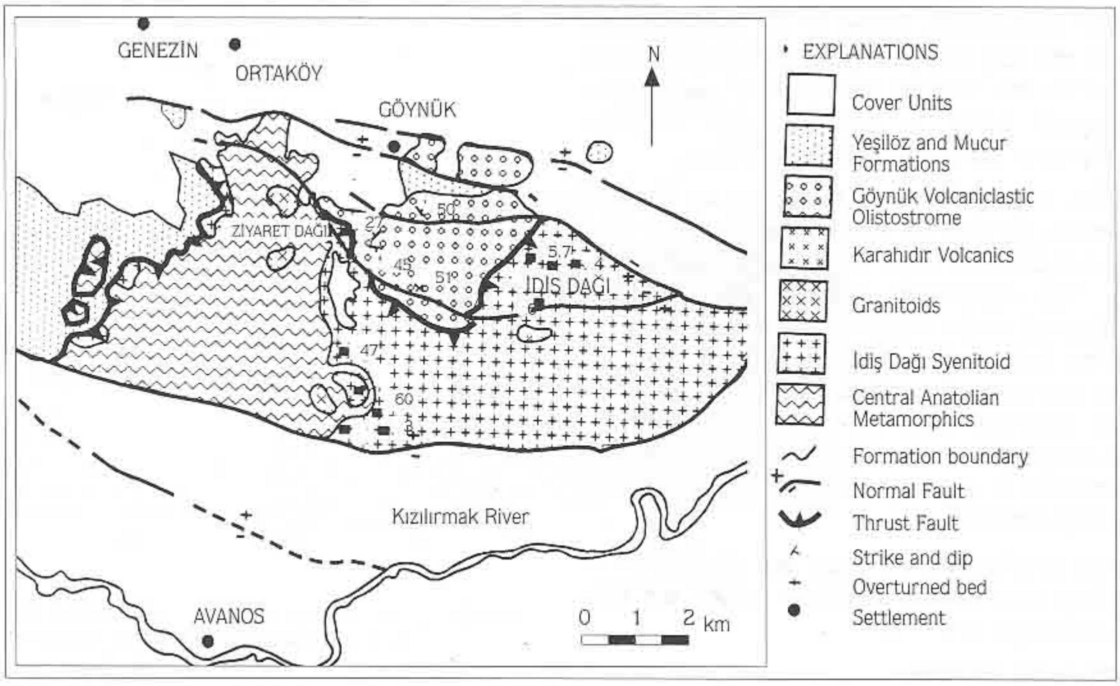

Figure 2. Simplified geological map of the İdiş Dağı-Avanos area (modified after Köksal, 1996).

stitute an important portion of the Central Anatolian Granitoid suite.

Atabey et al. (1988) and Atabey (1989), who mapped the area around Avanos, stated that the granitic rocks in the area consist of granite, granite porphyry, quartz porphyry, granodiorite, granodiorite porphyry, quartz diorite, quartz diorite porphyry, monzonite porphyry, microgranodiorite porphyry, leucogranite, syenite porphyry and rhyodacite. Detailed work on the regional geology and geological evolution was performed by Göncüoğlu et al. (1993a).

Geology of the İdiş Dağı Syenitoid

In the İdiş Dağı area, plutonic rocks of IIC containing a little quartz are minerologically defined as syenitoids. They form pat of the basement units in the study area, together with the Aşıgediği Metamorphics and the granitoids. The İdiş Dağı Syenitoid (Göncüoğlu et al, 1993a) is a large stock which forms Ötedikme Hill and the eastern and western parts of Ziyaret Hill. Dykes of the İdiş Dağı Syenitoid intrude the adjacent Aşıgediği Metamorphics (Figure 2) which are also seen as roof pendants in the syenite body. The İdiş Dağı Syenitoid is unconformably covered by the Göynük volcaniclastic olistostrome unit (uppermost Cretaceous-Lower Paleocene age, Köksal, 1996; Köksal and Göncüoğlu, in print) which contains olistoliths of the syenitoids, as well as Paleocene-Eocene Sediments (Yeşilöz and Mucur Formations). Dykes of the Karahıdır Volcanics cut the İdiş Dağı Syenitoid and occur as olistoliths within the Göynük volcaniclastic olistostrome. The youngest rocks in the area are Miocene-Quaternary cover series of clastic sediments.

The İdiş Dağı Syenitoid is faulted at its northern and southern margins, as well as being cut by local faults and mylonitized zones in the eastern part of the complex. The relationship between the granitoids, mainly observed in the western part of the study area and the İdiş Dağı Syenitoid could not be observed, and no aplitic and pegmatitic dykes cutting the syenitoids were not observed. Since the granitoids intrude the Mesozoic Aşığediği Metamorphics they must be at least late Cretaceous in age; a similar age is inferred for the İdiş Dağı Syenitoid.

Detailed stratigraphy, structure and geodynamic of the İdiş Dağı area is given in Köksal (1996) and Köksal and Göncüoğlu (in print).

Petrographic Features

The İdiş Dağı Syenitoid is generally yellowish-pink in color, commonly showing large tabular crystals of alkali feldspar (up to 3 cm) with lesser amounts of a finer-grained matrix of quartz, plagioclase and biotite. The body is considerably altered throughout, with argillization and chloritization being well-developed, but especially so at the contacts with the metamorphic pendants and country rocks.

Petrographically, the İdiş Dağı Syenitoid is composed of a quartz syenite and an alkali feldspar-rich syenite (Figure 3), although these two lithologies are cannot be easily differentiated during mapping in the field. The quartz syenite is the dominant type in the study area, whereas the alkali feldspar-rich type becomes more abundant in the eastern and northernparts of the body. The syenites are generally medium- to fine-grained with a dominant phaneritic fabric, although a porphyritic texture is also common. Grain sizes of the porphyritic type range from 1-3 mm, although some megarcrysts can have a maximum dimension of 20 mm. Disregarding the minor differences in modal mineralogy of the two subtypes, the İdiş Dağı Syenitoid is generally composed of alkali feldspar, quartz, plagioclase and amphibole, with minor amounts of biotite, muscovite and pyroxene (Table 1). Accessory mineralsinclude sphene, zircon, apatite and opaque phases, and latestage secondary minerals such as epidote, chlorite and calcite.

K-feldspar is the dominant mineral in the İdiş Dağı Syenitoid, exceeding 50 value % in some samples. It

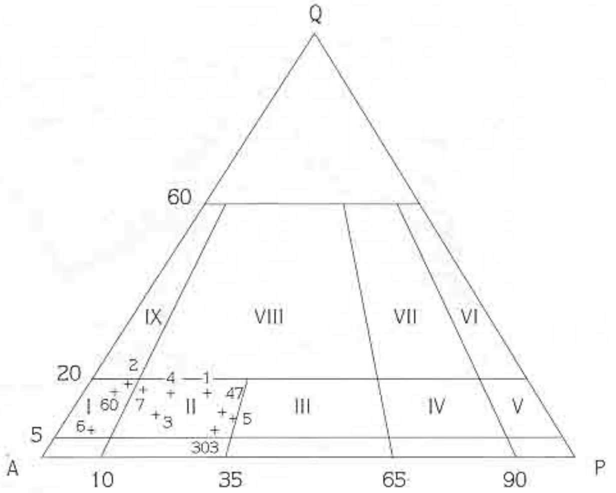

Figure 3. The classification of İdiş Dağı Syenitoid in modal QAP ternary plot of Streckeisen (1976). I-Alkali feldspar quartz syenite, II- Quartz syenite, III- Quartz monzonite, IV-Quartz monzodiorite, V- Quartz diorite, VI- Tonalite, VII-Granodiorite, VIII- Granite, IX- Alkali feldspar granite, (+) İdiş Dağı Syenitoid.

