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Geochemistry of the Pontids granitoids in Turkey

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Abstract: Fifty-seven granitoids of mostly the Alpine orogenic cycle from the Pontids, Turkey, were analyzed for the major components and for such trace elements as total C, total S, Cu, Pb, Zn, Rb, Sr, Li and Be. Magnetic susceptibility was also measured. It was found that most of the studied rocks have the magnetite-series characteristics of calc-alkaline suite but the same series of low-K, calcic granitoids are locally present in the eastern area. Trace amounts of copper and Cu/S ratio of some granitoids are as high as those of the Chilean granitoids of the famed porphyry copper province. Thus, a high potentiality for copper may be assumed in the Turkish plutonic province.

Introduction

Turkey is divided into four geotectonic provinces from north to south; Pontids, Anatolids, Taurids and Border Folds (KETIN, 1966). The boundaries among these provinces were slightly revised by HIRANO (1981) as shown in Figure 1. Granitic rocks in Turkey are found mostly in the Pontids and Anatolids. Almost all of them are formed during the Hercynian and Alpine movements, and accompany various kinds of mineralization.

The Pontids extends east-westward along the Black Sea coast and its southern border is bounded by the active North Anatolian Fault except its eastern part. The Pontids has a marked difference in geology between the eastern and western parts. The eastern Pontids is characterized by an enormous amount of Cretaceous volcanics and coeval plutonic rocks called Rize plutonic complex, thus together constituting a volcano-plutonic terrane, while the western Pontids is underlain by Paleozoic to Mesozoic sediments and scattered granitic bodies.

Chemistry of granitoids in Turkey has been discussed by several authors (TANER, 1977; KAMITANI and AKINCI, 1979; MOORE *et al.*, 1980). MOORE *et al.* (1980) studied the relationship between petrochemistry and porphyry copper-type mineralization in the Pontids and concluded that the Pontids does not have favourable condition to produce economic porphyry copper deposits. However, the chemical data are still limited to certain areas in Turkey; thus, granitoids obtained from the Thrace, Bakirçay, Giresun and Rize regions were analyzed for major components and also for some trace elements by the methods described in TERASHIMA *et al.* (1984), and TERASHIMA and ANDO (1987). The results are presented and discussed in this paper.

Analyzed Samples

Number of the smaples analyzed is fifty-seven. Their localities are given in Figures 2-4 and Table 1. The results are listed in

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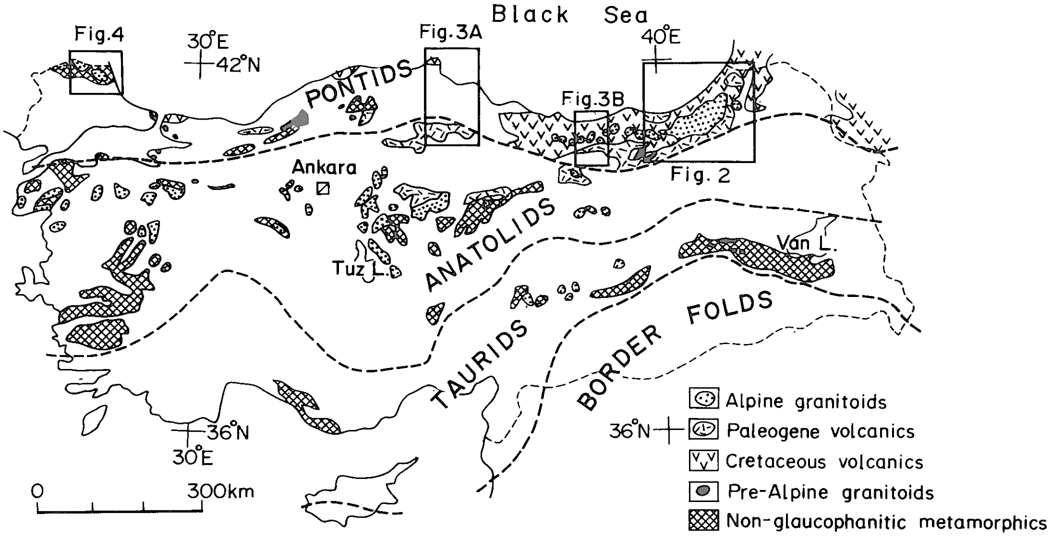

Fig. 1 Geo-tectonic division of Turkey (after HIRANO, 1981) and locality of the studied areas.

