International Geology Review, Vol. 38, 1996, p. 714–726.

Geologic and Tectonic Setting of the Yozgat Batholith, Northern Central Anatolian Crystalline Complex, Turkey[1]

AYHAN ERLER AND M. CEMAL GÖNCÜOGLU

Department of Geological Engineering, Middle East Technical University, 06531 Ankara, Turkey

Abstract

The Yozgat Batholith lies along the northern edge of the Central Anatolian Crystalline Complex in Central Anatolia, Turkey. The batholith intruded the Paleozoic–Mesozoic metamorphics and Cretaceous ophiolitic mélange, and was nonconformably overlain by latest Maastrichtian–Paleocene and/or Eocene clastics, carbonates, and volcanics. The batholith itself may be subdivided into several mappable subunits bounded by Cretaceous ophiolitic mélange, Eocene cover, and/or faults.

Major- and trace-element as well as REE analyses of the subunits indicate that the granitoids of the Yozgat Batholith are principally metaluminous monzogranites, of subalkaline-calcalkaline character, except for the peraluminous leucogranitoids of the Yozgat subunit. The granitoids were derived by thickening of the continental crust and related partial melting; the thickening was caused by emplacement of ophiolitic nappes during collisional events.

Introduction

THE ASSEMBLAGE OF magmatic, metamorphic, and ophiolitic rocks in Central Anatolia east and southeast of Ankara commonly is refered to as the Central Anatolian Crystalline Complex (CACC) (Göncüoglu et al., 1991, 1992, 1993; Akiman et al., 1993). The assemblage also is called the Central Anatolian Massif (Erkan, 1981), the Kirsehir Massif (Seymen, 1982), and the Kirsehir Complex (Lünel, 1985). The Complex lies in a triangular area demarcated by a line connecting the settlements of Sulakyurt, Yozgat, Sivas, Kayseri, Nigde, and Aksaray. Geologically it is bounded by the Tuzgölü fault to the west, the Ecemis fault to the east, and the Izmir-Ankara-Erzincan suture to the north (Fig. 1).

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, including granitoids and syenitoids. These rocks are generally overlain by latest Maastrichtian–Paleocene and/or Eocene volcanics, clastics, and carbonates, Miocene evaporites and clastics, and Plio-Quaternary continental clastics.

The Central Anatolian Granitoids (CAG) are an assemblage of plutonic rocks that may reach batholithic dimensions and that principally intrude into, and locally assimilate, the metamorphic units and the ophiolites thrust over them. The granitoid types also display intrusive relationships among one another. Within the granitoids, metamorphic rock and mafic rock enclaves, mafic mineral segregations, and fragments of older granitoids are observed. The granitoids in the CACC, in general, are grouped according to physical features identified in the field as: (1) two-mica leucogranites; (2) biotite/hornblende granites; (3) alkali-feldspar megacryst granites; (4) granodiorites; (5) tonalites; and (6) aplitic dikes. Leucogranites are probably the oldest group; their outcrops, except for occasional fresh ones, are generally more altered than those of the other groups and they intrude into the mafic units and locally display assimilation features. Biotite/hornblende granites are observed in four settings: (1) as dikes cutting the mafic units, leucogranites, and alkali-feldspar megacryst granites; (2) as the transitional phase resulting from assimilation between mafic units and leucogranites or alkali-feldspar megacryst granites; (3) as the border phase of the alkali-feldspar megacryst granites; and (4) as outcrops of various dimensions. Alkali-feldspar megacryst granites are the most widespread group, with extensive outcrops, sometimes reaching batholithic dimensions. Tonalites are observed locally, generally

[1]Paper initially presented at the Second International Turkish Geology Symposium, Cumhuriyet University, Sivas, Turkey; Orhan Tatar, Convention Editor.

0020-6814/96/202/714-13 $10.00

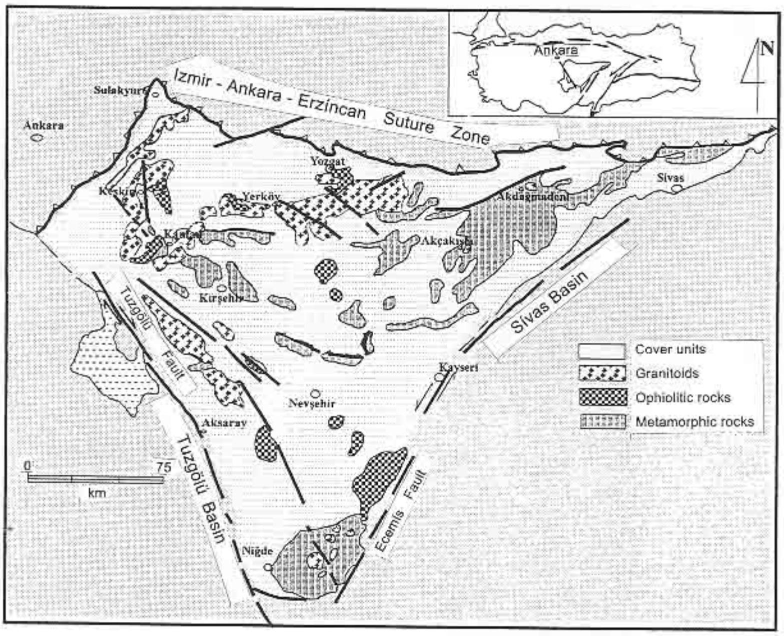

FIG. 1. Simplified geological setting of the CACC (modified from Bingöl, 1989).

close to the boundaries with the mafic units. Aplitic alkali-feldspar granites are the youngest group, and are observed as dikes and, locally, dike swarms cutting other groups. The granitoids of the CACC can be subdivided geographically into three belts (Erler et al., 1991): (a) a NE-SW to NW-SE curved zone covering large outcrop areas along the western margin, which was reviewed by Akiman et al. (1993); (b) a relatively small set of disconnected plutons extending along the eastern margin; and (c) a very large batholith along the northern margin—the Yozgat Batholith.

The Yozgat Batholith is the largest granitoid outcrop within the CACC; it underlies an area bounded by a line connecting Yerköy on northwest, Yozgat on north, Sorgun on northeast, Akbucak on the southeast, and Sefaatli on southwest, and it has a WSW-ENE trend. The geology of the Yozgat Batholith and its surroundings has been studied by Ketin (1955), who concluded that the plutonic rocks, post–Late Cretaceous to pre-Lutetian in age, intruded the metamorphic rocks. The fluorite veins and the surrounding granitoids northwest of Sefaatli were studied by Bayramgil (1953), and the geology, petrography, and geochemistry of the region to south of Yozgat were analyzed by Dalkilic (1985), Dalkilic and Erler (1986), and Erler et al. (1989, 1991). The geology of the region around Sefaatli was studied by Karatas (1985), and the petrography and geochemistry of the granitoids of the eastern Yozgat Batholith (outcropping south of Sorgun) are being investigated currently by Boztug (unpubl. data).