Table 1. Modal composition of the İdiş Dağı Syenitoids

Sample No. Rock type	SK-1 Quartz syenite	SK-2 Alkali Fsp.Q. syenite	SK-3 Quartz syenite	SK-4 Quartz syenite	SK-5 Quartz syenite	SK-6 Alkali Fsp.Q. syenite	SK-) Quartz syenite	SK-47 Quartz syenite	SK-60 Alkali Fsp.Q. syenite	SK-303 Quartz syenite
Minertals (modal %)										
Quartz	10	13	9	15	7	5	12	6	12	5
Plagioclase	15	5	13	15	24	5	7	17	4	23
Orthoclase	36	56	55	59	44	73	52	35	46	51
Microcline	4	-	8	5	3	-	-	-	14	-
Amphibole	23	13	3	-	11	-	-	19	-	-
Clinopyroxene	-	-	8	-	4	-	-	16	-	-
Biotite	6	7	-	-	3	-	5	2	14	-
Muscovite	-	2	-	-	-	-	-	-	-	0.5
Sphene	2	3	-	2	1.5	-	1.5	2.5	-	-
Apatite	-	-	-	-	-	0.5	-	-	-	-
Zircon	1	-	0.5	-	0.5	0.5	0.5	0.5	-	0.5
Orthite	-	-	1	-	-	-	-	-	-	-
Epidote	-	-	-	3	-	4	15	-	-	-
Chlorite	1	-	-	-	-	-	2	1	6	16
Calcite	-	-	-	-	-	-	-	-	3	2
Opaque	2	1	2.5	1	2	12	5	1	1	2
Calculated parameters (%)										
Q	15.4	17.6	10.6	16.0	9.0	6.0	16.9	10.3	15.8	6.3
A	61.5	75.6	74.1	68.0	60.2	88.0	73.2	60.4	78.9	64.6
P	23.1	6.8	15.3	16.0	30.8	6.0	9.9	29.3	5.3	29.1

mainly occurs as euhedral to subhedral orthoclase phenocrysts with Carlsbad twinning, and rarely as microcline. Perthitic texture with thin exsolution lamellae arranged at right angles to the twin planes is very common, especially in the larger crystals. Poikilitic texture is formed by the inclusion of plagioclase, quartz and rarely biotite, and sphene, apatite and zircon in K-feldspar phenocrysts. Plagioclase inclusions parallel the long axes of the K-feldspar phenocrysts. Graphic intergrowths of quartz and orthoclase are seen in some samples.

Plagioclase is generally present in minor amounts and its composition ranges from An10 - An33. In a few samples, however, it may exceed 20 volume %. Plagioclases are euhedral to subhedral and exhibit typical polysynthetic twinning. Oscillatory concentric zoning observed in some samples, is accompanied by multiple twinning. Sphene and zircon occur as inclusions in some plagioclases.

Quartz is found in lesser amounts (<15 volue %) than the feldspars. It occurs as interlocking fine grains and in larger anhedral crystals. Undulatory extinction is very common together with numerous inclusions of zircon and sphene.

Amphibole is found but not restricted in samples near the contact with host marbles. Generally euhedral amphiboles display a light to dark green pleochroism, although brownish green varities with light green rims are also observed. Most of the large amphiboles appear to be primary and have a replacement relationship with any preserved pyroxene, although some of the pale varieties are later and may have formed during deuteric alteration.

Clinopyroxene is present in a few samples and occurs as subhedral prismatic pale green crystals of diopsidic composition (oblique extinction of about 38°). Biotite occurs as small subhedral flakes displaying greenish to brown pleochroism: the colour scheme being a consequence of partial chloritisation. Muscovite is found in minor amounts as short flaky crystals mainly associated with K-feldspars and is invarialy an alteration product.

Sphene, in association with opaque minerals, is the main accessory mineral and occurs as euhedral inclusions in all the major phases. Both clear and metamict varieties of zircon, another important accessory, occur as small euhedral inclusions in quartz and in the feldspar. Apatite is not as abundant as zircon, ut is again enclosed in K-feldspars. Opaque minerals are mainly in contact with sphene and pyroxene, occurring as small subhedral crystals, but may also be found in amphibole and biotite. Small anhedral epidote-group mineral generally occur associated with K-feldspar and quartz. Light to dark brown pleochroic orthite is scare, whereas greenish or reddish-yellow pistacite may be a common interstitial mineral in dykes from the eastern part of the syenite body.

Chemical Data and Discrimination of Tectonic Environment

Geochemical analyses were carried out on 7 fresh, representative samples from the İdiş Dağı Syenitoid; the data are presented in Table 2. The samples were analyzed by X-ray fluorescence spectrometry (ARL 8420 spectrometer) in the Department of Earth sciences, Keele University, and calibrated against both international and internal Keele standards of appropriate composition. Details on methods, accuracy and precision are given in Floyd and Castillo (1992).

Table 2. Whole rock geochemistry of syenitoid samples from İdiş Dağı

Sample no.	SK-1	SK-2	SK-3	SK-4	SK-5	SK-6	SK-7
Major oxides (wt.%)							
SiO2	64.00	65.35	65.25	67.38	66.34	62.25	64.91
TiO2	0.56	0.39	0.49	0.25	0.43	0.44	0.44
Al2O3	15.47	17.61	16.40	17.31	16.53	17.12	15.79
Fe2O3*	3.88	2.63	3.72	1.70	2.93	3.53	3.48
MnO	0.04	0.05	0.07	0.02	0.03	0.05	0.07
MgO	1.36	0.95	0.75	0.04	0.75	0.08	0.80
CaO	4.30	2.87	4.29	1.14	3.48	1.72	2.37
Na2O	3.02	4.78	4.13	5.32	3.77	3.04	3.82
K2O	4.28	4.40	4.68	6.00	4.82	8.87	5.31
P2O5	0.12	0.09	0.09	0.09	0.14	0.13	0.09
LOI	3.33	0.74	0.32	0.66	0.64	2.41	2.70
Total	100.36	99.86	100.19	99.91	99.86	99.64	99.78
Trace elements (ppm)							
Ba	903	1370	1180	991	1424	2933	1130
Ce	66	56	94	157	85	183	129
Cl	462	448	178	121	508	470	221
Cr	16	21	15	12	11	8	15
Cu	5	4	6	2	5	42	3
Ga	17	19	20	23	19	21	18
La	39	30	43	101	43	83	64
Nb	16	11	20	20	14	36	19
Nd	30	18	42	37	23	55	41
Ni	3	1	2	1	2	2	3
Pb	48	44	43	58	32	30	63
Rb	153	146	179	262	159	259	198
S	82	69	237	60	60	93	66
Sr	679	1249	997	592	826	847	650
Th	28	14	30	62	30	61	40
V	67	40	45	27	38	55	35
Y	22	17	31	13	17	25	27
Zn	40	44	46	37	28	49	57
Zr	209	240	284	343	235	331	281

Chemical Classification

On the basis of their SiO_2 contents, the samples range from intermediate to acid types (62-67 wt. % SiO_2) and are generally characterized by high K_2O contents and K_2O/Na_2O ratios varying between 1 and 3. In common with other quartz syenites they display high large-ion-lithophile (LIL) contents, especially in terms of Ba, Sr, Rb, Th, and the light REE. Zr contents are moderate for intermediate/acid rocks (ranging from about 200-350 ppm), whereas the Nb/Y ratio is high (>0.7) and typical of alkaline suites.

