Geochemical characteristics of some plutons from the Kastamonu granitoid belt (Northern Anatolia, Turkey)

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Geochemical characteristics of some plutons from the Kastamonu granitoid belt (Northern Anatolia, Turkey)

by *Durmuş Boztuğ*[1], *François Debon*[2], *Patrick Le Fort*[2] and *Osman Yilmaz*[1]

Abstract

Located in the Outer Pontides area, the Kastamonu granitoid belt, of Mid-Jurassic age, has been recently evidenced. On the basis of 22 new analyses (major and some trace elements), the chemical-mineralogical and petrographic features of its Ahiçay-Elmaliçay and Büyükçay plutons are defined. These plutons are made up of three groups of deformed granitoids: a dark metaluminous to peraluminous granodiorite group with biotite ± amphibole, an intermediate peraluminous group with biotite ± muscovite, and a peraluminous leucoadamellite group with muscovite and accessory biotite. Twelve REE analyses support the existence of a close relationship between the three groups which belong to a single alumino-cafemic and calc-alkaline magmatic association. The emplacement of the Kastamonu granitoid belt is synchronous with the final stages of the northward subduction of the Palaeo-Tethys. The crustal continental contribution seems to be largely dominant in its genesis. We suggest that it is related to the suturing of this oceanic realm, that induced the melting of the Pontides' crust.

Keywords: granitoid, major element geochemistry, REE geochemistry, Northern Anatolia, Turkey.

INTRODUCTION

The investigated area is located in the Outer Pontides, to the South of Inebolu and Abana towns, some 30 km away from the Black Sea coast, in the Kastamonu province of northern Anatolia, Turkey (Fig. 1). The granitoid plutons belong to the "Kastamonu Granitoid Belt" 50 km wide and at least 150 km long, defined by YILMAZ & BOZTUĞ (1984, submitted). The Büyükçay and Elmaliçay granitoids and the surrounding rocks have been studied by BOZTUĞ (1983), and BOZTUĞ & YILMAZ (1983). The west part of the Elmaliçay pluton, named as Ahiçay, is being studied in the frame of a project from TÜBITAK by two of the authors (O. Y. and D. B.).

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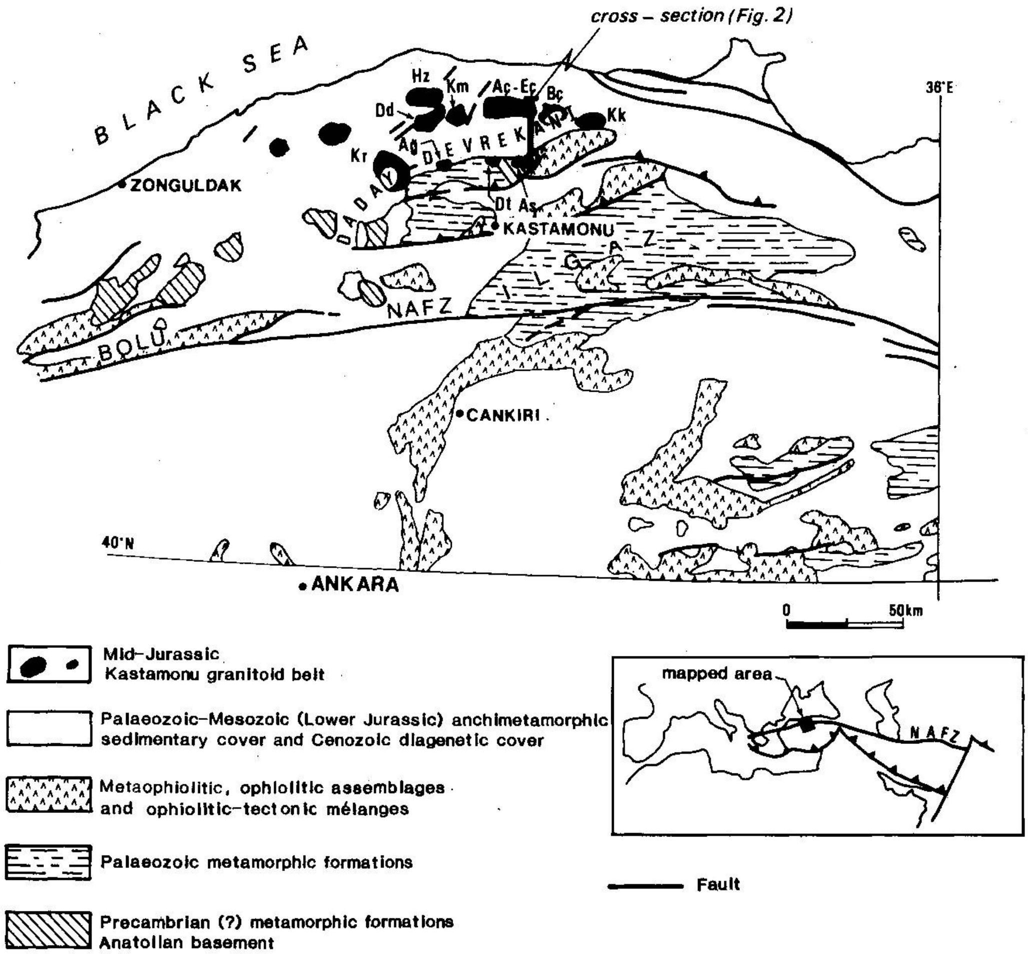

Fig. 1 Regional geological setting of the plutons belonging to the Kastamonu granitoid belt, northern Anatolia, Turkey: Aç-Eç Ahiçay-Elmaliçay, Ağ Ağli, As Asarcik, Bç Büyükçay, Dd Dikmendaği, Dt Devrekani town, Hz Hayzer, Kk Karacakaya, Km Karaman, Kr Kürek. NAFZ North Anatolian Fault Zone. Modified after YILMAZ (1984), YILMAZ & BOZTUĞ (1984, submitted).

