GEOLOGICAL JOURNAL, VOL. 28, 371–382 (1993)

# Geochemical characteristics of granitoids along the western margin of the Central Anatolian Crystalline Complex and their tectonic implications

**ORHAN AKIMAN, AYHAN ERLER, M. CEMAL GÖNCÜOĞLU, NILGÜN GÜLEÇ and AKIN GEVEN**
*Department of Geological Engineering, Middle Eastern Technical University, Ankara, Turkey*

**T. KEMAL TÜRELİ**
*Department of Mineral Analyses, Mineral Research and Technical Institute, Ankara, Turkey*

*and*

**YUSUF K. KADIOĞLU**
*Ankara University, Department of Geological Engineering, Ankara, Turkey*

The closely related assemblage of igneous and metamorphic rocks that lie within a triangular area approximately bounded by the Tuzgölü Fault, the Ecemiş Fault and the Izmir–Ankara–Erzincan Suture and between the lines connecting Ankara, Sivas and Niğde is called the Central Anatolian Crystalline Complex (CACC). The granitoids cropping out within the CACC can be divided areally into three groups: (1) a large number of individual small plutons which form an arcuate set and curve from NE–SW to NW–SE and extend from Sulakyurt to Niğde along the western margin; (2) a relatively narrow and smaller set of disconnected plutons extending from Sivas to Çamardi along the eastern margin; and (3) a very large batholith along the northern margin exposed around Yozgat.

This study deals only with the first group of rocks. Geochemical data have been used to classify the granitoids, to determine their chemical characteristics, and to estimate the possible source regions and tectonic environment of magma generation and emplacement. The geochemical data indicate that these western margin granitoids range in composition from monzonitic to granitic–granodioritic varieties, belong to the alumina–cafemic and cafemic associations and possess either a metaluminous or peraluminous character. All granitoid types display features which may indicate the presence of both S- and I-type igneous rocks. Interpretation of the trace element data suggests a syn-collisional to late/post-collisional tectonic setting and a continental crustal source for the granitoids.

KEY WORDS Central Anatolia Collision Granitoids Petrology Turkey

## 1. INTRODUCTION

The assemblage of magmatic and metamorphic rocks in the Central Anatolia region of Turkey, to the east and south-east of Ankara (Figure 1), is variously called the Central Anatolian Crystalline Complex (CACC) (Göncüoğlu *et al.* 1991), the Central Anatolian Massif (Erkan 1981) and the Kirşehir Complex (Lünel 1985). The massif lies in a triangular area approximately limited by the lines connecting Sulakyurt, Kirikkale, Yozgat, Sivas, Kayseri, Niğde and Aksaray. Geologically it is bounded by the Tuzgölü Fault to the west, the Ecemiş Fault to the east and the Izmir–Ankara–Erzincan Suture to the north (Figure 1). The CACC consists of the relatively larger Kirşehir Massif in the north and the smaller Niğde Massif in the south. The granitoids of the CACC can be subdivided into three: (1) a wide set of exposures curved from NE–SW to NW–SE covering relatively large outcrop areas and extending from Sulakyurt to Niğde along the western margin; (2) a relatively narrow and smaller number of disconnected outcrops

0072–1050/93/040371–12$11.00
© 1993 by John Wiley & Sons, Ltd.

which extend from Sivas to Çamardi along the eastern margin; and (3) a very large batholith exposed along the northern margin around Yozgat.

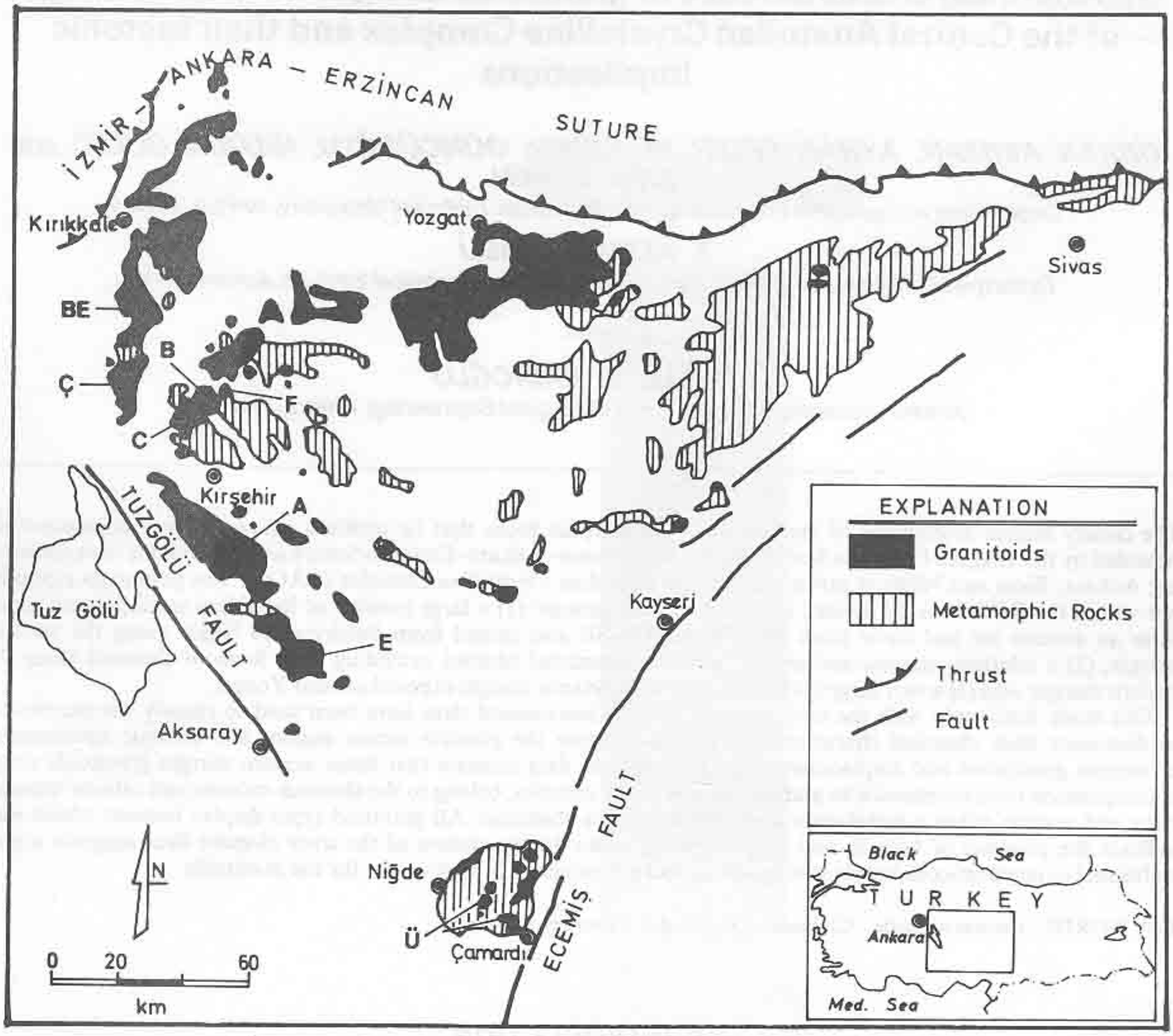

Figure 1. Simplified geological setting of the CACC (modified from Bingöl 1989)