In term of classification, the chemical data generally supports their characterization as syenites based on modal proportions (Table 1), even allowing for some mobility of the major oxides due to mild alteration. Based on the total alkalies-silica classification diagram for volcanic rocks (Le Bas et al., 1986), the İdiş Dağı samples are equivalent to trachytes and trachydacites in composition (Figure 4). In a similar fashion, trace element classifications based on stable elements (Winchester and Floyd, 1977) also indicate that the syenites are similar in composition to trachytes and trachyandesites (Köksal, 1996). Although in both cases the classification schemes are based on volcanic rocks, in plutonic terms the İdiş Dağı samples equate chemically to syenites and syenodiorites (Wilson, 1989).

Other features of the syenitoids based mainly on their major element chemistry can be summarized as follows:

(a) As expected the quartz syenites belong to an alkaline lineage (cf. Köksal, 1996), although alteration has reduced the total alkali content of some samples below the alkaline/subalkaline divide (Figure 4). In general terms they display compositions and trends that typify oversaturated peralkaline suites.

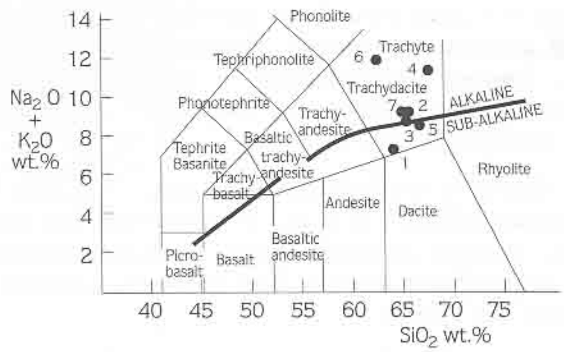

Figure 4. Total alkalies-silica classification diagram for the samples from the İdiş Dağı Syenitoid (after LeBas et al., 1986).

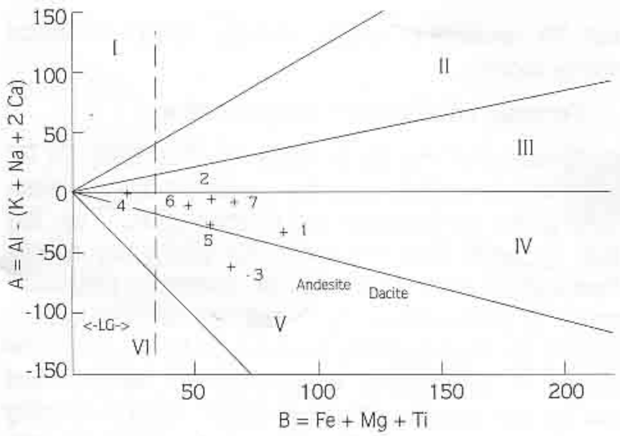

Figure 5. Distribution of the İdiş Dağı Syenitoid samples in the Debon and LeFort's (1983) characteristic minerals diagram. Peraluminous fields: I- muscovite or muscovite>biotite, II- biotite>muscovite, III- biotite, Metaluminous fields: IV- mainly hornblende and biotite, V- high proportion of clinopyroxene, VI- exceptional igneous rocks, LG-leuco-granitoids.

(b) They are meta-aluminous with cationic Na+K<Al. In the Debon and LeFort (1983) diagram (Figure 5) the majority lie in the filed characterized by a high proportion of biotite+amphibole±pyroxene, which agrees well with petrographic observations. The İdiş Dağı samples belong to their cafemic group which initially crystallizes hornblende and/or pyroxene, and ends with a biotite mica or two-mica paragenesis. In petrogenetic terms these types of rocks are generally formed from the mantle or a hybrid source dominated by mantle together with some continental crust (Wilson, 1989).

Petrogenetic Relationships

Using either SiO_2 or Zr as differentiation indices (Figure 6), element relationships suggest that the few samples in this study probably form part of a single comagmatic fractionation sequence. For example, positive correlations with Zr are shown by K, Na, Ce, Nb, Nd, Ga and Rb, although some scattered major element distributions are apparently affected by mobility

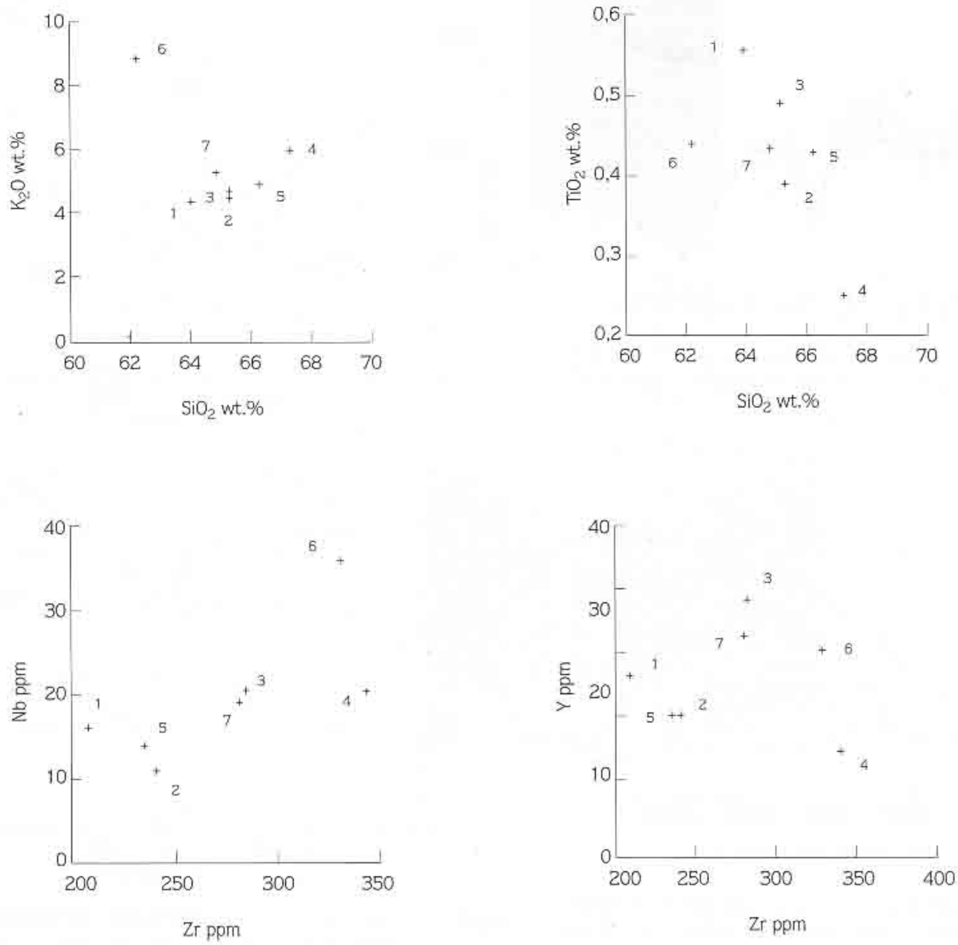

Figure 6. Major and trace element variations within the İdiş Dağı Syenitoid.

due to alteration; negative trends with SiO_2 are exhibited by Ti, Fe, Mn and Ca. The trends obtained are compatible with those expected from magmatic differentiation processes. In some of the diagrams (Figure 6), the one samle which apparently falls off the main magmatic trend (with highest K_2O and Nb), is either a consequence of a greater degree of alteration than the rest (Rice-Birchall and Floyd, 1988), or, more likely, the sole representative of the syenite suite featuring cumulate K-feldspar and opaques. The dominance of these mineral phases (Table 1) would account for the particularly high K and Nb contents respectively of this sample.