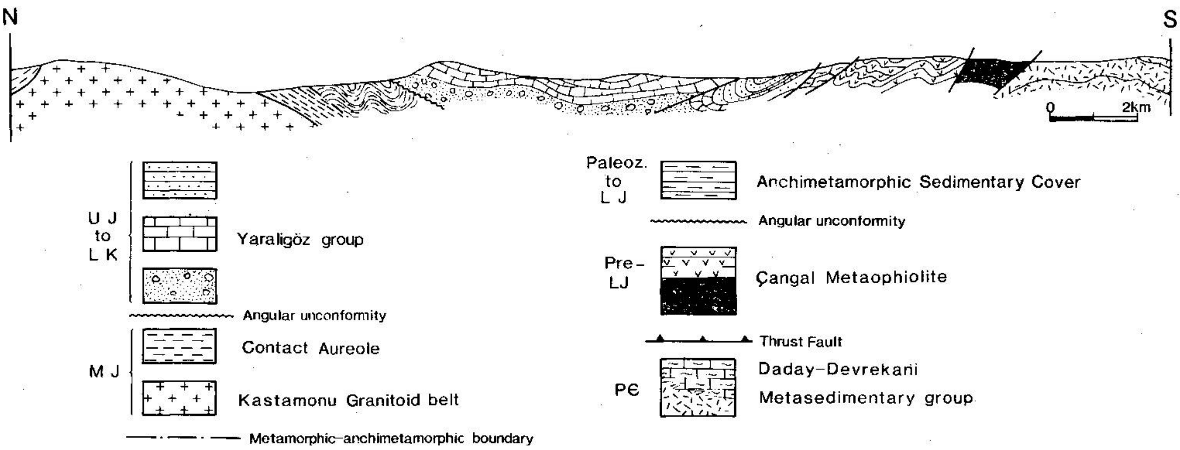

Fig. 2 North-South geological cross-section through the Kastamonu granitoid belt and surroundings, after YILMAZ & BOZTUĞ (1984, submitted). Its location is shown on Figure 1. Pє Precambrian, LJ, MJ, UJ Lower, Mid and Upper Jurassic respectively, LK Lower Cretaceous.

REGIONAL GEOLOGICAL SETTING

Geologically, the Kastamonu belt is located in the Outer Pontides, north of the North Anatolian Fault Zone (e.g. ADAMIA et al., 1980, and Fig. 1). In this area the following tectonostratigraphic units can be observed from bottom to top (Figs. 1, 2). The oldest unit is the Daday-Devrekani metasedimentary group of Precambrian age which attains the sillimanite-K-feldspar and migmatitic metamorphic facies (YILMAZ, 1979, 1980, 1981). The fossiliferous Palaeozoic-Lower Jurassic sedimentary-anchimetamorphic cover lies on top of it with unconformity. The Çangal metaophiolite of Pre-Lower Jurassic age is in tectonic contact with these two tectonostratigraphic units (YILMAZ, 1979, 1980, 1983a, b, 1984). Magmatic rocks, corresponding to many large and discrete granitoid plutons grouped as the Kastamonu granitoid belt by YILMAZ & BOZTUĞ (1984, submitted), cut and metamorphose at their contact the older units during Dogger time. The youngest unit cut by this granitoid belt is the Börümce formation of Lower Jurassic age that has undergone an intensive contact metamorphism ranging from the albite-epidote hornfels facies to the hornblende hornfels facies (BOZTUĞ, 1983; BOZTUĞ & YILMAZ, 1983; YILMAZ & BOZTUĞ, 1984). All these units are overlain with unconformity by the Yaraligöz group of Upper Jurassic-Lower Cretaceous age (YILMAZ, 1979, 1980). In some places, the polygenic basal conglomerate of this Yaraligöz group, namely the Muzrup formation of Malm age, overlies the granitoid plutons and includes granitoid pebbles and fragments (YILMAZ & BOZTUĞ, 1984, submitted). Finally all the units mentioned above are overlain by the Black Sea basin deposits made up of Mid-Upper Cretaceous to Cenozoic sedimentary and volcano-sedimentary series.

The famous Şeyhşaban Hg mineralization (Bozkurt town) and the Hayzer Hg, cupriferous pyrite, and pyrite mineralization (Inebolu town) are related to the Kastamonu granitoid belt. The genesis of the Küre town copper mineralization, located within the same belt, is not clearly understood although it is thought that it can be related to the basic-ultrabasic rocks (indeed they should belong to the Çangal metaophiolite). The marbles formed by the contact metamorphism constitute another industrial material.

Sampling and analysis

Due to typical Black Sea climate and intensive forest cover, the weathering processes are strongly developed in the investigated area. The outcrops of fresh rocks can only be found in the valleys and along the new road cuttings. All our samples have been collected from such convenient places, and their weight range from 3 to 5 kg. The study of the thin sections has enabled to choose the freshest ones for major element and REE analyses. Previous analysis performed on the studied plutons (BOZTUĞ & YILMAZ, 1983) have not been used in the present paper because some of them show strong discrepancies with the microscopical data. The 22 analyses of Table 1 are exclusively new ones that have been obtained on the quantometer (emission spectrometer) of the CRPG, Nancy (GOVINDARAJU et al., 1976). REE contents (Table 3) have been also determined for 12 of the same samples at the CRPG, using the emission spectrometry method developed by GOVINDARAJU & MEVELLE (1983).

CHEMICAL-MINERALOGICAL AND PETROGRAPHICAL TYPOLOGY

This typology is based on the method proposed by DEBON & LE FORT (1982) for the classification of igneous rocks and associations.

Chemical-mineralogical features

According to the chemical-mineralogical data (Tables 1, 2; Figs. 3 to 5), three groups of granitoids may be clearly distinguished in the Ahiçay-Elmaliçay and Büyükçay plutons: a dark granodiorite group, an intermediate group, and a leucoadamellite group. In addition, some strongly altered samples cannot be classified.