The tectonic setting of these granitoids within the massif is still unresolved. This paper is a compilation of relatively recent geological, petrological and geochemical studies on the granitoids of the western margin. It reviews individual and joint research work by the authors, in addition to published material. Geochemical data, especially the trace element data, are used to indicate a possible tectonic environment for these granitoids.

## 2. GEOLOGICAL SETTING

The CACC lies within the Anatolide tectonic belt as defined by Ketin (1966); this complex is surrounded by the Izmir–Ankara–Erzincan Suture Zone, which is characterized by an ophiolitic mélange of Upper Mesozoic age to the north-west, north and north-east, a Miocene–Pliocene sedimentary and Pliocene volcanic sequence in the south-west, and Eocene–Recent sedimentary and volcanic rocks along the south-east margin (Ketin 1963). The rocks that crop out within the area of the complex include metamorphic rocks, mafic to ultramafic rocks, slices of mélange, and felsic to intermediate plutonic rocks, which include granitoids and syenitoids. The granitoids contain various sizes of enclaves of both metamorphic and igneous origin. The massif is overlain by Maastrichtian and/or Eocene clastics and carbonates, Oligocene–Miocene evaporites and clastics, and Miocene–Pliocene continental clastics.

## 3. WESTERN MARGIN GRANITOIDS

### *3a. Behrekdağ granitoid*

The Behrekdağ granitoid (Figure 1, BE) was first included in the Çelebi intrusion (Ç) by Bayhan (1986), but was then later included in the Keskin intrusion by Bayhan (1989). Detailed mapping in the southern part (Yadete 1990) indicates that the pluton consists mainly of quartz monzonite with alkali feldspar megacrysts; this is surrounded by biotite–hornblende granite and is cross-cut by several dioritic and aplitic dykes. The unit trends north–south and covers an area of approximately 250 km$^2$. It intrudes the metamorphic rocks and is surrounded by the cover units.

The quartz monzonite consists mainly of plagioclase (oligoclase to andesine), perthitic alkali feldspar and quartz, with subordinate hornblende, biotite and clinopyroxene. Accessory minerals include sphene, apatite, zircon and opaque minerals. The rocks have occasional alkali feldspar megacrysts of 1–5 cm in length. The biotite–hornblende granite has a similar mineralogical composition, but is entirely lacking in the megacrysts of alkali feldspar.

### *3b. Çelebi granitoid*

The Çelebi granitoid (Figure 1, Ç) is defined as the Çelebi intrusion by Bayhan (1986) together with the Behrekdağ granitoid. The pluton consists mainly of granitic, granodioritic, quartz monzonitic and quartz monzodioritic compositions. The pluton trends north–south and covers an area of approximately 150 km$^2$. It intrudes the metamorphic rocks and is surrounded by the cover units. Gabbroic rocks often occur as roof pendants.

The essential minerals are plagioclase (oligoclase to andesine), perthitic alkali feldspar, quartz, hornblende, biotite and clinopyroxene; the accessory minerals are sphene, zircon, apatite and allanite. In some of the units within the pluton alkali feldspar megacrysts reach up to 3 cm in length.

### *3c. Ağaçören granitoid*

The Ağaçören granitoid (Figure 1, A) has been defined by Kadioğlu (1991). Bayhan (1990) originally called the unit the Ortaköy granitoid. The intrusion has a NW–SE trend and covers approximately 400 km$^2$. It intrudes the metamorphic rocks and is surrounded by the cover units. As with the Çelebi intrusion gabbroic rocks occur as roof pendants. Detailed mapping (Kadioğlu 1991; Göncüoğlu *et al.* 1992; Erler unpublished data) has shown that the core of the pluton mainly consists of monzogranite with alkali feldspar megacrysts and is surrounded by a unit of biotite–hornblende granite. There are also patches of leucogranite. All the separate units are intruded by dykes of felsic to intermediate composition.

The monzogranite consists of quartz, plagioclase (albite to oligoclase) and perthitic alkali feldspar, with hornblende and biotite; the accessory minerals are zircon, sphene, apatite and opaques. Alkali feldspar megacrysts reach up to 6 cm in length. Modal analysis results (Kadioğlu 1991) fall on Streckeisen's (1976) QAP diagram, mainly within the monzogranite field, with a slight overlap into the syenogranite field (Figure 2). The biotite–hornblende granite is similar to the monzogranite but there are no alkali feldspar megacrysts. Essential minerals of the leucogranite are quartz, orthoclase and plagioclase (albite to oligoclase), with minor biotite and local patches of garnet.