A chondrite-normalized spidergram (Figure 7) demonstrates the similarity of trace element patterns for the syenite samples and emphasizes their comagmatic character. The overall pattern is characterized by negative N, P, and Ti anomalies, coupled with positive Rb and Th anomalies, which probably reflect a crustal source region.

Tectonic environment discrimination

In terms of the de la Roche et al. (1980) R1-R2 multicationic scheme, and the major granitoid associations added by Batchelor and Bowden (1985), the İdiş Dağı Syenitoid does not apparently follow any specific fractionation trend, but could be related to magmatics typical of post-collision uplift and late-stage orogenesis (Figure 8). This diagram, however, is by no means definitive in determining environment of emplacement due to the possible effects of major element mobility and the coarseness of the parameters used in its construction. For this reason we have tended to use trace elements that are often considered to be immobile during alteration and more sensitive to characterize tectonic setting. For example, diagrams involving the trace elements Nb, Y and Rb (Pearce et al., 1984) are shown in Figure 9. Although the İdiş Dağı Syenitoid

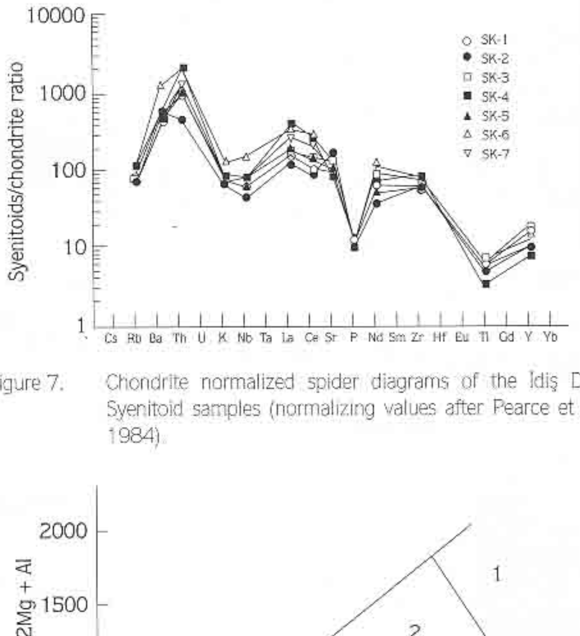

Figure 7. Chondrite normalized spider diagrams of the İdiş Dağı Syenitoid samples (normalizing values after Pearce et al., 1984).

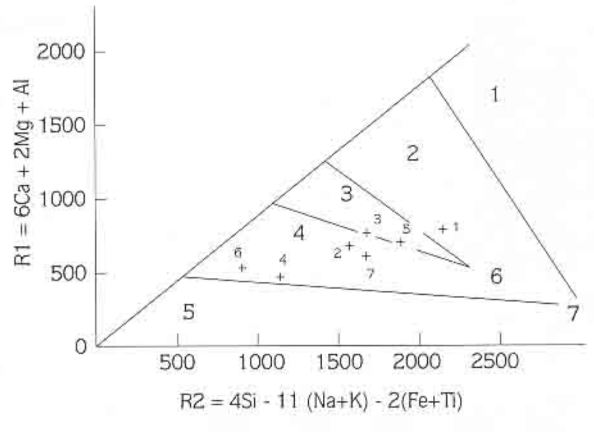

Figure 8. R_1-R_2 diagram plot of the İdiş Dağı Syenitoid samples (after Batchelor and Bowden, 1985). 1- Mantle Fractionates, 2- Pre-Plate Collision, 3- Post-Collision Uplift, 4- Late-Orogenic, 5- Anorogenic, 6- Syn-Collision, 7- Post-Orogenic.

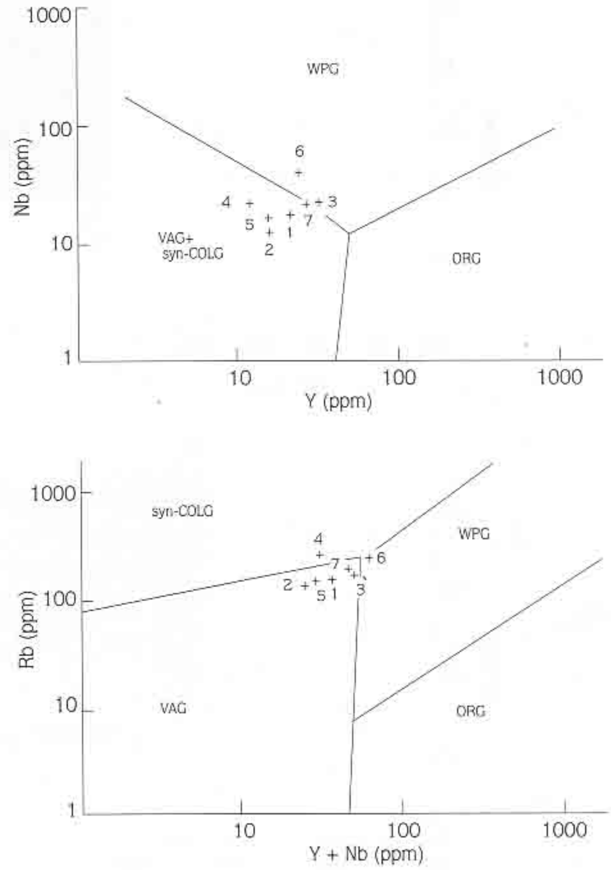

Figure 9. Nb vs Y and Rb vs Y+Nb tectonic discrimination diagrams (Pearce et al., 1984) of the İdiş Dağı Syenitoid samples. ORG: ocean ridge granite; WPG: within plate granite; syn-COLG: syn-collision granite; VAG: volcanic arc granite.

mainly falls in the volcanic arc field (VAG), as a group they plot near the intersection of the three fields displayed. Pearce et al. (1984) suggested that post-collisional granitoids could not be easily differentiated from other types in these diagrams, bu generally scatter across different fields adjacent to the triple junction of the syn-COLG-VAG-WPG segments.

In view of the similarity of trace element patterns for the samples, an average İdiş Dağı Syenitoid was compared with various M-, I-, S- and A-type granitoids from the literature (largely after Whalen et al., 1987) in Figure 10. In this ORG-normalized spidergram, the average syenitoid has a pattern similar to those for I-, felsic S- and A-type granitoids, but with a greater enrichment in Ba and Th, and depletion in Y. The normalized Nb, Ce and Zr values fall in-between A-type granitoids and the rest. Whalen et al. (1987) suggested that good discrimination could be obtained between A-type granitoids and other types on plots employing Ga/Al ratios vs. Y, Ce and Zr. As seen in

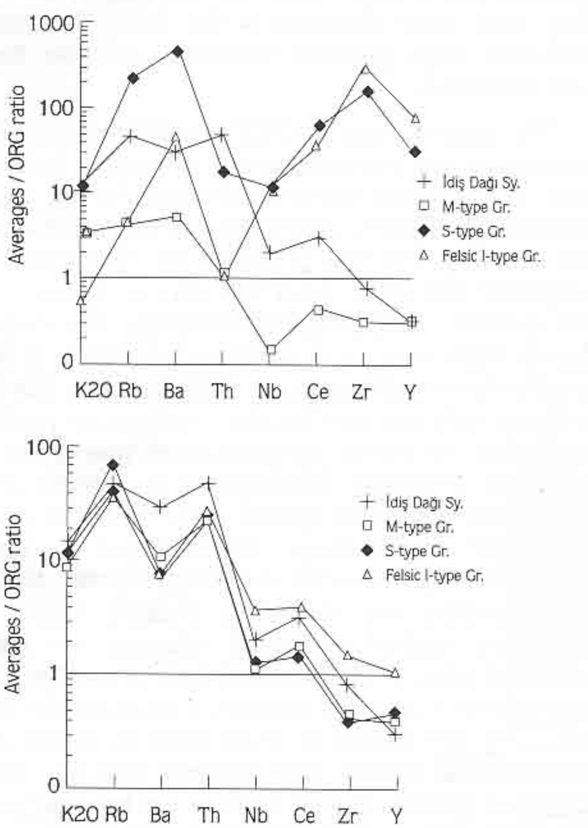

Figure 10. Comparative ORG normalized spider diagrams of a: M-, S- and felsic I-type granitoids. b: I-, felsic S, and A-type granitoids with the İdiş Dağı Syenitoid. ORG normalizing values are from Pearce et al. (1984). For both a and b data for granitoid types are from Whalen et al. (1987).