The geological features of the Yozgat Batholith and the surrounding areas were mapped during the 1992 and 1993 field seasons. Petrographic studies were performed at the Middle East Technical University (METU), and geochemical analyses at the laboratories of METU, the University of Nevada, Reno, and the University of Keele. In this paper we have compiled preliminary results of geological, petrological, and geochemical work in progress in order to interpret the tectonic setting of the northern-margin granitoids of the CACC and thus the geodynamic evolution of the passive margin of the Tauride-Anatolide Platform during the closure of the Izmir-Ankara-Erzincan Ocean, one of the most prominent branches of the Eastern Mediterranean Tethys.

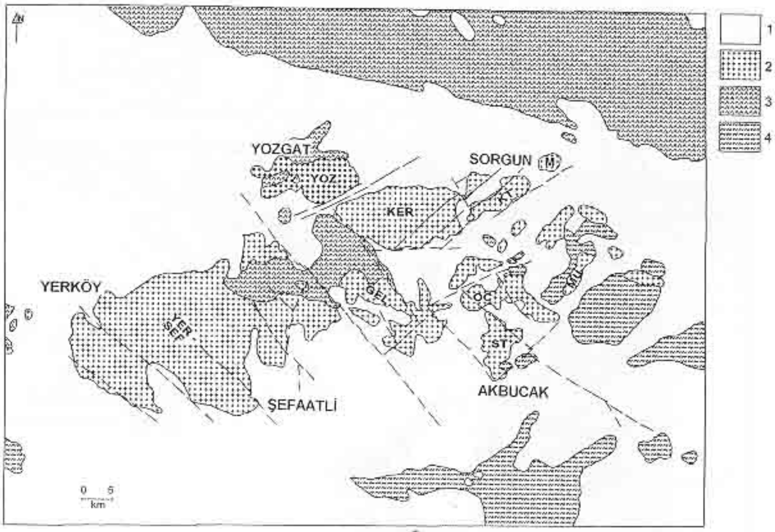

FIG. 2. Simplified geological map of the Yozgat Batholith. Legend: 1 = cover units; 2 = granitoids; 3 = ophiolitic units; 4 = metamorphic units. Subunits: YER-SEF = Yerköy-Sefaatli; YOZ = Yozgat; KER = Kerkenez; KT = Karlitepe; M = Mükremin; GEL = Gelingüllü; OC = Ocakli; ST = Sivritepe; MU = Mugalli.

Geology and Petrography

The Yozgat Batholith is subdivided into eight outcrop units on the basis of: (1) structural features; (2) units at the boundaries; and (3) textural-mineralogical features. These units are, from west to east: (1) Yerköy-Sefaatli; (2) Yozgat; (3) Kerkenez; (4) Karlitepe; (5) Gelingüllü; (6) Sivritepe; (7) Ocakli; and (8) Mugalli (Fig. 2). The outcrops of the Yozgat Batholith are generally relatively fresh, although locally they are quite altered.

According to modal classification (Streckeisen, 1967), the Yerköy-Sefaatli granitoid is a monzogranite, the Yozgat granitoids are monzogranites and tonalites, the Kerkenez granitoids are monzogranites, the Ocakli granitoids are monzogranites and quartz monzonites, the Gelingüllü granitoids are syenogranites and monzogranites, and the Sivritepe granitoids are monzogranites and quartz monzonites (Fig. 3). Average modal compositions of the subunits of the Yozgat Batholith are shown in Table 1.

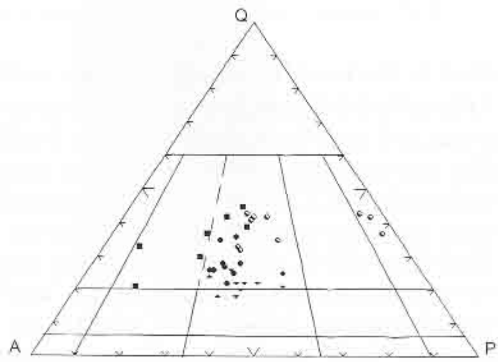

FIG. 3. Q-A-P modal classification of the granitoids from the Yozgat Batholith. Symbols: diamonds = Yerköy-Sefaatli; half-filled circles = Yozgat; filled circles = Kerkenez; open circles = Karlitepe; triangles = Ocakli; squares = Gelingüllü; inverted triangles = Sivritepe.

Yerköy-Sefaatli granitoid

The Yerköy-Sefaatli granitoid is located in the southwestern portion of the Yozgat Batholith; it crops out to the southwest and northeast of the Yerköy-Sefaatli line and encompasses ~400 km^2. This group was not studied in detail because of accessibility problems; it is probable that it may be subdivided into two or more subunits. The unit consists mainly of hornblende ($\pm$ biotite) granitoids (HBG). Biotite or hornblende is dominant locally; HBG locally displays a transition to alkali-feldspar megacryst granitoids (MKG). Around Sefaatli and Lökköy, MKG crop out. Within the MKG near Sefaatli there are rare microcrystalline mafic enclaves; the unit also is cut by alkali-feldspar

TABLE 1. Average Modal Analyses of the Subunits of the Yozgat Batholith

Mineral	Subunits						
	Yerköy-Sefaatli	Yozgat	Kerkenez	Karlitepe	Ocakli	Gelingüllü	Sivritepe
Plagioclase	27	29	27	n.a.	24	17	30
Orthoclase	32	29	38	n.a.	39	38	33
Quartz	30	35	24	n.a.	17	30	19
Hornblende	3	1	5	n.a.	11	7	8
Biotite	4	3	–	n.a.	4	5	2
Muscovite	–	–	–	n.a.	1	1	–
Opaque	1	2	3	n.a.	1	1	4
Zircon	1	–	–	n.a.	–	–	–
Sphene	1	–	2	n.a.	3	1	4
Augite	–	–	1	n.a.	–	–	–
Apatite	1	1	–	n.a.	–	–	–
Total	100	100	100	n.a.	100	100	100
P	30	32	31	n.a.	30	20	37
A	36	30	43	n.a.	49	45	40
Q	34	38	26	n.a.	21	35	23
Name[1]	MG	MG	MG		MG	MG	MG

[1]MG = monzogranite; P = plagioclase; A = alkali feldspar; Q = quartz; n.a. = not analyzed.

granite dikes with porphyritic textures and by quartz veins. On the north, west, and south, the Yerköy-Sefaatli granitoid is surrounded by conglomerates-sandstones-limestones-marls of the Eocene Mucur Formation, Eocene basalts, and Miocene–Pliocene cover units (Kizilirmak Group); on the east, it is separated from the Yozgat and Gelingüllü granitoids by outcrops of ophiolitic mélange and a NW-SE–trending fault. NW-SE–trending faults caused shearing within the Yerköy-Sefaatli granitoid; mylonitic bands are common along the Yerköy-Sefaatli line. Outcrops generally are fresh, but locally are extremely altered. A few samples collected around the fluorite occurrence northwest of Sefaatli were studied by Bayramgil (1953); they were described as hypidiomorphic-granular biotite-hornblende granodiorite, hornblende (± biotite) granite, hornblende (± biotite) tonalite, and hornblende monzonite. Several samples collected around Sefaatli were studied by Karatas (1985); they were described as hypidiomorphic-granular hornblende-biotite granites and granodiorites. The principal minerals are orthoclase, plagioclase, quartz, biotite and/or hornblende; uralitized clinopyroxene (augite), opaque minerals, zircon, sphene, and apatite are present as accessories.