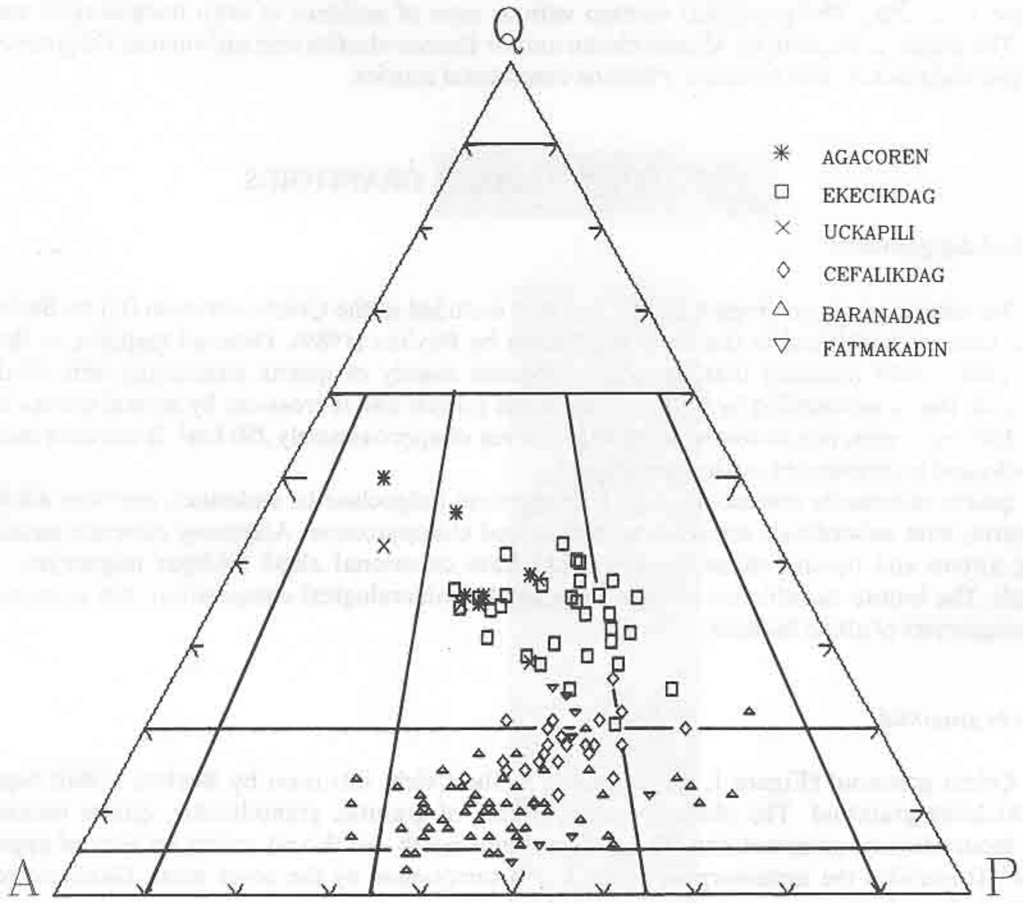

Figure 2. QAP diagram for the modal classification of the western margin granitoids of the CACC (compositional fields from Streckeisen, 1976)

### 3d. *Ekecikdağ granitoid*

The Ekecikdağ granitoid (Figure 1, E) is defined by Türeli (1991). The unit trends NW–SE and covers an area of approximately 250 km$^2$. It intrudes the metamorphic rocks and is surrounded by Tertiary to Quaternary volcanics. Gabbroic rocks occur as roof pendants. Detailed mapping by Türeli (1991) indicates that the pluton mainly consists of monzogranite–granodiorite with alkali feldspar megacrysts, with patches of biotite–hornblende granite and leucogranite; all are crossed by aplitic dykes.

The essential minerals of the monzogranite–granodiorite are quartz, plagioclase (albite to oligoclase) and perthitic alkali feldspar with subordinate biotite and hornblende. Accessories are apatite, zircon, sphene and opaque minerals. The rocks include megacrysts of alkali feldspar which reach up to 15 cm in length. Modal analysis results (Türeli 1991) fall on Streckeisen's (1976) QAP diagram, mainly within the monzogranite field, and slightly overlap into the granodiorite field (Figure 2). The biotite–hornblende granite has no alkali feldspar megacrysts. The mineralogical composition is similar to the monzogranite–granodiorite. Leucogranites consist mainly of orthoclase, plagioclase (albite to oligoclase) and quartz, with minor biotite; muscovite, garnet, or tourmaline occur locally.

### *3e. Üçkapili granite*

The Üçkapili granite (Figure 1, Ü) is defined by Göncüoğlu (1977) and dated by the Rb–Sr whole rock isochron method (Göncüoğlu 1986) as 95 ± 11 M.y. old. It intrudes both the high temperature/low pressure type and the migmatite-bearing metamorphic rocks of the Niğde Massif. It occurs as several patches up to 5 km$^2$ in area within the massif. Garnet-bearing aplite dykes cross-cut the granite.

The granite consists of quartz, plagioclase (albite to andesine) and orthoclase with subordinate biotite and muscovite. Accessories are apatite, zircon, tourmaline and opaque minerals. As with many of these granitoids the modal analysis results (Göncüoğlu 1986) indicate that they are mainly of monzogranitic or syenogranitic composition (Figure 2).

### *3f. Cefalikdağ quartz monzonite*

The Cefalikdağ quartz monzonite (Figure 1, C) is defined as a separate unit by Erler *et al.* (1991); Seymen (1982) accepts it as a part of the Baranadağ plutonics, whereas it is called the Cefalikdağ pluton by Bayhan (1987). The intrusion covers an area of 76 km$^2$. It intrudes the metamorphic rocks and includes migmatitic zones. It is bounded by the cover units and by the Baranadağ quartz monzonite. The boundary between the two plutons is a NW–SE trending fault zone. The unit has been dated by the Rb–Sr whole rock–mineral isochron method as 71 ± 1 M.y. by Ataman (1972).

The Cefalikdağ quartz monzonite consists mainly of plagioclase (andesine) and perthitic alkali feldspar with subordinate quartz and lesser hornblende and biotite. Accessory minerals include euhedral apatite, sphene, zircon and magmatically corroded opaques. The rocks display alkali feldspar megacrysts reaching up to 3 cm in length. Modal analysis results (Erler *et al.* 1991; Geven 1992) mainly fall on Streckeisen's (1976) QAP diagram within the quartz monzonite field, and overlap into the monzogranite field (Figure 2).

### *3g. Baranadağ quartz monzonite*

The Baranadağ quartz monzonite (Figure 1, B) is defined as a separate unit by Erler *et al.* (1991). Ayan (1963) originally included it among the undifferentiated granitic rocks; Seymen (1982), however, accepted it as a part of the Baranadağ plutonic complex, whereas it was called the Baranadağ monzonite by Lünel (1985) or the Baranadağ pluton by Bayhan (1987). The pluton covers an area of 52 km$^2$. It intrudes the metamorphic rocks and is bounded by the cover units.

The Baranadağ quartz monzonite consists mainly of perthitic orthoclase, plagioclase (andesine) and hornblende, with minor amounts of clinopyroxene and biotite. It also has smaller proportions of interstitial quartz. Perthitic alkali feldspar occurs as megacrysts which approach 3 cm in length. Accessory minerals include sphene, rutile, zircon, apatite and opaques. The modal analysis results (Erler *et al.* 1991) fall mainly within the quartz monzonite field, with a few analyses of quartz syenite and quartz monzodiorite composition (Figure 2).

### *3h. Fatmakadintepe quartz monzonite*

The Fatmakadintepe quartz monzonite (Figure 1, F) has been defined as a separate unit by Erler *et al.* (1991). Seymen (1982) considered it to be a part of the Baranadağ plutonic rocks, whereas Bayhan (1987) accepted it as equivalent to the Cefalikdağ pluton. The unit covers an area of 14 km$^2$.