Figure 11 the İdiş Dağı Syenitoid samples develop a trend across the granitoids field boundary, but plot mainly in the A-type field. In terms of magmatic environment and genesis, A-type granitic suites generally represent the final plutonic event in both orogenic belts and anorogenic rifting in shield areas, produced by the partial melting of volatile-enriched granulitic lower crust (Whalen et al., 1987). However, Craser et al. (1991) suggested that some A-type granitoids were formed by the partial melting of crustal magmatic rocks of tonalitic to granodioritic composition. Eby (1992), on the other hand, recognized two groups of A-type granites, termed A_1 and A_2, the former of which were largely generated by extreme differentiation, whereas the latter were produced by crustal anatexis. As deonstrated from the references quoted above, the melting of crustal materials clearly plays an important role in the generation of within-plate A-type

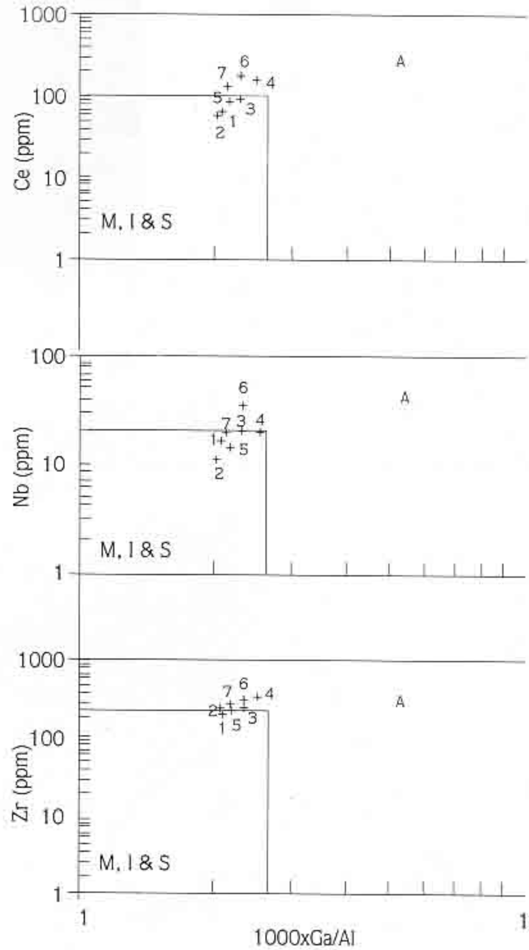

Figure 11. a- 10000xGa/Al vs Ce; b- 10000xGa/Al vs Nb; c- 10000xGa/Al vs Zr plots of the İdiş Dağı Syenitoid (after Whalen et al., 1987).

granitoids. As exhibited in Figure 12 the İdiş Dağı Syenitoid can be characterized as A_2-type granitoid; the two samples in the A_1 field represent the most altered samples of the group. These data confirms the involvement of continental crust in the genesis of the post-collisional syenites as suggested by the overall spidergram pattern (Figure 7).

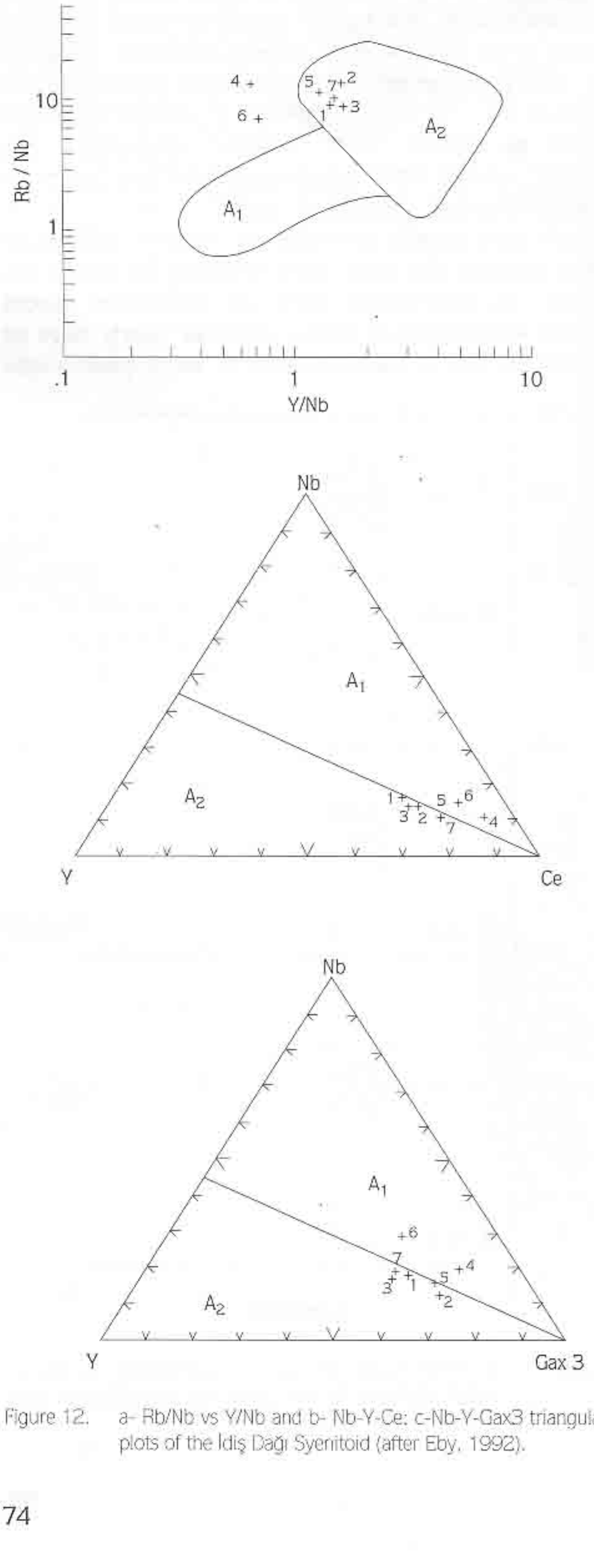

Figure 12. a- Rb/Nb vs Y/Nb and b- Nb-Y-Ce; c-Nb-Y-Gax3 triangular plots of the İdiş Dağı Syenitoid (after Eby, 1992).

Evolution and Geodynamic Setting

According to Göncüoğlu et al. (1993a) the CACC forms the northern edge of the Tauride-Anatolide Platform directly opposite to the İzmir-Ankara-Erzincan (IAE) ocean branch during the Mesozoic. The oceanic strand was consumed, not only by early subduction beneath the Pontides, but also along an intraoceanic subduction zone at a later stage (Göncüoğlu et al., 1991). The emplacement of supra-subduction zone oceanic crust/ophiolites (Göncüoğlu and Türli, 1993; Yalınız et al, 1994, 1996) onto the platformal units and subsequent closure of the IAE ocean eventually lead to the collision of the CACC with an ensimatic arc to the north. This event caused crustal thickening, HT/LP regional metamorphism and the formation of collision related S- and I-type granitoids in CACC. These ophiolitic and granitic rocks, not observed in the İdiş Dağı area, occur elsewhere in the CACC. This compressional stage probably continued until the Early Late Cretaceous.