Yozgat granitoid

The Yozgat granitoid constitutes the northern part of the Yozgat Batholith, encompassing an area of ~40 km^2. Close to its northern edges, garnet (± biotite)-bearing leucogranites are observed. Gabbros occur along the northern and western boundaries, as well as in the form of blocks within the unit. The southwestern and southeastern boundaries are faulted. Dikes of alkali-feldspar granite and diorite and quartz veins cross the granitoid. The Yozgat granitoid is surrounded primarily, and is unconformably overlain, by Eocene sandstones–sandy limestones–limestones with intercalations of conglomerates. Eocene basalts locally cover the granitoid on its western and southern margins.

The samples studied by Erler et al. (1989) are described as granites, granodiorites, and tonalites. The principal minerals are quartz, plagioclase, and orthoclase. Varying amounts of hornblende and biotite are present; however, the unit is relatively poor in mafic minerals and may be considered as a leucogranitoid. Accessories are apatite and opaque minerals.

Kerkenez granitoid

The Kerkenez granitoid is located along the northeastern part of the Yozgat Batholith; it encompasses an area of ~130 km^2. The unit consists principally of HBG; hornblende almost always is more abundant than the biotite. Along the northwestern portions of the granitoid, HBG display a transition to MKG. The unit is crossed by several NE-SW–trending fractures in the northeast. Around its southeastern margins, extensive mylonitization and epidote-filled fractures are observed in faulted rocks. The northwestern, southwestern, and southern boundaries are faulted as well. An upper Cretaceous pink pelagic limestone-radiolarite-basalt-diabase assemblage of ophiolitic mélange occurs along its western and southern borders; along its southern boundaries, outcrops are few, but skarns and hornfelses are present.

In its southeastern portion, thin aplitic dikes cut the granitoid. The granitoid is bounded by the ophiolitic mélange on the west and southwest and is covered by Eocene (?) andesites and sandstones on the south and by an Eocene sandstone-marl alternation on the north.

The samples studied by Yardimcilar (1995) are described as granites and quartz monzonites. Principal minerals are quartz, orthoclase, plagioclase, and hornblende. Clinopyroxenes are present in small amounts; accessories are sphene, allanite, zircon, garnet, apatite, and opaque minerals.

Karlitepe granitoid

The Karlitepe granitoid is located on the northeastern margin of the Yozgat Batholith; it covers an area of ~20 km^2. The unit consists principally of fine-grained felsic rock and hornblende granite; locally it includes mylonitic bands. Fine-grained felsic rock appears to be the shallow facies of the granitoid. The Karlitepe granitoid is bounded by NE-SW–trending faults; it is covered by Eocene conglomerates-sandstones and Miocene–Pliocene continental clastics; along the eastern edge, andesitic-dacitic-rhyolitic volcanics overlie the granitoid, and the volcanics are overlain by Eocene conglomerates and sandstones; on the northern edge, an Eocene marl-lignite-sandstone containing a fragmented volcanic rock–bituminous marl assemblage is found.

Ocakli granitoid

The Ocakli granitoid is situated in the eastern part of the Yozgat Batholith; it crops out as several blocks, and covers ~50 km^2. The unit consists principally of HBG and hornblende quartz monzonite. The HBG include a small amount of alkali-feldspar megacrysts in the west. The Ocakli granitoid intrudes the metamorphic units along the north and east; silicification and recrystallization are observed along the boundary with the marbles with graphite flakes. The unit is cut by quartz veins and by aplitic alkali-feldspar granites. Individual outcrops of the unit are surrounded by Miocene–Pliocene continental clastics.

Principal minerals in the samples are quartz, orthoclase, and plagioclase. Hornblende, biotite, and muscovite are present in varying amounts, with sphene and opaque minerals as accessories.

Gelingüllü granitoid

The Gelingüllü granitoid occupies the southeastern part of the Yozgat Batholith, covering ~70 km^2. The unit consists principally of HBG; hornblende is commonly more abundant than biotite. The rocks rarely include enclaves; feldspars locally display lineation. In the northwestern outcrops, MKG is observed; here, NW-SE–trending faults, shear zones, and mylonitic bands also occur. The northern and western boundaries are with units of the Central Anatolian ophiolite (basalt-diabase-gabbro-serpentinized peridotite). Quartz syenitic and aplitic dikes cross the granitoid. The central parts of the unit are weathered more extensively and are covered by Miocene–Pliocene weakly consolidated continental clastics. The unit is unconformably overlain by an Eocene fossiliferous (nummulitic) gray-white tuffaceous sandstone–light brown sandy limestone–yellowish brown sandstone assemblage on its southwestern edges; basaltic lava flows are observed locally within the Eocene sediments. The southern edge is covered by the continental clastics of the Kizilirmak Group.

Samples studied by Güldogan (1995) are described as granites; the principal minerals are quartz, orthoclase, and plagioclase. Hornblende, biotite, and muscovite are present in varying amounts, with sphene and opaque minerals as accessories.

Sivritepe granitoid

Sivritepe granitoid constitutes the southeastern edge of the Yozgat Batholith, covering ~30 km^2. The unit consists mainly of HBG.