The essential and accessory mineralogy of the Fatmakadintepe quartz monzonite is very similar to that of the Baranadağ pluton, but occasionally there are a few grains of muscovite present in some rocks. The modal analysis results (Erler *et al.* 1991) indicate that these rocks are of quartz monzonite, monzogranite and quartz monzodiorite compositions (Figure 2).

## GEOCHEMISTRY

The geochemical data have been evaluated to estimate the chemical characteristics of the crystallizing magmas and their possible tectonic environment of emplacement. Fresh samples were selected for geochemical analysis after the petrographic studies.

### *4a. Chemical characteristics*

Normative plots (Lünel 1985; Bayhan 1986; Erler *et al.* 1991) using the Streckeisen (1976) and Streckeisen and Le Maitre (1979) classifications support the modal analysis results. Using the Debon and Le Fort (1983) discrimination diagram, the Ağaçören, Ekecikdağ, Cefalikdağ, Baranadağ and Fatmakadintepe plutons have both metaluminous and peraluminous characters with cafemic to alumina–cafemic trends, whereas the Üçkapili pluton is entirely peraluminous (Figure 3). The Behrekdağ pluton also shows a metaluminous character with a cafemic trend (Bayhan 1989). According to the terminology devised by Chappell and White (1974), the Cefalikdağ, Baranadağ and Fatmakadintepe plutons are of the I-type; the Ağaçören, Ekecikdağ and Üçkapili plutons display both I-type and S-type characters.

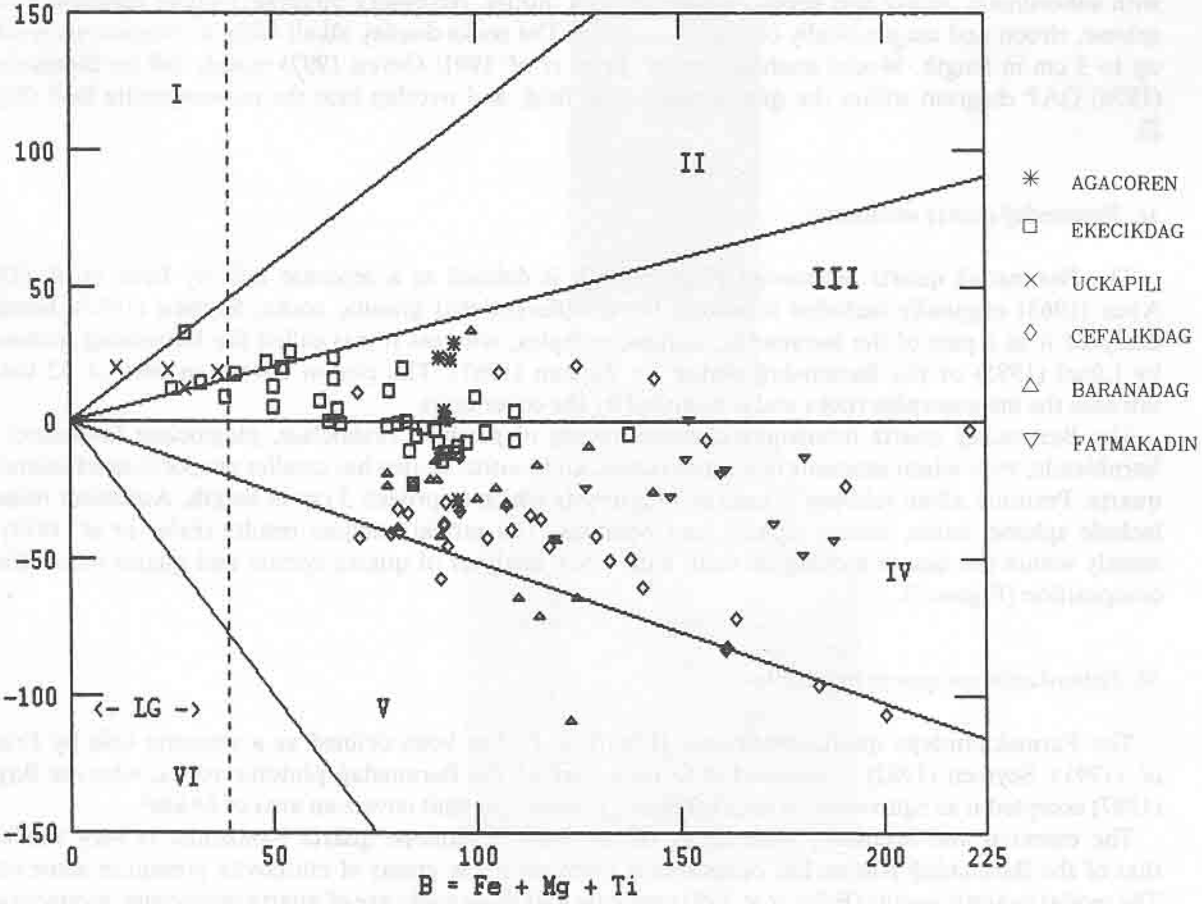

Figure 3. A–B characteristic minerals diagram for the western margin granitoids of the CACC (after Debon and LeFort, 1983)

### *4b. Trace element discrimination diagrams*

The tectonic settings of the western margin granitoids of the CACC have been estimated by the use of the trace element discrimination diagrams originally suggested by Pearce *et al.* (1984) and Harris *et al.* (1986). Analytical data on the western margin granitoids are taken from Göncüoğlu (1986, Üçkapili), Bayhan (1986, Çelebi; 1989, Behrekdağ; 1990, Ağaçören), Türeli (1991, Ekecikdağ), and Erler (unpublished data, Cefalikdağ, Baranadağ, Fatmakadintepe).

The ocean ridge granite (ORG) normalized trace element patterns are shown for the Ekecikdağ, Üçkapili, Cefalikdağ, Baranadağ and Fatmakadintepe granitoids (Figure 4), but due to the limited analytical data the pattern for the Ağaçören pluton is not shown. The patterns are almost identical: $K_20$, Rb, Ba and Th are all more than 10 times the ORG abundances; Ta, Nb and Ce are similar to the ORG; and Hf, Zr, Sm, Y and Yb are all less than the ORG. The patterns show a well defined decrease from the large ion lithophile to the high field strength elements. Compared with the patterns in Figure 1 of Pearce *et al.* (1984), the western margin granitoids show the closest similarities to the collision granites (patterns e and f).