The plutonic rocks in CACC are differentiated into syncollision and post-collision-type granitoids, together with the late-stage syenitoids discussed in this paper (Akıman et al, 1993; Göncüoğlu and Türeli, 1994). In the İdiş Dağı area the granitodis are represented by pegmatitic and aplitic dykes and also as intrusions in the asement of Aşıgediği Metamorphics. The magma source from which the granitoids originated is disputable (Erler and Göncüoğlu, 1996), but they may be cogenetic with the later İdiş dağı Syenitoid, or possibly related to the earlier, syn-postcollision-type phase of plutonism. Previously Göncüoğlu et al. (1993a) concluded that the CACC syenites were of mixed lower crust/upper mantle origin and developed as post-collisional intrusions in the early Maastrichtian. Mantle partial melting was caused by pressure release at depth and resulted in thermal relaxation and post-collisional uplift of the thickened CACC crust. The current geochemical work, however, emphasizes the part played by the continental crust, both as source and environmental setting, and suggests that the post-collisional syenites, at least those in the İdiş Dağı area, are largely the result of the anatexis of crustal materials. We consider that the İdiş Dağı Syenitoid belong to the within-plate A-type granitoid group on the basis of its geochemical composition (comparisons with Whalen et al., 1987). Further it is characteristic of the A_2

subgroup (Eby, 1992) which includes post-collisional granitoids emplaced after a long period of high heat flow and granitic magmatism. Interpretation of spidergram patterns confirm that the İdiş Dağı Syenitoid is very similar to post-collisional granitoids produced by crustal anatexis; a conclusion that supports the close relationship between the syenites and the post-collisional uplift of the CACC, resulting in the evolution of the Latest Cretaceous-Early Tertiary extensional basin in Central Anatolia (Göncüoğlu et al., 1991; 1993a; 1993b).

Conclusions

(a) The İdiş Dağı Syenitoid is a late-stage member of the Central Anatolian Plutonics. It intrudes the Central Anatolian metamorphic basement and is subsequently cut by feldspathoid dykes of the Karahıdır Volcanics. It is unconformably overlain by the Latest Cretaceous-Early Paleocene Göynük Volcaniclastic Olistostrome. Its emplacement age is assumed to be Early Maastrichtian.

(b) Geochemical and petrographic data indicates that the İdiş Dağı Syenitoid consists mainly of quartz syenites with a well-defined alkaline lineage and that it forms a comagmatic fractionated suite. Comparison of normalized geochemical patterns with other granitoids suggests they probably formed by the partial melting of crustal materials.

(c) Discrimination of their tectonic environment based on chemical data indicates that the İdiş Dağı Syenitoid has the character of within-plate A_2-type post-collisional granitoids; a feature consistent with other geoological and geochemical data within the CACC.

(d) The late orogenic alkaline plutonic rocks of the CACC are thus colletively assumed to be the melt products of a post-collisional uplift and extensional event which followed crustal thickening related to the closure of the İzmir-Ankara-Erzincan oceanic strand of Neotethys, which was suggested by Göncüoğlu et al. (1991).

Acknowledgements

We wish to express our thanks to the members of the "Working Group on Central Anatolian Magmatics" (Prof. Dr. A. Erler, Prof. Dr. H. Bayhan, Assoc. Prof. Dr. Nilgün Güleç and Dr. O. Akıman) for their cooperation and to Mrs. G. Kuşcu (Department of Earth sciences, Keele University) for her help in analysing samples. Thanks are also extended to Dr. S.K. Mittwede for his suggestions and the Turkish Petroleum Corporation (T.P.A.O.) for logistic support during the filed work. We further acknowledge the support of TÜBİTAK-YDABCAG-85 and a collaborative NATO research grant, number CRG-960549.

References

Akıman, O. and Boztug, D., 1993. Alkaline igneous rocks occurring in the Central Anatolian Complex. In: Symposium for the 25th Anniversary of Earth Sciences at Hacettepe University, November, 15-17, 1995, Beytepe-Ankara.

Akıman, O., Erler, A., Göncüoğlu, M.C., Güleç, N., Geven, A., Türeli, K. and Kadıoğlu, Y., 1993. Geochemical characteristics of granitoids along the western margin of the Central Anatolian Crystalline Complex and their tectonic implications: Geological Journal, 28, 371-382.

Atabey, E., 1989. "1:100 000 scaled geological maps of Turkey: Kayseri H-19 sheet". Mineral research Exploration Inst. Publ., Ankara, 18 p.

Atabey, E., Tarhan, N., Yusufoğlu, H. and Canpolat, M., 1988. Hacıbektaş, Gülşehir, Kalaba (Nevşehir) - Himmetdede (Kayseri) arasının jeolojisi. Mineral research exploration Inst. Rap. No: 8523, (unpublished).

Ataman, G., 1972. Ankara'nın güneydoğusundaki granitik granodiyoritik kütlelerden Cefalık Dağı'nın radyometrik yaşı hakkında ön çalışma. Hacettepe Fen ve Mühendislik Bilimleri Dergisi, 2, 44-49.

Ayan, M., 1963. Contribution a l' etude petrographique et geologique de la region situee au Nord-Est de Kaman. Mineral research Exploration Publ., no. 115, 332 p.

Aydın, N., 1985. Geological Evolution of Gümüşkent Town and It's Surrounding In the Middle Anatolian Massif. Communications. De la Faculté Des Sciences de l' Université d' Ankara, série C_1 Géologie, 31, 43-56.

Batchelor, R. A. and Bowden, P., 1985. Petrogenetic interpretation of granitoid rock series using multicationic parameters. Chemical Geology, 48, 43-55.

Bayhan, H., 1987. Cefalıkdağ ve Baranadağ plutonlarının (Kaman) petrografik ve kimyasal-mineralojik özellikleri. Jeoloji Mühendisliği, 30/31, 11-16.

Bayhan, H., 1988. Bayındır-Akpınar (Kaman) yöresindeki alkali kayaçların jeokimyası ve kökensel yorumu. Geol. Soc. Turkey Bull, 31, 59-69.

Bayhan, H. and Tolluoğlu, A.Ü., 1987. Çayağazı siyenitoidinin (Kırşehir kuzeybatısı) mineralojik-petrografik ve jeokimyasal özellikleri. Hacettepe üniversitesi Yerbilimleri Dergisi, 14, 109-120.

Boztuğ, D., Yılmaz, S. and Kesgin, Y., 1994. İç-Doğu Anadolu alkalin provensindeki Kösedağ plutonu (Suşehri-KD Sivas) doğu kesiminin petrografisi, petrokimyası ve petrojenezi. Geol. Soc. Turkey Bull, 37, no. 2, 1-14.

Craser, R. A., Price, R. C. and Wormald, R.J., 1991. A-type granites revised: Assessment of a residual-source model: Geology, 19, 163-166.

Çevikbaş, A., Boztuğ, D., Demirkol, C., Yılmaz, S., Akyıldız, M., Açlan, M., Demir, Ö. and Taş, R., 1995. Horoz Plütonunun (Ulukışla-Niğde) Oluşumunda Dengelenmiş Hibrid Sistemin Mineralojik ve Jeokimyasal Kanıtları. Geol. Soc. Turkey Congr. Bull., no. 10, 62-77.