TABLE 2. Major-Element Chemical Analyses of the Yozgat Batholith, wt%

Sample no.	Type[1]	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
CANK-1A	GRD	66.21	0.46	13.75	4.77	0.00	1.72	4.69	3.31	3.84	n.a.	0.97	99.72
CANK-2A	QD	58.92	0.51	16.26	6.46	0.00	3.07	7.45	3.54	3.08	n.a.	0.66	99.95
Y-1	GR	73.93	0.26	13.77	3.48	0.07	0.06	0.34	3.10	4.48	0.09	0.33	99.91
Y-5	GR	75.05	0.06	13.59	1.11	0.10	0.19	0.50	3.66	4.53	0.03	0.79	99.61
Y-10	GR	74.99	0.04	14.43	0.58	0.02	0.07	0.46	3.90	4.77	0.02	0.27	99.55
Y-16	TO	74.98	0.11	14.05	1.47	0.03	0.28	0.94	7.03	0.34	0.03	0.75	100.01
Y-22	GR	75.97	0.04	14.25	0.03	0.10	0.02	0.49	4.05	4.35	0.02	0.66	99.98
Y-29	TO	74.85	0.14	13.51	1.89	0.03	0.25	0.79	7.04	0.67	0.02	0.84	100.03
Y-57	GRD	70.89	0.31	14.40	2.70	0.09	1.63	0.46	3.81	2.16	0.02	3.08	99.55
Y-89	GRD	71.24	0.20	15.12	2.46	0.11	0.83	1.82	3.97	3.68	0.06	0.52	100.01
Y-122	TO	65.56	0.52	14.55	6.43	0.22	1.99	2.91	6.40	0.57	0.22	0.59	99.96
Y-124	GR	74.97	0.15	15.25	2.37	0.04	0.17	0.30	3.46	3.76	0.03	0.33	100.83
KERK-7	GR	68.88	0.79	15.18	3.56	0.06	0.44	3.00	2.84	5.19	0.17	0.38	100.49
KERK-23	GR	68.95	0.57	14.69	3.28	0.05	0.46	2.21	3.13	5.44	0.13	1.08	99.99
KERK-28	GR	68.95	0.76	15.29	3.15	0.05	0.34	3.16	2.58	5.14	0.11	0.45	99.98
KERK-29	GR	69.33	0.72	15.48	3.30	0.09	0.45	2.69	2.83	5.46	0.13	0.48	100.96
KERK-62	GR	68.60	0.44	16.18	3.84	0.09	0.60	3.31	2.74	4.52	0.12	0.40	100.84
KERK-63	GR	68.65	0.53	15.93	3.36	0.06	0.69	3.76	2.57	3.75	0.15	0.57	100.02
KERK-64	GR	70.82	0.37	14.84	3.19	0.03	0.49	2.99	2.32	4.20	0.15	0.61	100.01
KERK-65	GR	67.33	0.96	15.47	3.74	0.12	0.71	3.93	2.79	4.65	0.10	0.55	100.35
KERK-66	GR	67.60	0.86	15.75	3.76	0.06	0.48	3.69	3.07	4.68	0.11	0.60	100.66
KARLI-3A	M	62.29	0.50	13.96	4.57	0.05	1.94	8.57	3.29	5.57	0.03	0.21	100.98
OCAK-34	GR	68.72	1.07	16.91	1.29	0.04	0.96	2.91	2.82	4.37	n.a.	0.92	100.01
OCAK-35	GR	66.60	1.17	16.07	1.86	0.12	1.85	3.23	3.14	5.23	n.a.	0.72	99.99
GELIN-3	QM	66.28	0.68	16.09	1.64	0.06	1.76	4.45	3.65	4.65	n.a.	0.75	100.01
GELIN-4	GR	68.78	0.98	14.89	1.63	0.06	1.45	3.84	2.87	4.20	n.a.	1.03	99.73
GELIN-17	GR	67.71	0.46	15.77	1.46	0.05	1.01	2.68	3.25	5.25	n.a.	2.32	99.96
GELIN-18	GR	72.26	0.77	14.37	1.70	0.07	1.01	3.08	2.45	4.38	n.a.	0.81	100.90
GELIN-19	GR	72.05	0.59	12.94	1.29	0.03	0.71	2.73	3.07	4.93	n.a.	2.14	100.48
GELIN-20	GR	68.60	1.09	17.14	1.34	0.06	0.75	2.71	2.58	4.85	n.a.	0.87	99.99
GELIN-22	GR	72.62	0.48	13.41	1.34	0.05	1.31	2.24	3.06	4.84	n.a.	0.66	100.01
SIVRI-10	QM	63.09	0.61	15.22	4.45	0.12	3.04	6.41	2.39	4.66	n.a.	0.58	100.57
SIVRI-11	M	61.52	1.08	16.23	4.19	0.10	1.10	7.12	3.02	5.64	n.a.	0.62	100.62
SIVRI-12	GR	65.05	0.80	16.72	3.31	0.07	0.42	4.54	2.97	4.81	n.a.	1.30	99.99
SIVRI-13	QM	66.24	0.54	15.17	4.01	0.09	1.12	4.70	3.27	4.85	n.a.	0.53	100.52
SIVRI-14	QM	63.91	0.70	16.11	4.44	0.09	1.27	5.34	3.37	4.77	n.a.	0.52	100.52
SIVRI-15	GR	69.86	0.83	14.67	3.24	0.08	0.77	3.09	2.73	4.73	n.a.	0.74	100.74
SIVRI-16	QM	64.35	1.07	16.52	4.08	0.09	1.06	4.45	3.22	5.14	n.a.	0.59	100.57

[1]GR = granite; QM = quartz monzonite; M = monzonite; GRD = granodiorite; QD = quartz diorite; TO = tonalite; n.a. = not analyzed.

Hornblende generally is more abundant than biotite; biotites are dominant only in the southern parts. The feldspars in granites display distinct lineation (N40°E or N45–50°W).

On the south, coarse-grained muscovite-bearing granite intrudes marbles and is intruded by fine-grained granodiorites with both metamorphic and granitic enclaves; monzogranites with lineated feldspars represent the youngest intrusion. The unit is surrounded and overlain by the continental clastics of the Kizilirmak Group.

Samples studied by Tokgöz (1995) are described as granites and quartz monzonites. The principal minerals are quartz, orthoclase, and plagioclase; hornblende is the only mafic mineral, except in one sample where biotite is the only mafic mineral. Accessories are sphene and opaque minerals.

Mugalli granitoid

The Mugalli granitoid crops out as a separate body east of the Yozgat Batholith and covers

TABLE 3. Trace-Element Analyses of the Yozgat Batholith, ppm

Sample no.	Type	Rb	Ba	Sr	Ga	Ta	Nb	Hf	Zr	Y	Th	U
Y-5	GR	606	139	17	n.a.	2.80	27.0	3.60	116	16	14.20	4.60
Y-10	GR	683	116	12	n.a.	2.80	31.0	3.30	134	14	14.40	5.00
Y-16	TO	137	143	90	n.a.	3.60	25.0	4.90	270	18	8.00	1.90
Y-22	GR	522	118	12	n.a.	2.80	22.0	3.60	171	12	16.80	4.20
Y-29	TO	158	104	50	n.a.	4.60	24.0	5.20	400	14	9.20	2.10
Y-89	GRD	230	187	103	n.a.	2.00	21.0	3.00	115	15	5.80	2.30
Y-122	TO	116	193	161	n.a.	2.20	9.0	9.30	83	12	14.20	0.80
KERK-29	GR	252	944	623	22	n.a.	18.0	n.a.	227	18	52.00	n.a.
KERK-63	GR	222	1150	725	21	n.a.	16.0	n.a.	248	17	53.00	n.a.
KERK-64	GR	202	1270	809	21	n.a.	16.0	n.a.	268	18	41.00	n.a.
KERK-65	GR	235	1317	937	22	n.a.	19.0	n.a.	287	18	48.00	n.a.
KERK-66	GR	231	1225	881	24	n.a.	19.0	n.a.	301	19	50.00	n.a.
SIVRI-10	QM	159	1028	1108	23	n.a.	25.0	n.a.	336	36	29.00	n.a.
SIVRI-11	M	190	1235	1456	22	n.a.	29.0	n.a.	283	34	24.00	n.a.
SIVRI-13	QM	189	895	1077	21	n.a.	24.0	n.a.	311	28	31.00	n.a.
SIVRI-14	QM	190	890	1037	22	n.a.	23.0	n.a.	303	27	33.00	n.a.
SIVRI-15	GR	185	1018	1067	22	n.a.	22.0	n.a.	287	26	42.00	n.a.
SIVRI-16	QM	197	1198	1226	23	n.a.	24.0	n.a.	293	28	41.00	n.a.