Tables 2 through 4. Almost all the studied rocks seem to be the products of the Alpine magmatism, but a few samples from the Thrace region belong to the Hercynian cycle.

From the Yolgecen area of the eastern Pontids, two gabbroids were analyzed. The sample Y 1/22 is fine-grained amphibole gabbro containing plagioclase, amphibole and magnetite. The plagioclase is euhedral in shape and rarely zoned. Amphibole is mostly pale brownish green one, the margin of which is partly converted to greenish variety. The opaque minerals show a typical magnetite outline under the transmitted light; a few of large grained sphene are associated with them. Quartz is always interstitial to plagioclase and amphibole.

The sample Y2/22 is a similar rock to the above, but two generations of biotite: euhedral-subhedral one and fine aggregates of secondary one replacing amphibole, are observed. Thus potassic alteration is obvious. Fine specks of sericite in plagioclase and some limonite around magnetite indicate overlapping hydrothermal alteration in this rock.

The rocks from the Bacili area are coarser in grain size and more felsic in composition than those described above. The sample B8/21 is actinolite-bearing biotite granodiorite. Plagioclase is often zoned and weakly sericitized. Amphibole mineral is fine crystals of actinolite, which could have been originally euhedral hornblende. Biotite occurs as both euhedral crystals, and fine aggregates. Pyrite is dominant along fractures but hydrothermal alteration minerals such as epidote and chlorite are rather rare.

The sample B7/21 is the same as the above but altered weakly to hydrothermal minerals. The sample B6/21 is also similar in texture and mineral composition, but contains large subhedral perthitic K-feldspar.

Eighteen samples were analyzed from the area to the south of Rize (Fig. 2). Only powdered samples were available for the main part of the river lyidere (Nos. 56, 43, 287, 280 and 296). The samples from the İkizdere-Cimilbaşköy area (CD11/23-KD5) are composed mostly of coarse-grained biotite granodiorite, quartz monzodiorite and monzogranite, with or without amphibole. The K-feldspar has pale pinkish color with naked eyes. Some others are granodiorite porphyry (CB11/21 and 10/19).

In the coarse-grained holocrystalline rocks,

Table 1 List of the analyzed samples.