The *dark granodiorite group* is mainly located in the Büyükçay pluton. It is made up of granodiorites, rarely of adamellites (Fig. 3), peraluminous (III) and sometimes slightly metaluminous (IV) (Fig. 4), with brown-mahogany biotite, and, generally, olive-green prismatic hornblende. One can notice that such hornblende-bearing rocks should normally be metaluminous, and the observed discrepancy between their actual composition and the chemical-mineralogical data probably reflects a conspicuous alteration (see after). Comparatively to the reference granodiorite composition, these rocks are, on an average (Table 2; Figs. 4, 5): rich in dark minerals (18.0 to 23.6%; average 21.3%), alkalines [high Na and K contents; (Na + K) = 204 g-atoms × 10^3], Ba and Sr, but rather poor in quartz (22.7 to 26.5%; average 23.8%), feldspars (53.4 to 55.9%; average 54.9%), Ca and Cu, with a more or less high loss on ignition, aluminous character [A = Al - (K + Na + 2 Ca) = 17 g-atoms × 10^3] and Mg/(Fe + Mg) ratio (0.59). Thus, these rocks are not common granodiorites.

The *intermediate group* is mainly located in the Ahiçay-Elmaliçay pluton. It is made up of granodiorites, sometimes of adamellites (Fig. 3), always peraluminous (III and rarely II) (Fig. 4), with brown-mahogany biotite ± some muscovite. Comparatively to the reference granodiorite composition, these rocks are, on an average (Table 2; Figs. 4, 5): rather rich in quartz (28.0 to 31.3.%; average 29.4%), alkalines [(Na + K) = 195] and Ba, rather common in feldspars ± muscovite (57.2 to 60.0%; average 58.7%), Rb and Sr, poor in dark minerals (10.6 to 14.1%; average 11.9%), Ca and Cu, with a high loss on ignition and aluminous character (A = 27) and a low Mg/(Fe + Mg) ratio (0.36). Thus, these rocks are again not common granodiorites.

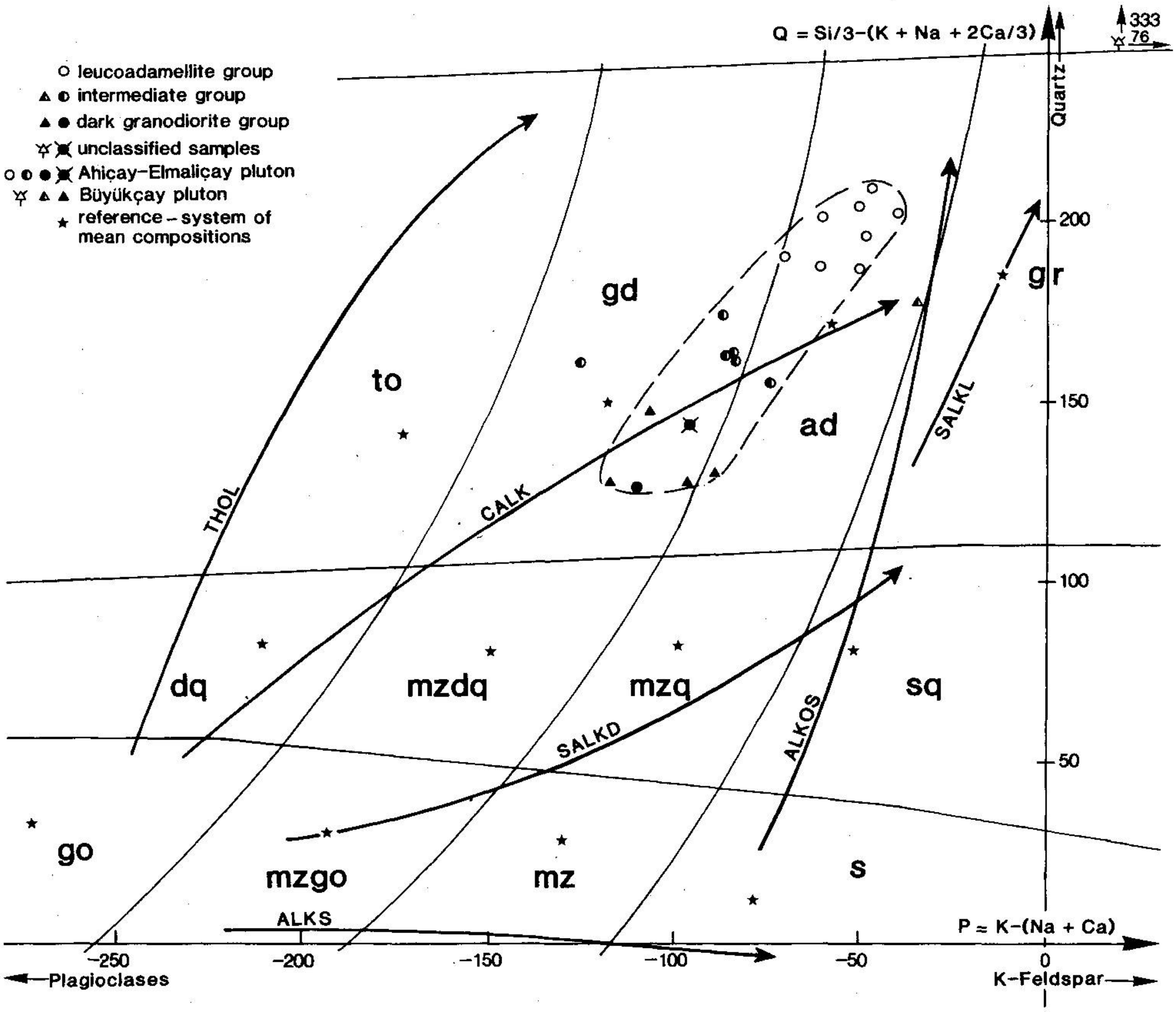

Fig. 3 Distribution of Ahiçay-Elmaliçay and Büyükçay granitoids in the "nomenclature" diagram proposed by Debon & Le Fort (1982) after La Roche (1964, 1966) modified. The two parameters are in gram-atoms × 10^3 in 100 g of rock or mineral. Each pigeon hole corresponds to a petrographic type: gr granite, ad adamellite, gd granodiorite, to tonalite, sq quartz syenite, mzq quartz monzonite, mzdq quartz monzodiorite, dq quartz diorite, s syenite, mz monzonite, mzgo monzogabbro, go gabbro. Moreover, combined with the "Q–B–F triangle" (Fig. 5), this diagram enables to distinguish different subtypes among the three main types of magmatic associations (Fig. 4); for comparison, typical trends of different subtypes of cafemic or aluminocafemic associations are shown: tholeiitic (THOL), calc-alkaline (CALK), dark (SALKD) and light-coloured (SALKL) subalkaline (i.e. monzonitic), alkaline saturated (ALKS) and oversaturated (ALKOS). Other explanations in text.