~15 km^2. The unit consists of hornblende granite. It intrudes metamorphic rocks on the south, and is covered by sandy-fossiliferous (nummulitic) limestones of the Eocene Mucur Formation on the north and east and by Miocene–Pliocene continental clastics on the west.

Mükremin syenitoid

The Mükremin syenitoid crops out northeast of Sorgun, encompassing around 5 km^2. The unit cuts hornblende granites, is crossed by rhyolitic dikes, and is covered by Miocene–Pliocene continental clastics. The principal components of the syenite are perthitic orthoclase, plagioclase, and hornblende. The rock is light gray–gray–pink in coloration, is medium grained (1–10 mm), and has a holocrystalline-granular texture.

Geochemistry

Analytical data for the Yozgat Batholith include: (1) 2 samples from the Yerköy-Sefaatli granitoid, collected around the fluorite occurrence northwest of Sefaatli (Bayramgil, 1953); (2) 10 samples from the Yozgat granitoid (Dalkilic, 1985; Erler et al., 1989); (3) 9 samples from the Kerkenez granitoid (Yardimcilar, 1995); (4) 1 sample from the area of the Karlitepe granitoid (Boztug, unpubl. data); (5) 2 samples from the Ocakli granitoid (Güldogan, 1995); (6) 7 samples from the Gelingüllü granitoid (Güldogan, 1995); and (7) 7 samples from the Sivritepe granitoid (Tokgöz, 1995) (Tables 2–4).

In the classification diagram of Debon and Lefort (1983) (Fig. 4) Yerköy-Sefaatli samples are granodiorite and quartz diorite, and they plot in the metaluminous region (Fig. 5). Yozgat samples plot in granite-adamellite-granodiorite-tonalite fields, dominantly in the peraluminous region. Kerkenez samples are granites and adamellites; they plot dominantly in the metaluminous field. The Karlitepe sample is a metaluminous monzonite. Ocakli samples are granite and adamellite; they are metaluminous and peraluminous. Gelingüllü samples are principally adamellites with a few samples in the neighboring fields of granite and quartz monzonite; they are principally metaluminous. Sivritepe samples are adamellites, quartz monzonites, and monzonites and plot in the metaluminous field. Analyses of almost all the samples studied plot in the subalkaline region on the TAS and in the calcalkaline region on the AFM diagram of Irvine and Baragar (1971) (Figs. 6 and 7).

The Kerkenez and Sivritepe samples plot in pre-plate collision and post-collisional uplift fields of the tectonic discrimination diagram of

TABLE 4. REE Analyses of Yozgat Batholith, ppm

Sample no.	Type	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Yb	Lu
Y-5	GR	85	131	11.0	39.00	5.80	1.50	6.70	0.60	8.10	1.30	3.80	4.30	0.30
Y-10	GR	121	132	9.9	42.00	7.00	2.10	5.20	0.50	5.50	1.70	3.80	2.30	0.20
Y-16	TO	124	134	13.0	42.00	6.10	2.00	7.30	0.90	8.20	1.90	4.90	4.70	0.30
Y-22	GR	111	126	6.3	39.00	6.50	1.20	4.00	0.40	6.80	1.30	3.40	3.20	0.20
Y-29	TO	89	146	17.0	37.00	10.00	2.00	4.90	0.90	6.00	1.70	5.70	4.50	0.30
Y-89	GRD	110	168	11.0	26.00	7.00	0.90	6.80	0.80	5.40	0.90	3.20	1.70	0.20
Y-122	TO	92	174	17.0	55.00	9.50	1.90	7.50	0.70	6.20	0.80	3.80	2.40	0.20
KERK-63	GR	57	80	n.a.	18.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
KERK-64	GR	66	98	n.a.	25.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
KERK-65	GR	61	100	n.a.	37.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
KERK-66	GR	57	108	n.a.	25.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
SIVRI-10	QM	70	138	n.a.	58.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
SIVRI-11	M	66	143	n.a.	44.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
SIVRI-13	QM	66	97	n.a.	28.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
SIVRI-14	QM	61	122	n.a.	55.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
SIVRI-15	GR	66	89	n.a.	32.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
SIVRI-16	QM	57	117	n.a.	37.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

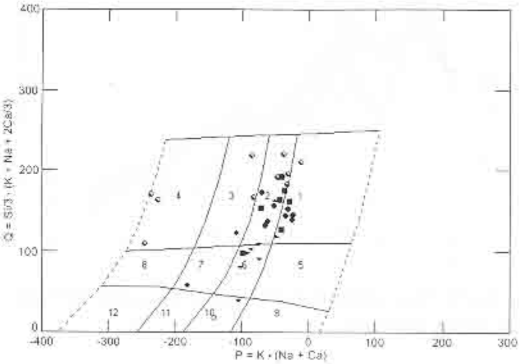

FIG. 4. Q-P classification of the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3. Modified from Debon and LeFort (1983, Fig. 1)

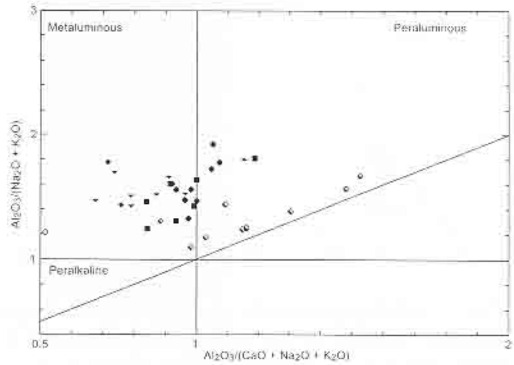

FIG. 5. Shand Index diagram (Maniar and Piccoli, 1989, Fig. 2) for the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3.

Batchelor and Bowden (1985) (Fig. 8). The ORG-normalized trace-element patterns for Kerkenez and Sivritepe samples (Fig. 9) are almost identical: K_2O, Rb, Ba, and Th all are more than 10 times the ORG abundances, resembling post-collision granites; Nb and Ce are similar to ORG, and Zr and Y are less than ORG. The Yozgat samples plot in a syn-collision field (Fig. 8). The ORG-normalized trace-element pattern (Fig. 9) of this group with peaked abundances for K_2O, Rb, and Th also resembles syn-collision granites if compared with the patterns given in Pearce et al. (1984, Fig. 1). The pattern, however, clearly differs from the other types in that they are at least twice as enriched in Rb but are depleted in Ba, Th, Hf, and Zr.

Yozgat and Kerkenez analyses are in the VAG + syn-COLG field of the trace-element tectonic discrimination diagrams of Pearce et al. (1984). The Sivritepe analyses are in the WPG field on Y-Nb plots (Fig. 10). On the Y + Nb-Rb plots of the Yozgat samples, granites and granodiorites are in the syn-COLG field, tonalites are in the VAG field, Kerkenez samples are in the VAG field, and Sivritepe samples are divided into VAG and WPG fields, close to the triple junction, suggesting post-collision granites (Fig. 11).