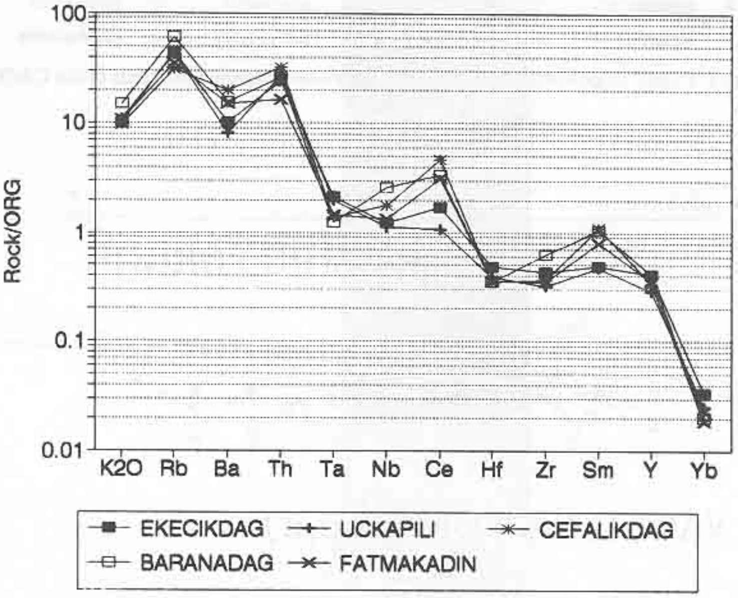

Figure 4. ORG normalized trace element patterns for the western margin granitoids of the CACC

The Y–$SiO_2$ diagram (Figure 2a of Pearce *et al.* 1984) discriminates between 'within-plate granites (WPG) + oceanic ridge granites (ORG), types a–c' and 'volcanic arc granites (VAG) + collision granites (COLG) + ORG, type d'. On the Y–$SiO_2$ diagram (Figure 5) all the western margin granitoids of the CACC plot in the VAG+COLG+ORG (d) field.

The Nb–$SiO_2$ diagram (Figure 2e of Pearce *et al.* 1984) was used to discriminate between WPG+ORG, type b and VAG+COLG+ORG, types a,c,d. On the Nb–$SiO_2$ diagram (Figure 6), most of the western margin granitoids plot in the VAG+COLG+ORG (a,c,d) field, whereas some analyses from the Baranadağ pluton, which have slightly more alkaline affinities, plot in the WPG+ORG (b) field.

The Rb–$SiO_2$ diagram (Figure 2c and 2d of Pearce *et al.* 1984) was used to discriminate between either WPG and ORG or VAG and synCOLG, depending on the results derived from the previously described diagrams. As the western margin granitoids plot in the VAG+COLG fields on Figures 5 and 6, the discrimination pattern on Figure 2e of Pearce *et al.* (1984) is used. On the Rb–$SiO_2$ diagram (Figure 7), the

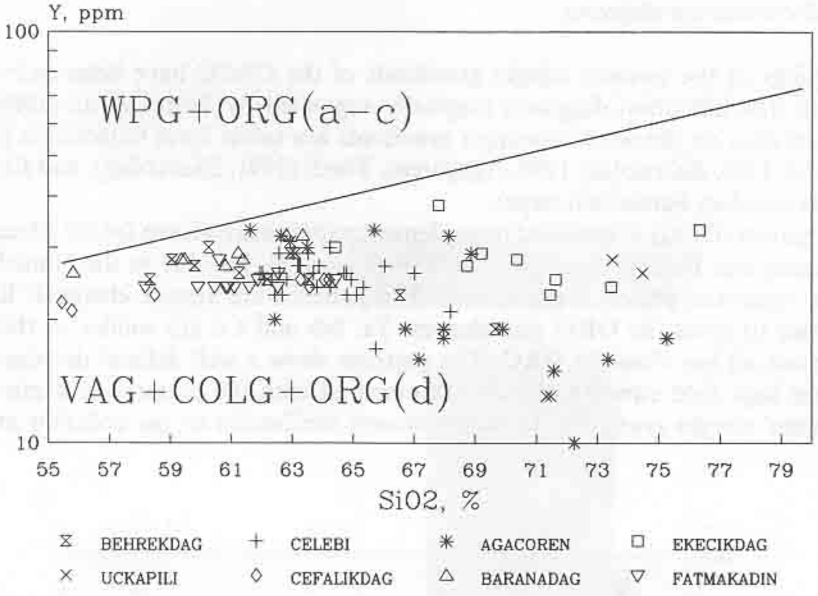

Figure 5. Y–Si02 discrimination diagram for the western margin granitoids of the CACC

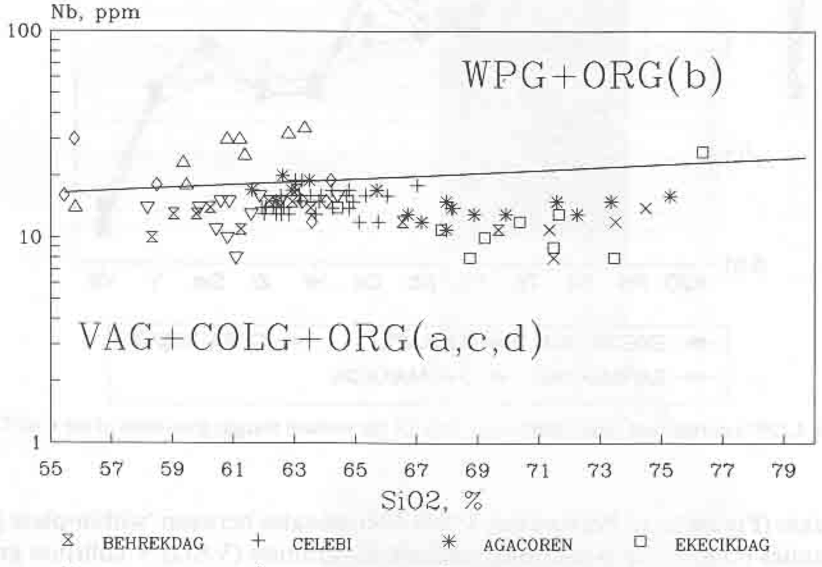

Figure 6. Nb–Si02 discrimination diagram for the western margin granitoids of the CACC

western margin granitoids define a linear trend which crosses from the VAG field to the synCOLG field. This type of pattern has been cited as representing a probable post-collision origin (Pearce *et al.* 1984).

The Nb–Y diagram (Figure 3a of Pearce *et al.* 1984) discriminates between WPG, ORG and VAG+synCOLG. On this diagram (Figure 8), most of the western margin granitoids plot in the VAG+synCOLG field, close to the triple junction of the discrimination pattern. There are a few exceptions which are from the Baranadağ intrusion.