Finally, the *leucoadamellite group,* located in the Ahiçay-Elmaliçay pluton, is exclusively made up of adamellites sensu stricto (Fig. 3), always strongly peraluminous (I) (Fig. 4), with muscovite and accessory biotite. Comparatively to the reference adamellite composition, these rocks are, on an average (Table 2; Figs. 4, 5): rich in quartz (32.1 to 37.7%; average 35.3%), alkalines [high Na content; (Na + K) = 213], common in feldspars + muscovite (57.6 to 63.4%; average 60.6%) and Ba, poor in dark minerals (always leucocratic; 1.4 to 6.9%; average 4.0%), Ca, Co (Rb and Sr), with a rather high loss on ignition, a very high aluminous index (A = 65), and a normal Mg/(Fe + Mg) ratio (0.33). Thus, these rocks are not common adamellites.

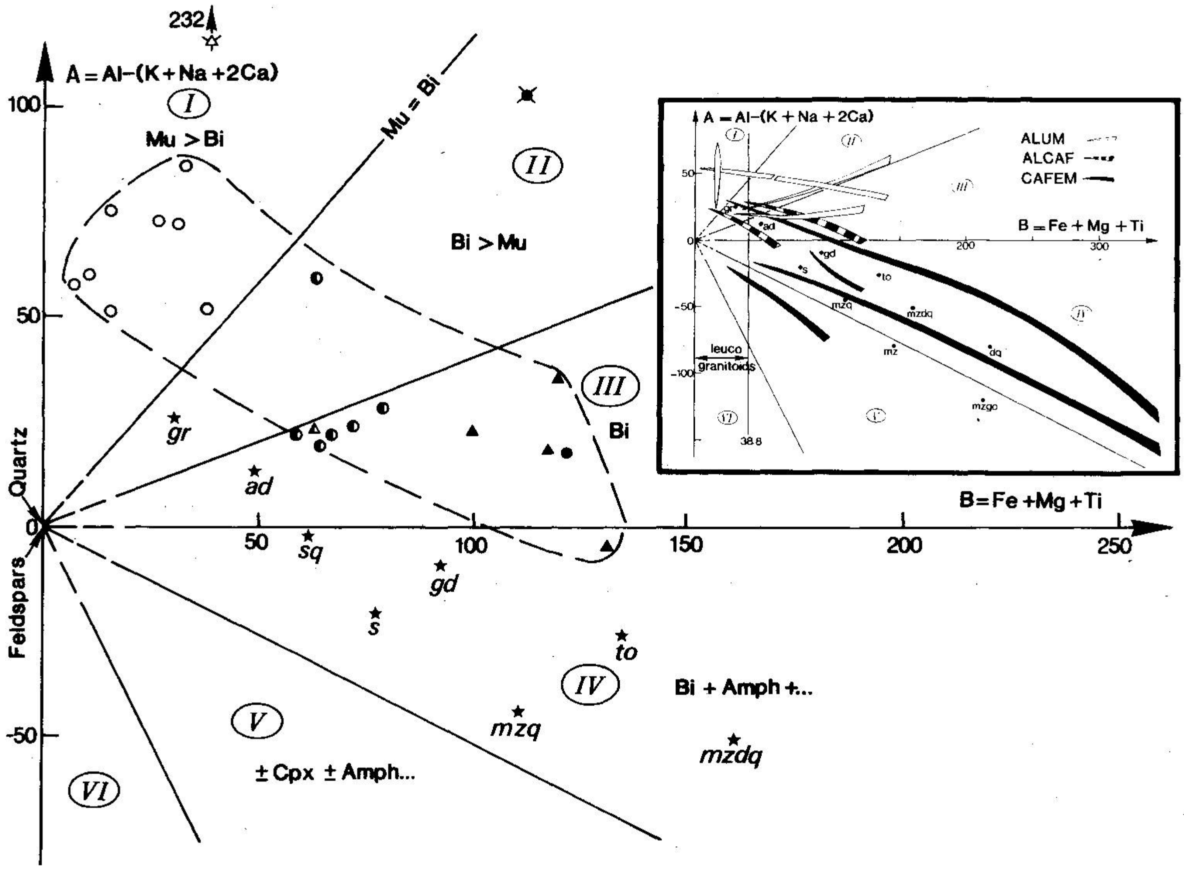

Fig. 4 Distribution of Ahiçay-Elmaliçay and Büyükçay granitoids in the "characteristic minerals" diagram of Debon & Le Fort (1982). The parameters are again in gram-atoms × 10^3 in 100 g of rock or mineral; A is a classical "aluminous index" and B is proportional to the dark minerals content in common plutonic rocks (La Roche, 1964). This diagram separates the peraluminous rocks or minerals (positive value of A; e.g. Bi biotite, Mu muscovite) from the metaluminous ones (e.g. Amph amphibole, Cpx clinopyroxene). Each of its six sectors, numbered from I to VI, corresponds to a specific mineralogical composition; in a first approximation: I rocks with Mu > Bi (by volume), II Bi > Mu, III Bi, IV Bi + Amph,... Moreover, this diagram enables to distinguish three main types of magmatic associations (see the inset): aluminous (ALUM), alumino-cafemic (ALCAF), cafemic (CAFEM). Typical trends corresponding to each of these three types are shown in the inset. Explanation of the other abbreviations and symbols as in Figure 3.