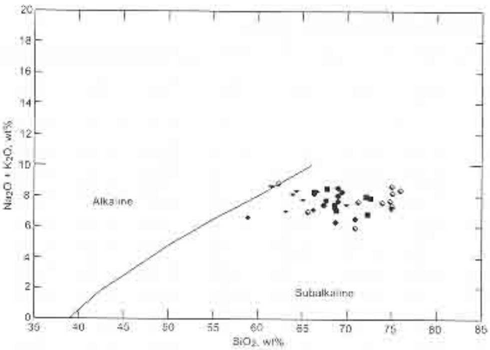

FIG. 6. Total alkalies vs. silica plot of the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3. Modified from Irvine and Baragar (1971, Fig. 3).

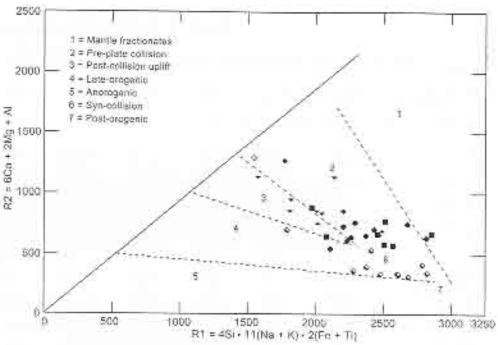

FIG. 8. R1-R2 tectonic discrimination diagram for the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3. Modified from Batchelor and Bowden (1985, Fig. 10).

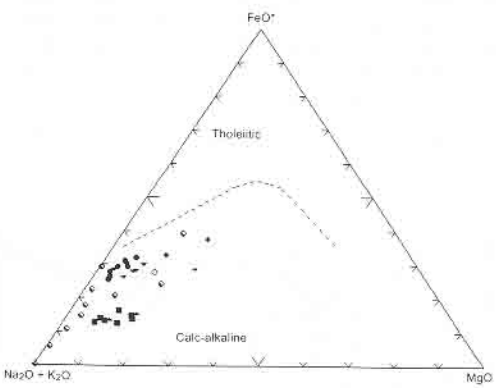

FIG. 7. AFM diagram of the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3. Modified from Irvine and Baragar (1971, Fig. 2).

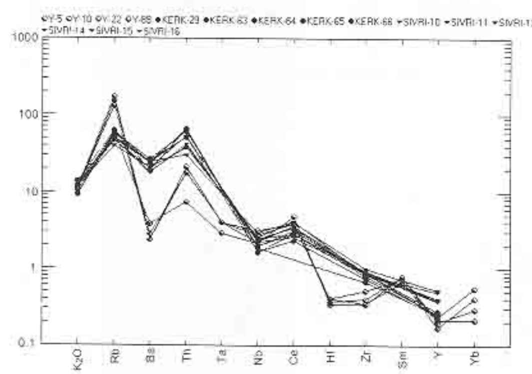

FIG. 9. Trace-element spidergram of the granitoids from the Yozgat Batholith.

The difference between the Yozgat samples and the rest is further underscored by trace-element ratios, such as Zr/Sr and Zr/Y (Figs. 12 and 13), and average Th (Yozgat: 10, Kerkenez: 50, Sivritepe: 33), Sr (Yozgat: 63, Kerkenez: 795, Sivritepe: 1160), Ba (Yozgat: 143, Kerkenez: 1180, Sivritepe: 1044), and total REE contents (Tables 3 and 4).

Discussion and Conclusions

The Yozgat Batholith is located along the northernmost edge of the Central Anatolian Crystalline Complex, which is believed to represent the passive margin of the Tauride-Anatolide Platform, facing toward the Izmir-Ankara branch of the Alpine Neotethys. It is commonly accepted that this oceanic basin was closed by northward subduction during the Late Cretaceous; the geodynamic evolution of the northern and active margin in the Pontides has been well documented by detailed petrological work (for references, see Tokel, 1996). The geology and petrology of the southern and passive margin, however, are relatively less known.

In previous evolutionary models, which mainly lack detailed geochemical data, the plutonic rocks in the northern part of CACC were interpreted in three quite different geodynamic settings: (1) Göncüoglu et al. (1992, 1993) and Göncüoglu and Türeli (1993, 1994), relying on the preliminary geochemical data of Erler et al. (1989, 1991), suggested that the granitoids in this area were generated by the collision of an ensimatic arc within the main body of the CACC; (2) Tüysüz et al. (1995) ascribed the

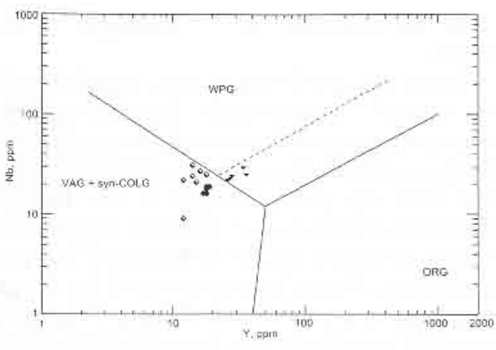

FIG. 10. Nb-Y tectonic discrimination diagram for the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3. Modified from Pearce et al. (1984, Fig. 3).

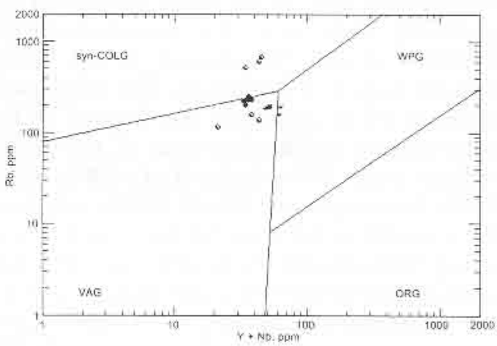

FIG. 11. Rb – Y + Nb tectonic discrimination diagram for the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3. Modified from Pearce et al. (1984, Fig. 4).

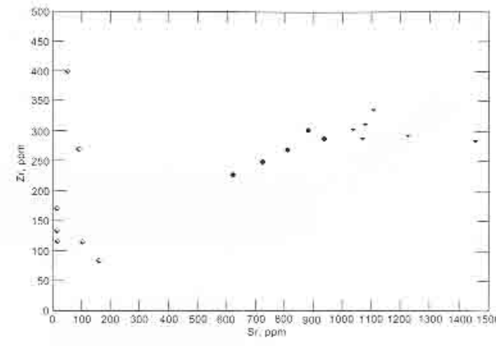

FIG. 12. Zr vs. Sr plot for the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3.

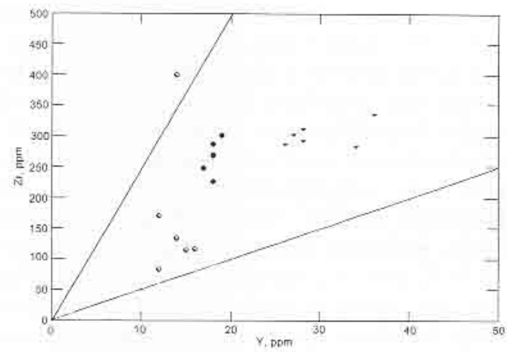

FIG. 13. Zr vs. Y plot for the granitoids from the Yozgat Batholith. Symbols are the same as those in Figure 3.

formation of the granitoids to the Late Cretaceous–Paleocene southward subduction of the Izmir-Ankara oceanic plate beneath the CACC and related arc-type magmatism; and (3) Boztug (unpubl. data) suggested that the granitoids in the Yozgat area were formed by partial melting of a deep-seated pre–Early Tertiary magmatic arc pluton during the Early Tertiary, as a result of the collision of the Pontide and Kirsehir (Tauride-Anatolide) blocks.