The Rb–(Y+Nb) diagram (Figure 4a of Pearce *et al.* 1984) discriminates between synCOLG, VAG,

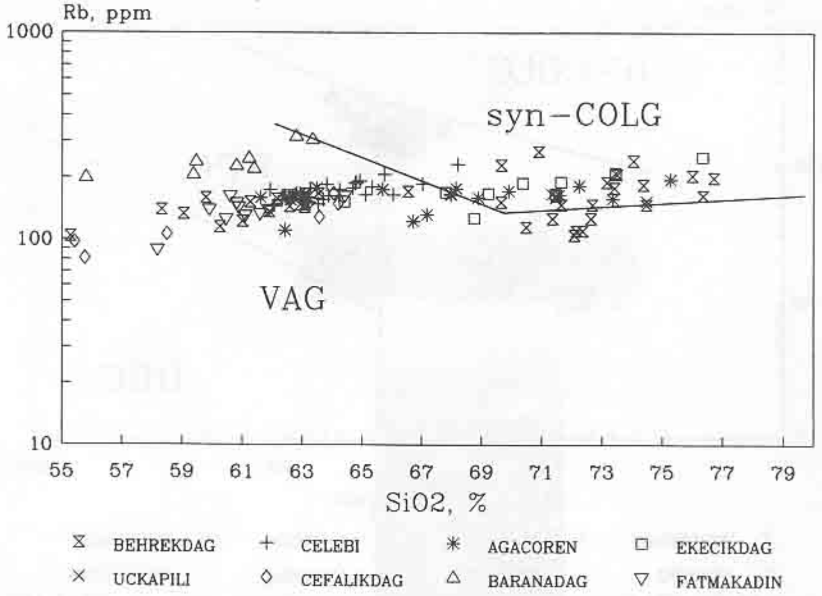

Figure 7. Rb–Si02 discrimination diagram for the western margin granitoids of the CACC

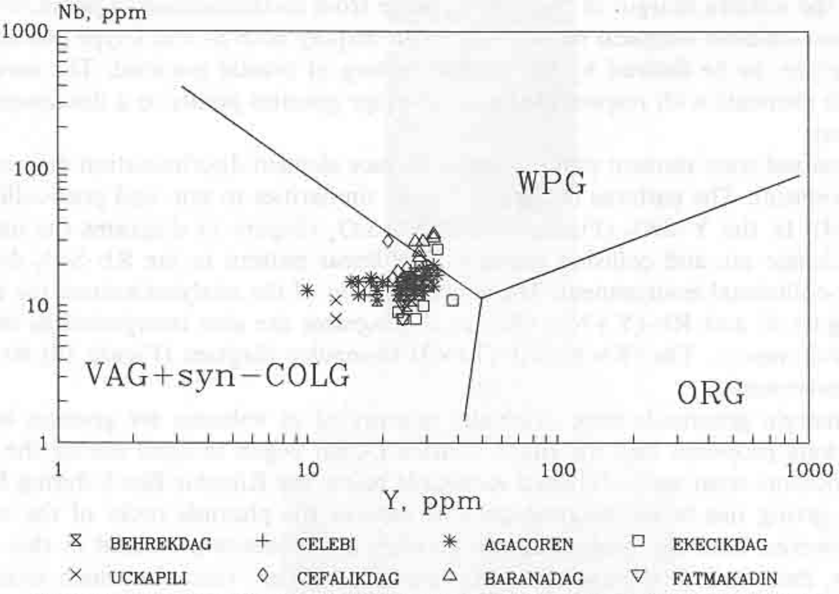

Figure 8. Nb–Y discrimination diagram for the western margin granitoids of the CACC

WPG and ORG. On this diagram (Figure 9), all the western margin granitoids plot around the triple junction between VAG, synCOLG and WPG, and all are on the VAG and WPG sides.

The (Rb/30)–Hf–(Ta × 3) triangular diagram (Figure 6 of Harris *et al.* 1986) discriminates between VAG, syn-collision granites (GR-II), post-collision granites (GR-III) and WPG. On this diagram (Figure 10), only five plutons are shown due to the limited amount of available data. Most of the western margin granitoids plot in the GR-III field (post-collision granites), close to the triple junction between VAG, GR-II and GR-III, with a slight overlap into the VAG and GR-II fields.

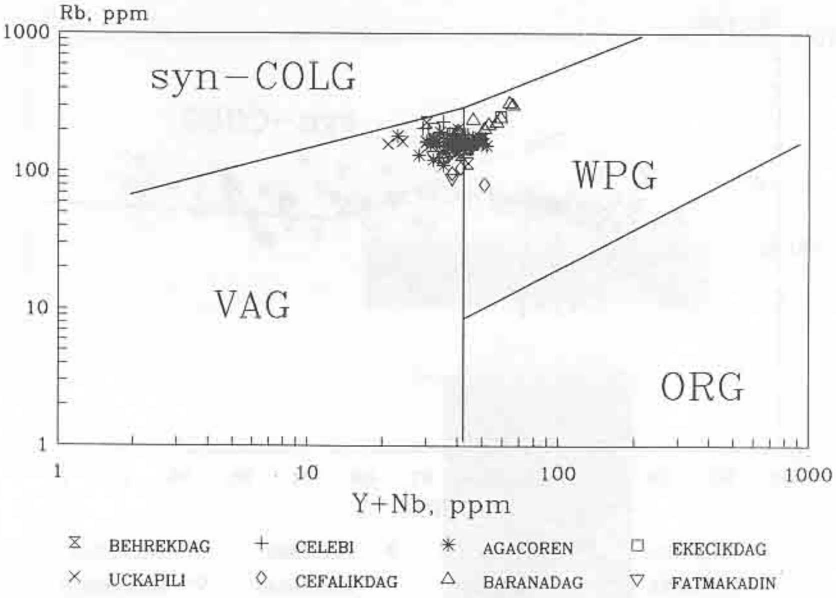

Figure 9. Rb–(Y + Nb) discrimination diagram for the western margin granitoids of the CACC

## 5. DISCUSSION

The granitoids of the western margin of the CACC range from metaluminous to peraluminous and have cafemic and alumina–cafemic chemical trends. They also display both S- and I-type characteristics. They are believed, therefore, to be derived by the partial melting of crustal material. The enrichment in the large ion lithophile elements with respect to the ocean ridge granites points to a dominant source within the continental crust.