Microscopical study

Except for the frequent existence of amphibole in the dark granodiorite group, the microscopic observations agree very well with the mineralogical characteristics deduced from chemical data (see above). In addition, these observations show that:

- the studied granitoids are fine- or medium-grained rocks, cataclastic and more or less laminated, with a partial recrystallization of the quartz, and, much more rarely, of the brown biotite into green biotite, and, maybe, of amphibole into fibrous actinolite;

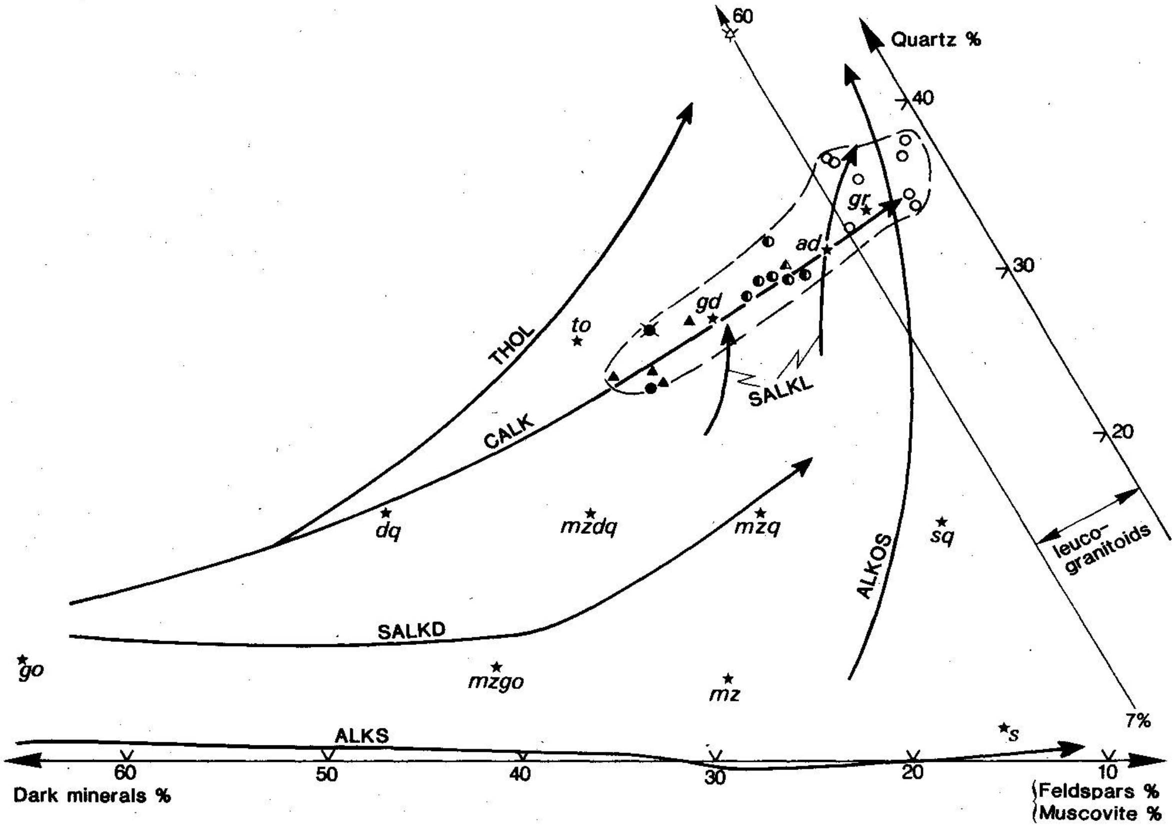

Fig. 5 Distribution of Ahiçay-Elmaliçay and Büyükçay granitoids in the triangular diagram Quartz–Dark minerals–Feldspars + Muscovite ("Q–B–F diagram"). The parameters are directly calculated from chemical analyses (La Roche, 1964; Debon & Le Fort, 1982) and are given as weight percentages. Combined with the "nomenclature diagram" (Fig. 3), this triangle enables to distinguish different subtypes among the three main types of magmatic associations (Fig. 4); for comparison, typical trends of different subtypes of cafemic or alumino-cafemic associations are shown. Explanation of the abbreviations and symbols as in Figures 3 and 4.

- the K-feldspar is xenomorph, pœcilitic, often with the typical microcline twinning, while the plagioclase is slightly concentrically-zoned. Both of them, especially the plagioclase, are more or less altered into sericite and/or saussurite ± calcite. The biotite is also often altered into chlorite, epidote, opaques,... and the amphibole is sometimes transformed into epidote. This conspicuous alteration is chemically evidenced by high loss on ignition contents (Tables 1, 2) and it could be responsible for an increase of the aluminous index [A = Al - (K + Na + 2 Ca); Fig. 4] of our granitoids, particularly in the case of the dark granodiorite group (L.I. = 1.72%). However, inside a given petrographic group, no clear correlation exists between the loss on ignition and the Al, Na, K or Ca contents, and, thus, it is difficult to accurately decipher the chemical trend(s) induced by the alteration;
- the accessory minerals (apatite, zircon, allanite, and maybe monazite) are rather frequent in the dark granodiorite and the intermediate groups. They vanish in the leucoadamellite group and quasi-totally disappear in most leucoc-

Table 1 Chemical compositions of Ahiçay-Elmaliçay (Aç-Eç) and Büyükçay (Bç) granitoids.