Yolgeçen		
Y 1/22	:	Very fine-grained amphibole gabbro
Y 2/22	:	Fine-grained sphene-quartz-bearing amphibole gabbro, weakly altered
Balcili		
B 8/21	:	Fine-grained amphibole-bearing biotite granodiorite, pyrite disseminated on cracks
B 7/21	:	Fine-grained amphibole-bearing biotite granodiorite
B 6/21	:	Fine-grained hornblende-biotite monzogranite
İkizdere-Cimilbaşköy		
CD11/23	:	Coarse-grained hornblende-bearing biotite granodiorite, argillized propylitized and pyritized
CD10/23	:	Medium-grained biotite monzogranite
CD 8/23	:	Coarse-grained biotite monzogranite
CD 6/23	:	Medium-grained biotite-hornblende quartz monzodiorite
CD 4/23	:	Coarse-grained hornblende-bearing biotite quartz monzonite
CD 3/23	:	Coarse-grained biotite monzogranite
CD 2/23	:	Coarse-grained acitnolite-bearing biotite monzogranite, pyrite on crack
CB10/19	:	Amphibole granodiorite porphyry
CB11/21	:	ditto, argillized and propylitized
CB37/22	:	Coarse-grained biotite monzogranite, sericitized, argillized and pyritized
Kümbet-Emeksan		
ED 2/17	:	Fine-grained biotite granodiorite, gneissosed
EK 2	:	Fine-grained sphene-bearing biotite granodiorite (monzonitic)
ED 6	:	Coarse-grained porphyritic biotite granite, gneissosed
ED 5	:	ditto, altered
Ḅakirçay		
BC27, 46	:	Fine-grained biotite granodiorite
BC54	:	Fine-grained actinolite-bearing biotite granodiorite
BC61	:	Fine-grained biotite granodiorite porphyry
BC64	:	Fine-grained hornblende-biotite granodiorite porphyry
BC72	:	Fine-grained hornblende-biotite granodiorite, pyrite dissemination and molybdenite-quartz veinlet
BC74	:	Fine-grained hornblende-biotite granodiorite porphyry
Uludağ		
UD11/24	:	Medium-grained biotite monzogranite
Dereköy		
C 1	:	Coarse-grained hornblende-bearing biotite monzonite
CO 4	:	Hornblende quartz monzodiorite porphyry
CO 5	:	Biotite-bearing hornblende quartz monzodiorite porphyry, altered
Sükrüpasa		
SP103/24	:	Fine-grained biotite-clinopyroxene-monzodiorite
SP 1/15	:	Hornblende-biotite granodiorite porphyry
SP15/19	:	Hornblende granodiorite porphyry, altered
SP 4/22E	:	Medium-grained amphibole-biotite-clinopyroxene monzodiorite
SP 1/22E	:	Hornblende-biotite granodiorite porphyry
SP13/17	:	ditto
SP-S4	:	ditto, altered
80b/21	:	ditto
SP 3/23	:	ditto, pyrite on cracks
SP15/8E	:	Hornblende-bearing biotite granodiorite porphyry

Table 1 (continued)

Karanlikdere		
KD 4/26	:	Hornblende-biotite granodiorite porphyry
KD12/26	:	ditto
KD14/26	:	Hornblende-bearing biotite granodiorite porphyry, altered
KD 5/26	:	Medium-grained hornblende-biotite granodiorite
Demirköy		
DK16/21	:	Fine-grained sphene-bearing amphibole monzodiorite
DK 9/21	:	Coarse-grained biotite-bearing hornblende quartz monzodiorite
DK D2	:	Medium-grained hornblende-biotite granodiorite
DK D3	:	ditto
DK DS4	:	Coarse-grained biotite-hornblende granodiorite