The ORG normalized trace element patterns and the trace element discrimination diagrams all indicate a collisional environment. The patterns in Figure 4 show similarities to syn- and post-collisional granites (Pearce *et al.* 1984). In the Y–$SiO_2$ (Figure 5) and Nb–$SiO_2$ (Figure 6) diagrams the analyses all plot in the fields of volcanic arc and collision granites. The linear pattern in the Rb–$SiO_2$ diagram (Figure 7) indicates a post-collisional environment. The concentrations of the analyses around the triple junctions on the Nb–Y (Figure 8) and Rb–(Y + Nb) (Figure 9) diagrams are also interpreted as indications of a post-collisional environment. The (Rb/30)–Hf–(Ta × 3) triangular diagram (Figure 10) strongly suggests a post-collisional environment.

These western margin granitoids were originally interpreted as volcanic arc granites by Görür *et al.* (1985). These workers proposed that the Inner Tauride Ocean began to open during the Early Jurassic and the resulting oceanic crust was subducted eastwards below the Kirşehir Block during Maastrichtian–Palaeocene times, giving rise to the magmatism now seen as the plutonic rocks of the western margin of the CACC. However, both the geological and geochemical evidence presented in this review dispute this model. Firstly, there is little evidence for the presence of the arc volcanics which should accompany this plutonism. Secondly, the mafic intrusions which are often associated with such arc granitoids (Pitcher 1978) are not known to exist. The mafic rocks (gabbro and diabase) which are observed are tholeiitic (Önen and Unan 1988; Türeli 1991) rather than of calc-alkaline affinity and are occasionally associated with ultramafic rocks (peridotite and pyroxenite). They are therefore interpreted to be ophiolitic fragments. Thirdly, the trace element data indicate a collisional rather than a volcanic arc environment; and fourthly, the plutons are older than the Maastrichtian age required by the model of Görür *et al.* (1985).

We therefore propose that the western margin granitoids of the CACC were formed by a two-stage collision process: (1) an island arc, formed within the İzmir–Ankara–Erzincan oceanic crust by northward intraoceanic subduction, collided with the northernmost promontory of the Tauride–Anatolide platform

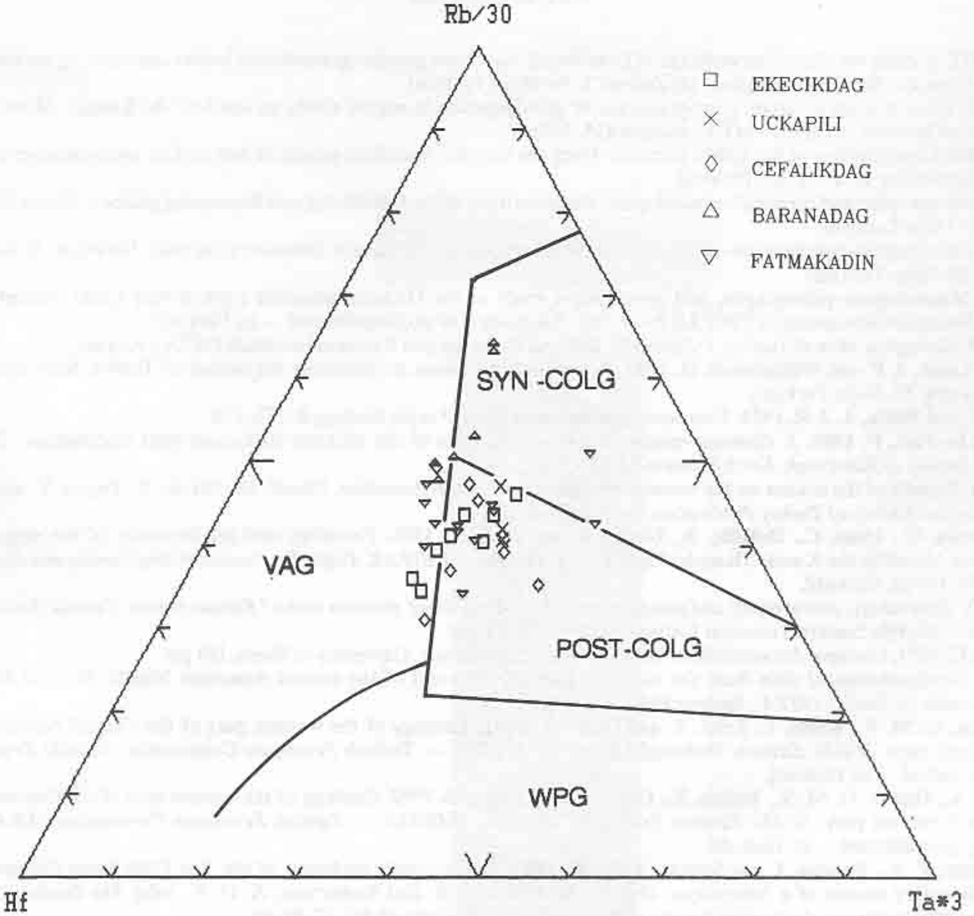

Figure 10. (Rb/30)–Hf–(Ta × 3) triangular discrimination diagram for the western margin granitoids of the CACC

causing (a) overthrusting of ophiolitic slabs onto the platform, indicated by the high temperature–low pressure metamorphism and (b) the formation of the syn-collision granitoids; and (2) the Sakarya continent, representing the northern continental block, then collided with the western edge of the promontory, causing the formation of both syn- and post-collision granitoids.

The regional geological evidence, which indicates a pre-Upper Cretaceous collision of the Tauride–Anatolide platform with the Pontides and/or the Sakarya continent (Çapan *et al.* 1983; Okay 1989; Tekeli *et al.* 1991) is entirely consistent with this model.

## 6. CONCLUSIONS

The principal conclusions of this review are: (1) the western margin granitoids of the CACC are dominantly of monzogranite/quartz monzonite to granodiorite/quartz monzodiorite composition — they are metaluminous to peraluminous in nature and possess cafemic and alumina–cafemic chemical trends; (2) the granitoids display both S- and I-type characteristics and they are principally derived from the continental crust; and (3) the granitoids most probably formed in a collisional environment, where partial melting took place in a shortened and thickened crust and were then emplaced in a continental platform metamorphosed by ophiolite obduction and collision.

# REFERENCES

**Ataman, G. 1972.** A study on the radiometric age of Cefalikdağ, one of the granite–granodiorite bodies outcropping on the south-east of Ankara. *Hacettepe Science and Engineering Journal* **2**, 44–49 [in Turkish].

**Ayan, M. 1963.** Contribution a l'etude petrographique et géologique de la region située au nord-est de Kaman. *Mineral Research and Exploration Institute of Turkey (MTA) Bulletin* **115**, 332pp.

**Bayhan, H. 1986.** Geochemistry of the Çelebi intrusion from the Central Anatolian granitoid belt and an interpretation of its origin. *Geological Engineering* **29**, 27–35 [in Turkish].