The Yozgat area was chosen for the study of the geochemical characteristics of granitoids, and thus their tectonic setting, to test the proposed geodynamic models in the northern part of the CACC. Detailed geological work on the plutonic rocks in the northern part of the CACC reveals that the Yozgat Batholith, previously considered as a single pluton, may be subdivided into several mappable units bounded by Cretaceous ophiolitic mélange, Eocene cover, and/or faults. These subunits are, from west to east: Yerköy-Sefaatli, Yozgat, Kerkenez, Gelingüllü, Karlitepe, Ocakli, Sivritepe, Mükremin, and Mugalli, all of which differ slightly in mineralogical and chemical composition. Most of the subunits of the Yozgat Batholith are principally metaluminous monzogranites of subalkaline-calcalkaline character; however, detailed geochemical data suggest the presence of two distinct subunits in the Yozgat Batholith: (1) Yozgat-type; (2) others.

The Yozgat granitoid samples are peraluminous and of the S type, containing biotite ± garnet as mafic phases. They differ in their trace-element and REE contents and Zr/Sr and Zr/Y ratios, clearly indicating a difference in origin. Their average Rb/Zr ratio is relatively high (>2.5, like the syn-collision granites) (Harris et al., 1986) in comparison to the

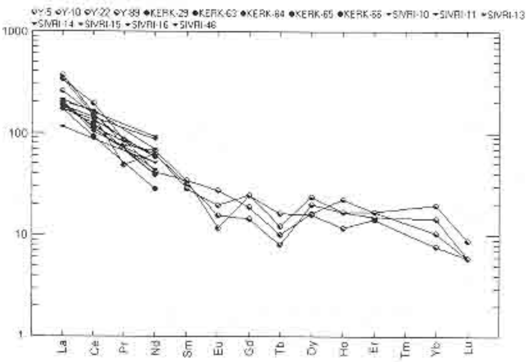

FIG. 14. REE spidergram of the granitoids from the Yozgat Batholith.

monzogranitic types (Rb/Zr ratio of Kerkenez = 0.8, Sivritepe = 0.6, like the syn- to post-collisional granites) (Harris et al., 1986). The Yozgat-type granitoid displays lower Rb and higher Sr and Ba values (Tables 3 and 4; Fig. 9), which also are used to differentiate leucogranites from monzogranitic derivatives in the Himalayas (LeFort, 1981). Furthermore, these rocks, with their relatively weak fractionation of REE and considerable Eu anomalies (Fig. 14), give a pattern similar to Hercynian granitoids, for which a predominantly metasedimentary source was proposed (Vidal et al., 1982). The I-type granitoids are distinguished by their hornblende ± biotite contents and post-collisional characteristics, unlike the syn-collisional geochemical features of the S-type ones.

No radiometric age data exist for the granitoids of the Yozgat Batholith. Field data indicate intrusion into fossiliferous Turonian–Campanian pelagic limestone of the Central Anatolian Ophiolitic Mélange, and thus a post-Campanian age; the earliest fossils in the cover are uppermost Cretaceous–Early Paleocene, and thus suggest a pre-Paleocene age. The contacts between the I-type and S-type granitoids in the study area are commonly faulted and/or covered, so that the relative ages of the single intrusions are not directly observable. Regional work, however, suggests that the S-type granitoids represent the earlier phases (Göncüoglu et al., 1991, 1992; Akiman et al., 1993), which is conformable with the existing radiometric age data from the CACC; S-type syn-COLG granite ages range between 85 and 110 Ma (Göncüoglu, 1986; Gülec, 1994); I-type post-COLG granite/monzonite ages, however, are ~70 Ma (Ataman, 1972; Gündogdu et al., 1988).

Using the geochemical data, together with the tectonic discrimination diagrams and the regional geological framework, we suggest that the granitoids of the northern edge of the CACC, and thus the passive margin of the Tauride-Anatolide Platform, are collision related. The earlier intrusive phase, represented by peraluminous, S-type leucogranites of the Yozgat type, displaying geochemical characteristics of syn-COL granitoids, are formed by the partial melting of the upper crustal rocks of the Tauride-Anatolide Platform. This partial melting may have been caused by crustal thickening resulting from the southward emplacement of ophiolitic (accretionary wedge and oceanic lithosphere) and crustal (slope and part of the platform) units onto the Tauride-Anatolide Platform during the closure of the Izmir-Ankara branch of Neotethys. The subsequent collision of an ensimatic arc, formed in the intra-oceanic subduction zone of the Izmir-Ankara ocean (Göncüoglu et al., 1991, 1992, 1993; Göncüoglu and Türeli, 1993), may have been an additional cause for the crustal thickening. This crustal thickening quite probably was followed by extension that began as a result of gravitational instability of the crust, culminating in melting in the upper mantle. We suggest that the CACC crust was sufficiently thick that heat resulting from the ponding of magmas at the crust-mantle boundary triggered melting of the lower crust to produce post-collisional I-type monzogranites in the Yozgat area. The mantle input, suggested as an explanation for similar plutonic bodies in the CACC (Gülec and Kadioglu, 1995), may be explained with this model by the dehydration melting of the subcontinental lithosphere, which does not necessitate a subduction component, as proposed by Tüysüz et al. (1995). The absence of mafic components as discrete plutons or dikes in the field can be used as an additional feature to distinguish the Yozgat pluton from subduction-related massifs.

Acknowledgments

We are grateful for the support provided by Professors L. T. Larson (University of Nevada, Reno) and P. A. Floyd (Keele University) for trace-element analyses. The Turkish Petroleum Corporation partially supported the field work.

REFERENCES

Akiman, O., Erler, A., Göncüoglu, M. C., Gülec, N., Geven, A., Türeli, T. K., and Kadioglu, Y. K., 1993, Geochemical characteristics of granitoids along the western margin of the Central Anatolian Crystalline Complex and their tectonic implications: Geol. Jour., v. 28, p. 371–382.

Ataman, G., 1972, Preliminary study on the radiometric age of the Cefalikdag granite-granodiorite southwest of Ankara: Hacettepe Fen ve Müh. Bil. Der., v. 2, no. 1, p. 44–49, in Turkish.

Batchelor, R. A., and Bowden, P., 1985, Petrogenetic interpretation of granitoid rock series using multicationic parameters: Chem. Geol., v. 48, p. 43–55.

Bayramgil, O., 1953, Study of the Cangili (Yozgat) fluorites and plutonics: Türkiye Jeol. Kur. Bült., v. 4, no. 2, p. 37–51 (in Turkish).

Bingöl, E., 1989, Geological Map of Turkey, scale 1:2,000,000: Ankara, Gen. Dir. Mineral Research and Exploration Publ.