Debon, F. and Le Fort, P., 1983. A chemical-mineralogical classification of common plutonic rocks and their associations. Transactions of the Royal society of Edinburgh: Earth Sciences, 73, 135-149.

de la Roche, H., Leterrier, J., Grand Claude, P. and Marchal, M., 1980. A classification of volcanic and plutonic rocks using R1-r2 diagrams and major element analyses-its relationships with current nomenclature. Chemical Geology, 29, 183-210.

Eby, G. N., 1992. Chemical subdivision of the A-type granitoids: Petrogenetic and tectonic implications. Geology, 20, 641-644.

Erkan, Y. and Ataman, G., 1981. Orta Anadolu Masifi (Kırşehir Yöresi) metamorfizma yaşı üzerine K-Ar yöntemi ile bir inceleme. Hacettepe Üniversitesi Yerbilimleri Dergisi, 8, 27-31.

Erler, A. and Göncüoğlu, M.C., 1996. Geologic and tectonic setting of the Yozgat Batholith, Northern Central Anatolian Crystalline Complex, Turkey: Int. Geol. Rev., 38/8, 714-726.

Erler, A., Akıman, O., Unan, C., Dalkılıç, F., Dalkılıç, B., Geven, A. and Önen, P., 1991. Kaman (Kırşehir) ve Yozgat yörelerinde Kırşehir Masifi magmatik kayaçlarının petrolojisi ve jeokimyası. TÜBİTAK, Doğa-Turkish Journal of Earth Sciences, 15, 76-100.

Floyd, P. A. and Castillo, P. R., 1992. Geochemistry and petrogenesis of Jurassic ocean crust basalts, ODP leg 129, site 801. In: R. Larson et al., (Eds), Proceedings of ODP, Scientific Results, 129, 361-388. College Station, Texas.

Göncüoğlu, M. C., 1977. Geologie des westlichen Niğde massives. Ph. D. Thesis, Bonn University, 167p., (unpublished).

Göncüoğlu, M. C., 1986. Geochronological data from the southern part (Niğde Area) of the Central Anatolian Massif. Mineral Research Exploration Bull., 105/106, 83-96.

Göncüoğlu, M. C. and Türeli, K., 1993. Petrology and geodynamic interpretation of plagiogranites from central Anatolian ophiolites (Aksaray, Turkey): Doğa Turkish Journal of Earth Sciences, 2, 195-203.

Göncüoğlu, M. C. and Türeli, T.K., 1994. Alpine collision-type granitoids in the western central Anatolian Crystalline Complex, journal of Kocaeli Univ., 1, 39-46.

Göncüoğlu, M. C., Erler, A., Toprak, G. M., Olgun, E., and Kuşçu, I., 1991. Orta Anadolu Masifinin batı bölümünün jeolojisi, Bölüm 1: Güney Kesim. T.P.A.O. Report No: 2909, (unpublished).

Göncüoğlu, M. C., Erler, A., Toprak, G. M., Olgun, E., Yalınız, K. Kuşçu, I., Köksal, S. and Dirik, K., 1993a. Orta Anadolu Masifinin orta bölümünün jeolojisi, Bölüm 3: Orta Kızılırmak Tersiyer Baseninin jeolojik evrimi. T.P.A.O. Report No: 3313, (unpublished).

Göncüoğlu, M. C., Toprak, V., Olgun, E., Kuşçu, I., Erler, A. and Yalınız, K., 1993b. Tertiary Evolution of Central Kızılırmak Basin: 8 th Meeting, Assoc. European Geological Soc., 19-26 Sept. Budapest, Abstracts, p 19.

Güleç, N., 1994. Rb-Sr Isotope Data From the Ağaçören Granitoid (East of Tuz Gölü): Geochronological and Genetical Implications. Turkish Journal of Earth Sciences, 3, 39-43.

Irvine, T. N., and Baragar, W. R. A., 1971. A guide to the chemical classification of the common volcanic rocks. Canadian Journal of Earth Sciences, 8, 523-548.

Köksal, S., 1986. The geological and petrological characteristics of the İdiş Dağı-Avanos area (Nevşehir-Central Anatolia): Middle East Technical University, M Sc Thesis, 141p., (Unpublished).

Köksal, S and Göncüoğlu, M. C., Geology of the İdiş Dağı-Avanos area (Nevşehir, Central Anatolia). Mineral Res. Explor. Bull., 119, (in print).

Kuruç, A., 1990. Rb/Sr geochemistry of syenitoids from Kaman-Kırşehir region. Hacettepe University, M Sc Thesis, 97p, (unpublished).

Le Bas, M. J., 1986. A chemical classification of volcanic rocks based on the total alkali-silica diagram. J. Petrology, 27, 745-750.

Le Bas, M. J., Le Maitre, R. W., Streckeisen, A. and Zanettin, B., 1986. A chemical classification of volcanic rocks based on the total Alkali-Silica diagram. Journal of Petrology, v. 27/3, pp 745-750.

Lünel, A. T., 1985. An aroach to the naming, origin and age of Baranedağ monzonite of Kırşehir intrusive suite. METU Journal of Pure and Applied Sciences, 13, no. 3.

Lünel, A. T. and Akıman, O., 1986. Hamitköy, Kaman, Kırşehir bölgesinde bulunan psödolösit oluşuğu ve basınç göstergesi olarak kullanımı. Mineral Research Exploration Bull., 103/104, 117-123.

Özkan, H. M., 1987. Petrological and geochemical investigation of Hayriye (Kayseri) nepheline-syenite intrusion. M Sc Thesis, Ankara University, 33 p., (unpublished).

Özkan, H. M. and Erkan, Y., 1994. A petrological study on a foid syenite intrusion in Central Anatolia (Kayseri, Turkey). Turkish Journal of Earth Sciences, 3, 45-55.

Pearce, J. A., Harris, N. B. W. and Tindle, A. G. W., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, 25, 956-983.

Rice-Birchall, B. and Floyd, P. A., 1988. Geochemical and source characteristics of the Tintagel Volcanic Formation. Proc. Ussher Soc., 7, 52-55.

Streckeisen, A. L., 1976. To each rock its proper name. Earth-Science Reviews, v. 12, pp 1-33.

Tolluoğlu, A. Ü., 1993. Kırşehir Masifini kesen felsik intruziflerin (Kötüdağ ve Buzlukdağ) petrografik ve jeokimyasal karakterleri. Hacettepe Üniversitesi Yerbilimleri Dergisi, 16, 19-41.

Whalen, J. B., Currie, K. L. and Chaell, B. W., 1987. A-type granites: Geochemical characteristics, discrimination and petrogenesis. Contrib. Min. Petrol., vol. 95, 407-419.

Wilson, M., 1989. Igneous petrogenesis: a global tectonic approach. Unwin Hyman, London, 466 pp.

Winchester, J. A. and Floyd, P. A., 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chem. Geol., 20, 325-343.

Yalınız, K., Floyd, P. A. and Göncüoğlu, M. C., 1994. Supra-subduction zone ophiolites in Central Anatolia: geochemical evidence from the basalts of the Sarıkaraman Ophiolite, Aksaray, Turkey: Int. Mineralogical Assoc., 16th General Meeting, Pisa, 4-9 Sept. 1994, Abstracts, 447.

Yalınız, M. K., Floyd, P. A. and Göncüoğlu, M. C., 1996. Supra-subduction zone ophiolites of Central Anatolia: geochemical evidence from the Sarıkaraman Ophiolite, Aksaray, Turkey. Minerolog. Mag., 60, 697-710.

Çevikbaş, A., Boztuğ, D., Demirkol, C., Yılmaz, S., Akyıldız, M., Açlan, M., Demir, Ö. and Taş, R., 1995. Horoz Plütonunun (Ulukışla-Niğde) Oluşumunda Dengelenmiş Hibrid Sistemin Mineralojik ve Jeokimyasal Kanıtları. Geol. Soc. Turkey Congr. Bull., no. 10, 62-77.