**—— 1987.** Petrographic and chemical–mineralogical characteristics of the Cefalikdağ and Baranadağ plutons. *Geological Engineering* **30–31**, 11–16 [in Turkish].

**—— 1989.** Petrographic and chemical–mineralogical characteristics of the Keskin intrusion (Ankara). *Hacettepe University Earth Sciences* **15**, 29–36 [in Turkish].

**—— 1990.** Mineralogical–petrographic and geochemical study of the Ortaköy granitoid (east of Salt Lake) located within the 1st Turkish National Geotraverse. *TÜBITAK Project no. TBAG-841*, 68 pp [unpublished — in Turkish].

**Bingöl, E. 1989.** *Geological Map of Turkey, 1:2,000,000.* Mineral Research and Technical Institute (MTA), Ankara.

**Çapan, U. Z., Lauer, J. P. and Whitechurch, H. 1983.** An important element to determine the closure of Tethys. *Hacettepe University Earth Sciences* **10**, 35–34 [in Turkish].

**Chappell, B. W. and White, A. J. R. 1974.** Two contrasting granite types. *Pacific Geology* **8**, 173–174.

**Debon, F. and Le Fort, P. 1983.** A chemical–mineralogical classification of the plutonic rocks and their associations. *Transactions of the Royal Society of Edinburgh, Earth Sciences* **73**, 135–149.

**Erkan, Y. 1981.** Results of the studies on the metamorphism of the Central Anatolian Massif. *In*: Akkök, R., Oygür, V. and Terlemez, I. (eds) *Geological Society of Turkey Publication*, 9–11 [in Turkish]

**Erler, A., Akiman, O., Unan, C., Dalkiliç, B., Geven, A. and Önen, P. 1991.** Petrology and geochemistry of the magmatic rocks of the Kirşehir Massif in the Kaman (Kirşehir) and Yozgat regions. *TÜBITAK, Doğa-Tr. Journal of Engineering and Environmental Science* **15**, 76–100 [in Turkish].

**Geven, A. 1992.** *Mineralogy, petrography and geochemistry of the Cefalikdağ plutonic rocks (Kaman region, Central Anatolia).* Ph.D. Thesis, METU (Middle Eastern Technical University), Ankara, 165 pp.

**Göncüoğlu, M. C. 1977.** *Geologie des westlichen Niğde Massivs.* Ph.D. Thesis, University of Bonn, 181 pp.

**—— 1986.** Geochronological data from the southern part (Niğde area) of the central Anatolian Massif. *Mineral Research and Technical Institute of Turkey (MTA) Bulletin* **105/106**, 83–96.

**——, Toprak, G. M. V., Kuşçu. I., Erler, A. and Olgun, E. 1991.** Geology of the western part of the Central Anatolian Massif. Part 1: southern part. *Middle Eastern Technical University (METU) — Turkish Petroleum Corporation (TPAO) Project Report*, 140 pp [unpublished — in Turkish].

**——, Erler, A., Toprak, G. M. V., Yaliniz, K., Olgun, E. and Rojay, B. 1992.** Geology of the western part of the Central Anatolian Massif. Part 2: central part. *Middle Eastern Technical University (METU) — Turkish Petroleum Corporation (TPAO) Project Report*, 76 pp [unpublished — in Turkish].

**Görür, N., Oktay, F. Y., Seyman, I. and Şengör, A. M. C. 1985.** Paleotectonic evolution of the Tuz Gölü Basin Complex, Central Turkey, sedimentary record of a Neotethyan closure. *In*: Dixon, J. E. and Robertson, A. H. F. (eds) *The Geological Evolution of the Eastern Mediterranean. Geological Society of London Special Publication No. 17*, 81–96.

**Harris, N. B. W., Pearce, J. A. and Tindle, A. G. 1986**. Geochemical characteristics of collision zone magmatism. *In*: Coward, M. P. and Ries, A. C. (eds) *Collision Tectonics. Geological Society of London Special Publication No. 19*, 67–81.

**Kadioğlu, Y. K., 1991.** *Geology, petrography and geochemistry of Ağaçören (Aksaray) magmatic rocks.* M.S. Thesis, Middle Eastern Technical University, Ankara, 141 pp.

**Ketin, I. 1963.** *Explanatory Text of the 1/500,000 Scale Geologic Map of Turkey, Kayseri Quadrangle.* Maden ve Teknik Arama [Mineral Research and Technical Institute (MTA)], Ankara, 83 pp.

**—— 1966.** Tectonic units of Turkey. *Mineral Research and Technical Institute Bulletin* **66**, 20–34. [in Turkish].

**Lünel, A. T. 1985.** An approach to the naming, origin and age of Baranedağ Monzonite of the Kirşehir Intrusive Suite. *Middle Eastern Technical University Journal of Pure & Applied Science* **18**, 385–404.

**Okay, A. 1989.** Tectonic units and sutures in the Pontides, Northern Turkey. *In*: Şengor, A. M. C. (ed) *Tectonic Evolution of the Tethyan region.* Kluwer Academic, Dordrecht, pp. 109–116.

**Önen, P. and Unan. C. 1988.** Mineralogy, petrography and geochemistry of the gabbros northeast of Kaman (Kirşehir). *Bulletin of the Geological Society of Turkey* **31**, 23–28 [in Turkish].

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

**Pitcher, W. S. 1978.** The anatomy of a batholith. *Journal of the Geological Society of London* **135**, 157–182.

**Seymen, I. 1982.** *Geology of the Kirşehir massif around Kaman.* D.Sc. Thesis. Istanbul Technical University Faculty of Mines, 164 pp [unpublished — in Turkish].

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

**—— and Le Maitre, R. W. 1979.** A chemical approximation to the modal QAPF classification of the igneous rocks. Neues Jahrbuch für Mineralogie, Abhandlung, **136**, 169–206.

**Tekeli, O., Varol, B., Gökten, E., Yildiz, M. and Özaksoy, V. 1991.** Geology of the Karaçayir and eastern part of the Akdağ Massif (area between Yildizeli, Sivas and Hafik). *Turkish Petroleum Corporation (TPAO) Report 3001*, 86 pp [unpublished — in Turkish].

**Türeli, T. K. 1991.** *Geology, petrography and geochemistry of Ekecidağ plutonic rocks (Aksaray region — Central Anatolia).* Ph.D. Thesis, Middle Eastern Technical University, Ankara, 194 pp.

**Yadete, H. M. 1990.** *Rock geochemical exploration in intrusive rocks of Behrekdağ area (Celebi — Kirikkale).* M.S. Thesis. Middle Eastern Technical University (METU), Ankara, 120 pp.