Petrographic group	Sample number	Pluton	Rock type	Symbol	SiO_2	Al_2O_3	Fe_2O_3t	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	L.I.	TOTAL	Ba	Co	Cr	Cu	Ni	Rb	Sr	V
Dark grano-diorite	DB 49	Bç	gd III	▲	66.78	15.18	3.46	0.06	2.07	2.13	4.14	3.06	0.40	0.24	1.44	98.96	1048	<10	330	<10	34	104	502	106
	DB 50	"	gd III	▲	65.98	15.46	3.73	0.07	2.59	1.89	4.35	3.62	0.53	0.27	1.35	99.84	1145	<10	304	<10	40	125	451	123
	DB 512	"	ad III	▲	64.93	15.74	3.39	0.06	2.85	1.82	4.10	3.61	0.48	0.24	2.67	99.89	1099	<10	385	<10	52	137	329	122
	DB 513	"	gd IV	▲	64.96	15.27	3.84	0.07	3.08	3.02	4.02	3.16	0.46	0.27	1.37	99.52	1094	<10	421	<10	65	114	556	121
	DB 135	Aç - Eç	gd III	●	64.65	16.26	4.13	0.07	2.52	2.88	3.97	3.32	0.56	0.25	1.78	100.39	1226	<10	297	<10	40	107	561	124
Inter-mediate	DB 111	Bç	ad III	◭	68.63	14.07	2.78	0.07	0.77	1.65	3.08	4.48	0.61	0.12	2.66	98.92	1107	28349	110	14	86	105	387	145
	DB 162	Aç - Eç	gd II	◐	69.06	15.52	2.96	0.06	0.85	1.51	3.89	3.12	0.42	0.23	1.37	98.99	754	583	20	<10	12	105	316	84
	DB 1801	"	ad III	◐	67.72	14.95	3.05	0.07	1.40	1.87	3.70	3.73	0.43	0.16	2.45	99.53	619	<10	210	<10	<10	142	240	97
	YB 118	"	gd III	◐	68.32	15.62	3.61	0.09	0.82	2.69	4.07	2.58	0.52	0.15	1.15	99.62	562	<10	154	<10	<10	94	361	102
	YB 127	"	gd III	◐	69.52	15.23	3.29	0.08	0.70	2.29	3.70	3.68	0.40	0.17	0.99	100.05	974	<10	141	<10	<10	126	343	87
	YB 159	"	gd III	◐	69.76	15.24	3.18	0.08	0.88	2.19	3.78	3.60	0.43	0.14	1.06	100.34	703	<10	134	<10	<10	133	311	79
	YB 240	"	gd III	◐	69.62	15.11	3.09	0.07	0.70	2.12	3.78	3.61	0.23	0.17	1.11	99.61	789	<10	191	<10	<10	119	366	64
Leuco-adamellite	DB 164	Aç - Eç	lc ad I	○	71.85	15.11	1.88	0.06	0.49	1.00	3.89	3.94	0.20	0.09	0.99	99.50	624	<10	190	<10	<10	142	227	37
	DB 165	"	lc ad I	○	74.11	14.45	1.54	0.04	0.44	tr.	4.17	3.60	0.13	0.21	1.08	99.77	572	<10	268	<10	<10	127	191	56
	YB 1151	"	lc ad I	○	76.73	14.26	0.51	0.02	tr.	0.19	3.99	4.04	0.09	0.02	0.57	100.42	395	<10	203	<10	<10	155	100	36
	YB 198	"	lc ad I	○	72.92	15.29	1.66	0.06	0.39	0.49	3.52	3.91	0.17	tr.	1.56	99.97	564	<10	143	<10	<10	144	162	39
	YB 241	"	lc ad I	○	73.22	15.22	0.86	0.03	0.19	0.29	4.29	3.51	0.06	0.04	1.02	98.73	692	<10	185	<10	<10	131	233	44
	YB 269	"	lc ad I	○	73.80	14.85	1.19	0.04	0.45	0.15	3.98	3.96	0.08	0.11	1.14	99.75	506	<10	173	<10	<10	136	172	44
	YB 272	"	lc ad I	○	74.38	14.14	0.98	0.03	0.16	tr.	4.27	4.17	tr.	0.11	0.80	99.04	393	<10	127	<10	<10	145	95	18
	YB 273	"	lc ad I	○	75.67	14.19	0.60	0.03	0.11	0.09	4.08	3.94	0.06	0.02	0.59	99.38	291	<10	232	<10	<10	170	86	18
Unclas-sified	DB 114	Bç	gr I	✡	74.63	15.99	2.21	0.06	0.15	tr.	0.09	3.70	0.63	0.23	2.35	100.04	1007	<10	262	<10	36	97	300	118
	DB 137	Aç - Eç	gd II	✖	64.95	16.93	3.55	0.06	2.44	0.44	4.64	2.95	0.60	0.12	1.99	98.67	999	490	106	<10	52	86	296	105

"Rock type" refers to the chemical-mineralogical classification of Debon & Le Fort (1982); lc leucocratic (rocks with a dark minerals content less than 7%); ad adamellite, gd granodiorite, gr granite (Fig. 3); in a first approximation, the roman numerals (I to IV here) respectively correspond to rocks with: I muscovite > biotite (by volume), II biotite > muscovite, III biotite, IV biotite + amphibole,... (Fig. 4); alteration may disturb this correspondance; in particular, our "dark granodiorite group", though principally located in the sector III, often contains both biotite and amphibole. The "symbols" refer to the Figures 3 to 5. Analyses by K. Govindaraju, C.R.P.G., Nancy. Total iron as Fe_2O_3. L.I. loss on ignition. The abundance of the trace elements is in parts per million. High Co, Cr and Ni contents may result from pollution during crushing. In addition, the Co values > 150 ppm are only indicative.

Table 2 Mean chemical compositions.

	Ahiçay-Elmaliçay & Büyükçay			After DEBON & LE FORT (1982)	
Petrographic group	Dark granodiorite	Intermediate	Leucoadamellite	Reference granodiorite	Reference adamellite
n	5	7	8	208	194
SiO_2	65.46	68.95	74.09	67.02	71.58
Al_2O_3	15.58	15.11	14.69	15.38	14.39
Fe_2O_3t	3.71	3.14	1.15	4.01	2.31
MnO	0.07	0.07	0.04	0.08	0.05
MgO	2.62	0.87	0.28	1.43	0.60
CaO	2.35	2.05	0.28	3.77	1.80
Na_2O	4.12	3.71	4.02	3.54	3.58
K_2O	3.35	3.54	3.88	2.99	4.23
TiO_2	0.49	0.43	0.10	0.50	0.29
P_2O_5	0.25	0.16	0.08	n.d.	n.d.
L.I.	1.72	1.54	0.97	0.98	0.78
TOTAL	99.72	99.57	99.58	99.70	99.61
Ba	1122	787	505	579	552
Co	0-10	0-?	0-10	49	41
Cr	347	137	190	19-21	7-13
Cu	0-10	2-11	0-10	10-16	3-12
Ni	46	14-21	0-10	17-19	6-12
Rb	117	118	144	103	171
Sr	480	332	158	322	195
V	119	94	37	79	33-34

For the Ahiçay-Elmaliçay and Büyükçay granitoids, the compositions have been calculated using the data in Table 1. n : number of analysed samples. Other explanations as in Table 1.

Table 3 REE compositions (in parts per million) of selected Ahiçay-Elmaliçay and Büyükçay granitoids.