Dalkilic, B., 1985, Geology of the Sarihacili-Divanli-Azizli region (Yozgat, Turkey): Unpubl. M. S. thesis, Middle East Tech. Univ., Ankara, 81 p.

Dalkilic, B., and Erler, A., 1986, Geology of the Sarihacili-Divanli-Azizli (Yozgat) region [abs.]: Türkiye Jeoloji Kurultayi—1986, Abs. (in Turkish).

Debon, F., and LeFort, P., 1983, A chemical-mineralogical classification of common plutonic rocks and associations: Trans. Royal Soc. Edinburgh, Earth Sci., v. 73, p. 135–149.

Erkan, Y., 1981, Results of studies on the metamorphism of the Central Anatolian Massif: Türkiye Jeol. Kur., Ic Anadolu'nun Jeolojisi Simp., p. 9–11 (in Turkish).

Erler, A., Akiman, O., Unan, C., Dalkilic, F., Dalkilic, B., Geven, A. and Önen, P., 1989, Petrology and geochemistry of the magmatic rocks of the Kirsehir Massif at Kaman (Kirsehir) and Yozgat: Unpubl. report, TÜBITAK, Project No. TBAG-677, 111 p. (in Turkish).

Erler, A., Akiman, O., Unan, C., Dalkilic, F., Dalkilic, B., Geven, A. and Önen, P., 1991, Petrology and geochemistry of the magmatic rocks of the Kirsehir Massif at Kaman (Kirsehir) and Yozgat: Doga, Turk. Jour. Eng. and Env. Sci., v. 15, p. 76–100 (in Turkish).

Göncüoglu, M. C., 1986, Geochronological data from the southern part (Nigde area) of the Central Anatolian Massif: Min. Res. Explorat. Bull., v. 105/106, p. 83–96.

Göncüoglu, M. C., and Türeli, T. K., 1993, Petrology and geodynamic setting of plagiogranites from the Central Anatolian Ophiolites (Aksaray, Turkey): Doga, Turk. Jour. Earth Sci., v. 2, p. 195–203.

Göncüoglu, M. C., and Türeli, T. K., 1994, Alpine collision type granitoids in the western Central Anatolian Crystalline Complex: Jour. Kocaeli Univ., v. 1, p. 39–46.

Göncüoglu, M. C., Toprak, V., Kuscu, I., Erler, A., and Olgun, E., 1991, Geology of the western part of the Central Anatolian Massif, Part 1: Southern Section: Unpubl. Report No. 2909, Turkish Petroleum Company (in Turkish).

Göncüoglu, M. C., Erler, A., Toprak, V., Yaliniz, K., Olgun, E., and Rojay, B., 1992, Geology of the western part of the Central Anatolian Massif, Part 2: Central Section: Unpubl. Report No. 3155, Turkish Petroleum Company (in Turkish).

Göncüoglu, M. C., Erler, A., Toprak, V., Olgun, E., Yaliniz, K., Kuscu, I., Köksal, S., and Dirik, K., 1993, Geology of the central part of the Central Anatolian Massif, Part 3: Geologic evolution of the Central Kizilirmak Tertiary Basin: Unpubl. Report No. 3313, Turkish Petroleum Company (in Turkish).

Güldogan, E., 1995, Petrography and geochemistry of the Yozgat batholith in the Gelingüllü region: Unpubl. Grad. thesis, Middle East Tech. Univ., Ankara, 44 p.

Gülec, N., 1994, Rb-Sr isotope data from the Agacören granitoid (east of Tuz Gölü): Geochronological and genetic implications: Doga, Turk. Jour. Earth Sci., v. 3, p. 39–43.

Gülec, N. and Kadioglu, Y. K., 1995, Relative involvement of mantle and crustal components in the Agacören granitoid: Estimates from trace-element and Sr-isotope data [abs.]: Int. Earth Sci. Coll. on the Aegean Region, Abs., p. 22.

Gündogdu, M. N., Bros, R., Kuruc, A., and Bayhan, H., 1988, Rb-Sr whole rock systematics of the Bayindir (Kaman-Kirsehir) feldspathoidal syenites: Hacettepe Üniv., Yerbilimlerinin 20, Yili Semp., Bildiri Özleri, p. 55 (in Turkish).

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: London, Geol. Soc. London Spec. Publ. 19, p. 67–81.

Irvine, T. N., and Baragar, W. R. A., 1971, A guide to the chemical classification of the common volcanic rocks: Canad. Jour. Earth Sci., v. 8, p. 523–548.

Karatas, S., 1985, Geology of northeast of Sefaatli (Yozgat): Unpubl. M.S. thesis, Middle East Tech. Univ., Ankara, 82 p.

Ketin, I., 1955, On the geology of Yozgat region and the tectonic features of the Central Anatolian Massif (Kirsehir Crystallines): Türkiye Jeol. Kur. Bült., v. 6, no. 1, p. 29–40.

LeFort, P., 1981, Manaslu leucogranite: A collision signature in Himalaya. A model for its genesis and emplacement: Jour. Geophys. Res., v. 86, p. 10545–10586.

Lünel, A. T., 1985, An approach to the naming, origin, and age of Baranadag monzonite of Kirsehir intrusive suite: METU Jour. Pure Appl. Sci., v. 18, p. 385–404.

Maniar, P. D., and Piccoli, P. M., 1989, Tectonic discrimination of granitoids: Geol. Soc. Amer. Bull., v. 101, p. 635–643.

Pearce, J. A., Harris, N. B. W., and Tindle, A. G., 1984, Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: Jour. Petrol., v. 25, p. 956–983.

Seymen, I., 1982, Geology of the Kirsehir Massif around Kaman: Unpubl. Hab. thesis, Istanbul Tech. Univ., Faculty of Mines, 164 p. (in Turkish).

Streckeisen, A., 1967, Classification and nomenclature of igneous rocks: Neues Jahrb. Mineral. Abh., v. 107, p. 144–240.

Tokel, S., 1996, Magmatic and geochemical evolution of the Pontide segment of the Northern Tethys subduction system, *in* Erler, A., Ercan, T., Bingöl, E. and Örcen, S., eds., Geology of the Black Sea region: Ankara, Proc. Int. Symp. Geol. of Black Sea Region, p. 163–170.

Tokgöz, M., 1995, Petrography and geochemistry of the Sivritepe granitoid (Yozgat, Turkey): Unpubl. Grad. thesis, Middle East Tech. Univ., Ankara, 57 p.

Tüysüz, O., Dellaloglu, A., and Terzioglu, N., 1995, A magmatic belt within the Neotethyan suture zone and its role in the tectonic evolution of northern Turkey: Tectonophysics, v. 243, p. 1–19.

Vidal, P., Cocherie, A., and LeFort, P., 1982, Geochemical investigations on the origin of the Manaslu leucogranite (Himalaya, Nepal): Geochim. et Cosmochim. Acta, v. 46, p. 2279–2292.

Yardimcilar, C., 1995, Petrography and geochemistry of the Kerkenez granitoid (Sorgun-Yozgat): Unpubl. Grad. thesis, Middle East Tech. Univ., Ankara, 54 p.