Debon, F. and Le Fort, P., 1983. A chemical-mineralogical classification of common plutonic rocks and their associations. Transactions of the Royal society of Edinburgh: Earth Sciences, 73, 135-149.

de la Roche, H., Leterrier, J., Grand Claude, P. and Marchal, M., 1980. A classification of volcanic and plutonic rocks using R1-r2 diagrams and major element analyses-its relationships with current nomenclature. Chemical Geology, 29, 183-210.

Eby, G. N., 1992. Chemical subdivision of the A-type granitoids: Petrogenetic and tectonic implications. Geology, 20, 641-644.

Erkan, Y. and Ataman, G., 1981. Orta Anadolu Masifi (Kırşehir Yöresi) metamorfizma yaşı üzerine K-Ar yöntemi ile bir inceleme. Hacettepe Üniversitesi Yerbilimleri Dergisi, 8, 27-31.

Erler, A. and Göncüoğlu, M.C., 1996. Geologic and tectonic setting of the Yozgat Batholith, Northern Central Anatolian Crystalline Complex, Turkey: Int. Geol. Rev., 38/8, 714-726.

Erler, A., Akıman, O., Unan, C., Dalkılıç, F., Dalkılıç, B., Geven, A. and Önen, P., 1991. Kaman (Kırşehir) ve Yozgat yörelerinde Kırşehir Masifi magmatik kayaçlarının petrolojisi ve jeokimyası. TÜBİTAK, Doğa-Turkish Journal of Earth Sciences, 15, 76-100.

Floyd, P. A. and Castillo, P. R., 1992. Geochemistry and petrogenesis of Jurassic ocean crust basalts, ODP leg 129, site 801. In: R. Larson et al., (Eds), Proceedings of ODP, Scientific Results, 129, 361-388. College Station, Texas.

Göncüoğlu, M. C., 1977. Geologie des westlichen Niğde massives. Ph. D. Thesis, Bonn University, 167p., (unpublished).

Göncüoğlu, M. C., 1986. Geochronological data from the southern part (Niğde Area) of the Central Anatolian Massif. Mineral Research Exploration Bull., 105/106, 83-96.

Göncüoğlu, M. C. and Türeli, K., 1993. Petrology and geodynamic interpretation of plagiogranites from central Anatolian ophiolites (Aksaray, Turkey): Doğa Turkish Journal of Earth Sciences, 2, 195-203.

Göncüoğlu, M. C. and Türeli, T.K., 1994. Alpine collision-type granitoids in the western central Anatolian Crystalline Complex, Journal of Kocaeli Univ., 1, 39-46.

Göncüoğlu, M. C., Erler, A., Toprak, G. M., Olgun, E., and Kuşçu, I., 1991. Orta Anadolu Masifinin batı bölümünun jeolojisi, Bölüm 1: Güney Kesim. T.P.A.O. Report No: 2909, (unpublished).

Göncüoğlu, M. C., Erler, A., Toprak, G. M., Olgun, E., Yalınız, K. Kuşçu, I., Köksal, S. and Dirik, K., 1993a. Orta Anadolu Masifinin orta bölümünün jeolojisi, Bölüm 3: Orta Kızılırmak Tersiyer Baseninin jeolojik evrimi, T.P.A.O. Report No: 3313, (unpublished).

Göncüoğlu, M. C., Toprak, V., Olgun, E., Kuşçu, I., Erler, A. and Yalınız, K., 1993b. Tertiary Evolution of Central Kızılırmak Basin: 8 th Meeting, Assoc. European Geological Soc., 19-26 Sept. Budapest, Abstracts, p 19.

Güleç, N., 1994. Rb-Sr Isotope Data From the Ağaçören Granitoid (East of Tuz Gölü): Geochronological and Genetical Implications, Turkish Journal of Earth Sciences, 3, 39-43.

Irvine, T. N., and Baragar, W. R. A., 1971. A guide to the chemical classification of the common volcanic rocks. Canadian Journal of Earth Sciences, 8, 523-548.

Köksal, S., 1986. The geological and petrological characteristics of the İdiş Dağı-Avanos area (Nevşehir-Central Anatolia): Middle East Technical University, M Sc Thesis, 141p., (Unpublished).

Köksal, S and Göncüoğlu, M. C., Geology of the İdiş Dağı-Avanos area (Nevşehir, Central Anatolia). Mineral Res. Explor. Bull., 119, (in print).

Kuruç, A., 1990. Rb/Sr geochemistry of syenitoids from Kaman-Kırşehir region. Hacettepe University, M Sc Thesis, 97p. (unpublished).

Le Bas, M. J., 1986. A chemical classification of volcanic rocks based on the total alkali-silica diagram. J. Petrology, 27, 745-750.

Le Bas, M. J., Le Maitre, R. W., Streckeisen, A. and Zanettin, B., 1986. A chemical classification of volcanic rocks based on the total Alkali-Silica diagram. Journal of Petrology, v. 27/3, pp 745-750.

Lünel, A. T., 1985. An aroach to the naming, origin and age of Baranedağ monzonite of Kırşehir intrusive suite. METU Journal of Pure and Applied Sciences, 13, no. 3.

Lünel, A. T. and Akıman, O., 1986. Hamitköy, Kaman, Kırşehir bölgesinde bulunan psödolösit oluşuğu ve basınç göstergesi olarak kullanımı. Mineral Research Exploration Bull., 103/104, 117-123.

Özkan, H. M., 1987. Petrological and geochemical investigation of Hayriye (Kayseri) nepheline-syenite intrusion. M Sc Thesis, Ankara University, 33 p., (unpublished).

Özkan, H. M. and Erkan, Y., 1994. A petrological study on a foid syenite intrusion in Central Anatolia (Kayseri, Turkey). Turkish Journal of Earth Sciences, 3, 45-55.

Pearce, J. A., Harris, N. B. W. and Tindle, A. G. W., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, 25, 956-983.

Rice-Birchall, B. and Floyd, P. A., 1988. Geochemical and source characteristics of the Tintagel Volcanic Formation. Proc. Ussher Soc., 7, 52-55.

Streckeisen, A. L., 1976. To each rock its proper name. Earth-Science Reviews, v. 12, pp 1-33.

Tolluoğlu, A. Ü., 1993. Kırşehir Masifini kesen felsik intruziflerin (Kötüdağ ve Buzlukdağ) petrografik ve jeokimyasal karakterleri. Hacettepe Üniversitesi Yerbilimleri Dergisi, 16, 19-41.

Whalen, J. B., Currie, K. L. and Chaell, B. W., 1987. A-type granites: Geochemical characteristics, discrimination and petrogenesis. Contrib. Min. Petrol., vol. 95, 407-419.

Wilson, M., 1989. Igneous petrogenesis: a global tectonic approach. Unwin Hyman, London, 466 pp.

Winchester, J. A. and Floyd, P. A., 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chem. Geol., 20, 325-343.

Yalınız, K., Floyd, P. A. and Göncüoğlu, M. C., 1994. Supra-subduction zone ophiolites in Central Anatolia: geochemical evidence from the basalts of the Sarıkaraman Ophiolite, Aksaray, Turkey: Int. Mineralogical Assoc., 16th General Meeting, Pisa, 4-9 Sept. 1994, Abstracts, 447.

Yalınız, M. K., Floyd, P. A. and Göncüoğlu, M. C., 1996. Suprasubduction zone ophiolites of Central Anatolia: geochemical evidence from the Sarıkaraman Ophiolite, Aksaray, Turkey, Minerolog. Mag., 60, 697-710.