Petrographic group	Sample number	Dark minerals content in %	La	Ce	Nd	Sm	Eu	Gd	Dy	Er	Yb	Lu	La/Yb	Y
Dark granodiorite	DB 513	23.6	24.79	46.42	19.27	3.98	1.01	3.58	2.17	1.26	1.13	0.18	21.9	12.93
	DB 135	21.9	36.73	65.67	28.75	5.52	1.44	4.62	3.05	1.57	1.37	0.20	26.8	18.01
	DB 50	21.3	24.30	50.51	21.28	4.56	1.25	3.67	2.43	1.31	1.18	0.17	20.6	14.67
	DB 49	18.0	31.06	59.25	24.59	4.45	1.31	3.97	2.50	1.35	1.09	0.17	28.5	14.38
Intermediate	YB 118	13.0	35.16	73.03	31.19	6.77	1.39	5.17	3.30	1.57	1.34	0.20	26.2	18.80
	YB 127	11.5	28.10	57.03	25.14	5.32	1.36	4.32	2.86	1.37	1.17	0.18	24.0	16.41
	DB 162	11.4	31.98	70.47	27.87	5.33	1.30	3.98	2.61	1.35	0.97	0.14	33.0	14.24
	YB 240	10.6	33.61	68.59	27.85	5.69	1.26	4.55	2.59	1.21	0.95	0.11	35.4	13.77
Leucoadamellite	DB 165	5.7	23.01	41.11	18.70	3.99	0.95	3.70	2.90	1.32	1.39	0.22	16.6	19.40
	YB 272	2.9	11.71	24.33	9.70	2.19	0.54	2.29	2.33	1.30	1.49	0.20	7.9	14.98
	YB 273	2.0	5.26	8.57	4.81	1.56	0.46	1.88	1.97	1.24	1.52	0.21	3.5	14.31
	YB 1151	1.4	5.58	10.68	5.15	1.63	0.41	1.95	2.19	1.13	1.41	0.22	4.0	15.94

Samples are classified according to decreasing dark minerals contents; these contents have been calculated from chemical analyses (Fig. 5). Analyses by K. GOVINDARAJU, C.R.P.G., Nancy.

ratic members. Opaques are very rare everywhere and the allanite does not occur in the leucoadamellite group.

Rare-earth elements (REE)

The dark granodiorite and the intermediate groups have very similar REE patterns (Table 3, Fig. 6), and this similarity supports the existence of a close kinship between the two groups. These patterns display a light-REE enrichment with a rather strong and regular fractionation (La/Yb ratios range from 35.4 to 20.6) and with a slight or even completely lacking negative Eu anomaly. Such patterns, particularly by their rather regular slope from the light- to the heavy-REE, compare well with those obtained by FOURCADE (1981) for subalkaline (i.e. monzonitic) rocks. However, their most conspicuous feature is the similarity of their slope with that given by allanite and apatite (GROMET & SILVER, 1983) that are, as noticed above, actually present in our rocks. Such a similarity suggests that a major contribution to the REE-content of these rocks may be supplied by these two accessory minerals.

The leucoadamellite group is poorer in light-REE than the two other groups (Table 3, Fig. 6). As shown by several authors (e.g. FOURCADE, 1981; PAGEL, 1981; GROMET & SILVER, 1983; BRANDEBOURGER, 1984), the REE content of granitoid rocks is essentially controlled by the accessory minerals. Thus, the poorness in REE of the leucoadamellites probably reflects their poorness in such minerals (see above). In addition, the slope of their REE patterns is different from that given by the two other groups; it displays an enrichment in light-REE but the fractionation affects little or not at all the heavy-REE, and the La/Yb ratio is rather low (from 3.5 to 16.6); moreover, the negative Eu anomaly is more acute. Such patterns fairly well compare with those obtained by FOURCADE (1981) for two-mica leucogranitoids belonging to calc-alkaline associations. Finally, one can notice that one of our less leucocratic adamellite (DB 165) displays a REE pattern which compares both with those of the dark granodiorite and intermediate groups and those of the most leucocratic adamellites (Table 3, Fig. 6). This feature suggests the existence of a kinship between the leucoadamellites and the two other groups.

Type of magmatic association

Though chemical gaps exist between each of our three groups of granitoids (Figs. 3 to 5), several evidences indicate that these groups may belong to the same magmatic association:

- in all the chemical diagrams (e.g. Figs. 3 to 5), the three groups fall in line;

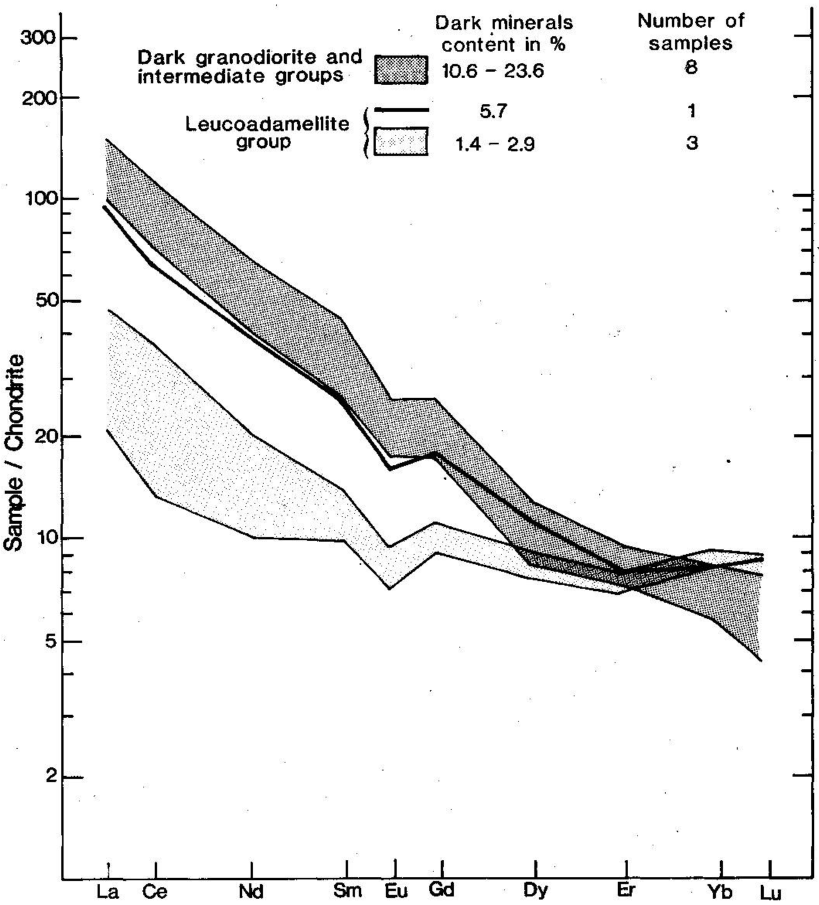

Fig. 6 REE patterns for twelve samples of the Ahiçay-Elmaliçay and Büyükçay granitoids. On this diagram, the data (Table 3) have been normalized to chondritic values given by EVENSEN et al. (1978). Other explanations in the text.

- the three groups display some common chemical pecularities (e.g. high Na and low Ca contents);
- the REE patterns are the same for the dark granodiorite and the intermediate groups and there is no gap with the less leucocratic members of the adamellite group (Fig. 6);
- the average Mg/(Fe + Mg) ratio decreases from the dark granodiorite to the leucoadamellite groups (Table 2).

According to its location in the «characteristic minerals» diagram (Fig. 4), the magmatic association made up by the three petrographic groups is typically "alumino-cafemic". Moreover, its location in the "Q-B-F" diagram (Fig. 5) shows that it belongs to the calc-alkaline subtype. This calc-alkaline character is partly supported by the REE patterns (see above). Let us mention two remarks:

- The classical calc-alkaline associations are of "cafemic" type, i.e. are rich in intermediate (and even basic) metaluminous rocks and poor or devoid in leucocratic peraluminous members (Fig. 4). Thus, by its typically "alumino-cafemic" type and its richness in peraluminous leucogranitoids, the Ahiçay-Elmaliçay-Büyükçay plutons do not correspond to a common calc-alkaline association.

- The richness of its dark granodiorite and intermediate groups in Ba and often also in Sr (Tables 1, 2) may indicate that this calc-alkaline association displays a subalkaline (i.e. monzonitic) tendency (PAGEL & LETERRIER, 1980). Such a tendency is also suggested by the marked fractionation of the heavy-REE in these two groups (FOURCADE, 1981) and by the steep trend of the whole association in the "nomenclature" diagram (Fig. 3).

CONCLUSION

According to most authors, suturing of a Palaeo-Tethys oceanic realm occurred in the Pontides sometimes around Mid-Jurassic. Evidences of this suturing include the presence of Permian to Liassic ophiolitic assemblage and the existence of north vergent late Triassic to late Jurassic orogenic phase. Opinions differ mainly concerning location and extension of the Palaeo-Tethys ocean as well as concerning the north or south dipping sense of subduction.

These differences in opinions partly result from the large overprinting by later events which have wiped out some of the characteristics features; there is no agreement even on the present localization of the Palaeotethyan suture. Some authors prefer to close towards the South a northern Palaeo-Tethys (e.g. ŞENGÖR et al., 1980, 1982; ŞENGÖR & YILMAZ, 1981); others close towards the North a southern ocean (e.g. ADAMIA et al., 1980; BERGOUGNAN & FOURQUIN, 1982). It must be emphasized that the interpretation of the Palaeo-Tethyan subduction zone as south-dipping is in part based on "the entire allochtoneity of the presently exposed eastern Pontides" (ŞENGÖR et al., 1982), an hypothesis that exceeds largely the scope of this paper.

However in the area concerned by this paper, there is little dispute about the location of the suture somewhere to the South of the plutons. In this region, ophiolitic assemblage and granitoids occur close to each other, some plutons intruding to the South the ophiolitic formation. Such a disposition is known elsewhere, for example along the Indus suture zone where the Transhimalaya plutons sometimes intrude the ophiolitic assemblage located to the South as in the Kargil area of Ladakh (FRANK et al., 1977; BROOKFIELD & REYNOLDS, 1981). The general occurrence of late granitoid plutons North of the ophiolitic assemblage fits with a north-dipping subduction plane.

Altogether the Büyükçay and Ahiçay-Elmaliçay granitoids seem to belong to a single association; their characteristics are complementary and they form a calc-alkaline association of alumino-cafemic type which is not so common and is usually attributed to the melting of a prevailing crustal continental component. Only the cafemic type is usually assigned to the subduction processes. Alumino-cafemic type of association has been proposed to proceed in orogenic belts from different mechanisms such as thickening of the crust followed by rapid denudation and melting of the lower crust (e.g. BRANDEBOURGER, 1984).

In fact, in these associations rich in two-mica leucogranitoids, the crustal contribution must be by far the most important, whatever the age of this crust and the process of magmatic genesis. However, in view of the close relationship in space and time between the Kastamonu granitoids and the Çangal ophiolite of Permo-Triassic age that they intrude, it is possible to envisage that the Kastamonu belt is a consequence of a northward subduction of oceanic crust that induced the melting of an overlying continental crust.

According to this model and to its Dogger age, the Kastamonu granitoid belt largely predates the northward subduction of the neo-Tethys under the Pontides (post Early-Cretaceous according to ŞENGÖR et al., 1980) and thus cannot be related to it. Actually this belt appears to be synchronous with the final stage of suturing of the Palaeo-Tethys with subsequent collision. As shown in unquestionably subduction-related plutonic belts such as the Transhimalaya (e.g. DEBON et al., 1985, in press and submitted), the culmination of magmatic emplacement seems to match the final stage of convergence around the time of collision.

In view of all these data, it is possible to suggest that the Kastamonu belt originated from the last stages of the northward subduction of the Palaeo-Tethys ocean as far as it induced the melting of the Pontides' crust.

Because of the very complex geological history of the adjacent areas, it is difficult to extend eastwards or westwards this model. Only detailed lithologic and structural mapping, which is not yet available, will enable to include the entire Pontides in a unique model.

In conclusion we may remark that this type of magmatism presents several interesting characteristics including its very early alpine age of formation, its emplacement at the southern tip of Eurasia and its special geochemistry.

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