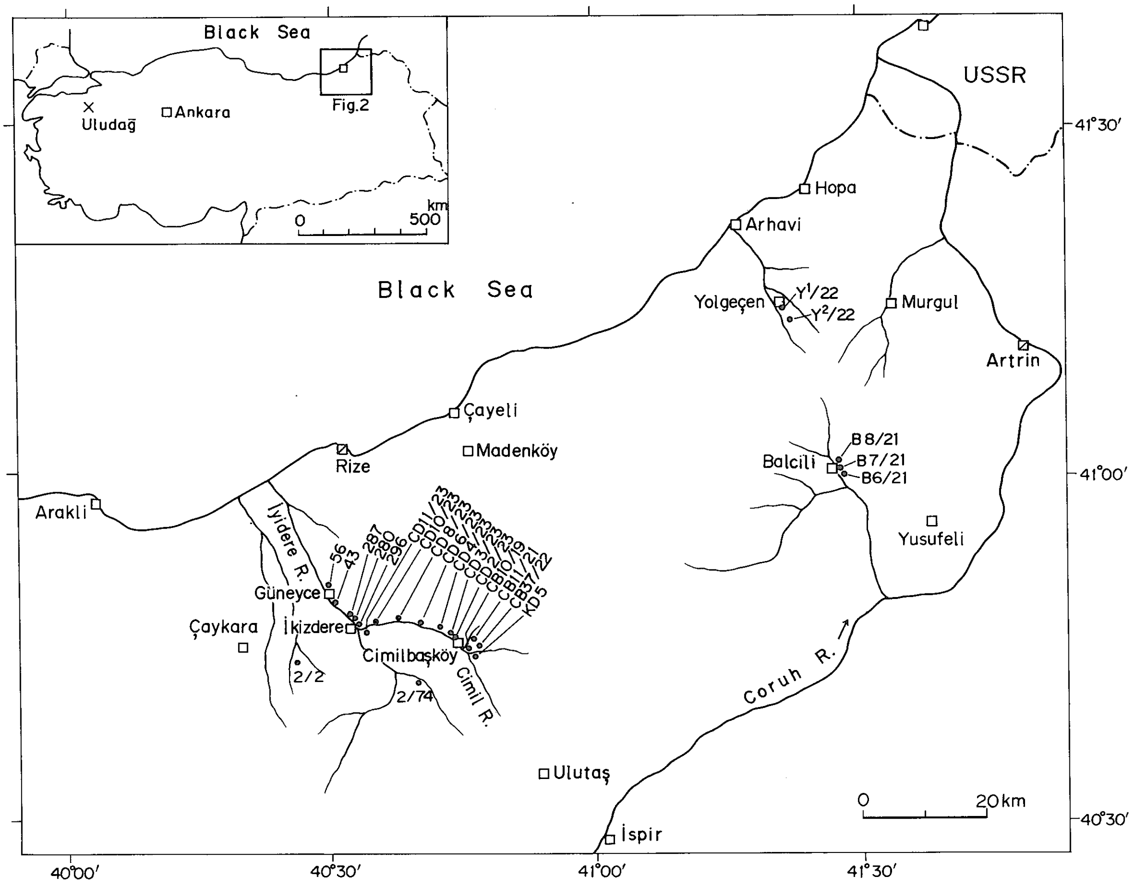

Fig. 2 Sample locality map of the Rize region (Yolgeçen, Balcili and İkizdere-Cimilbaşköy), Eastern Pontids.

K-feldspar is generally perthite and partly microcline-perthite, and often shows dusty appearance, due possibly to argillization. The microcline-perthite may have a high content of albite molecule, because some of the granite have low-K_2O content (hence called low-K granite), which will be described in the chemistry chapter later. Plagioclase is rarely zoned and often contains fine specks of sericite. Biotite is greenish brown and occurs together with magnetite. This mineral is weakly propylitized. Rarely found is large crystals of sphene, which could be secondary in origin. Weak stress effect is observed on quartz and biotite as indicated by wavy extinction in these minerals.

The holocrystalline rocks are argillized and propylitized to certain degrees. Low-K granitoids are weakly carbonatized. In one rock (CB37/22), euhedral biotites are filled with fine crystals of pale brown biotite, sericite and pyrite implying that the rocks have been altered to have potassic and phyllic mineral assemblages in some places.

The other rock type of amphibole granodiorite porphyry is a porphyritic rock having phenocryst of plagioclase, amphibole, quartz and magnetite. Epidote, chlorite and carbonate prevail generally in the groundmass, thus the rock is propylitized in a high degree.

The sample CD6/23 is not a normal rock but well digested mafic inclusion having plagioclase porphyroblast of 1 by 2 mm.

In the Emeksan area (Fig. 3), the samples consist of two types: gneissose biotite monzogranite (ED6, 5) and fine sphene-bearing biotite monzodiorite (EK2). The former looks as "Augen gneiss" for its large pink K-feldspar phenocryst (less than 10 by 15 mm), filled with recrystallized aggregates of quartz, K-feldspar and plagioclase. This could well be a different (older) age of granitoids from the others. In the sample ED5, the K-feldspar phenocryst is cut by fine aggre-

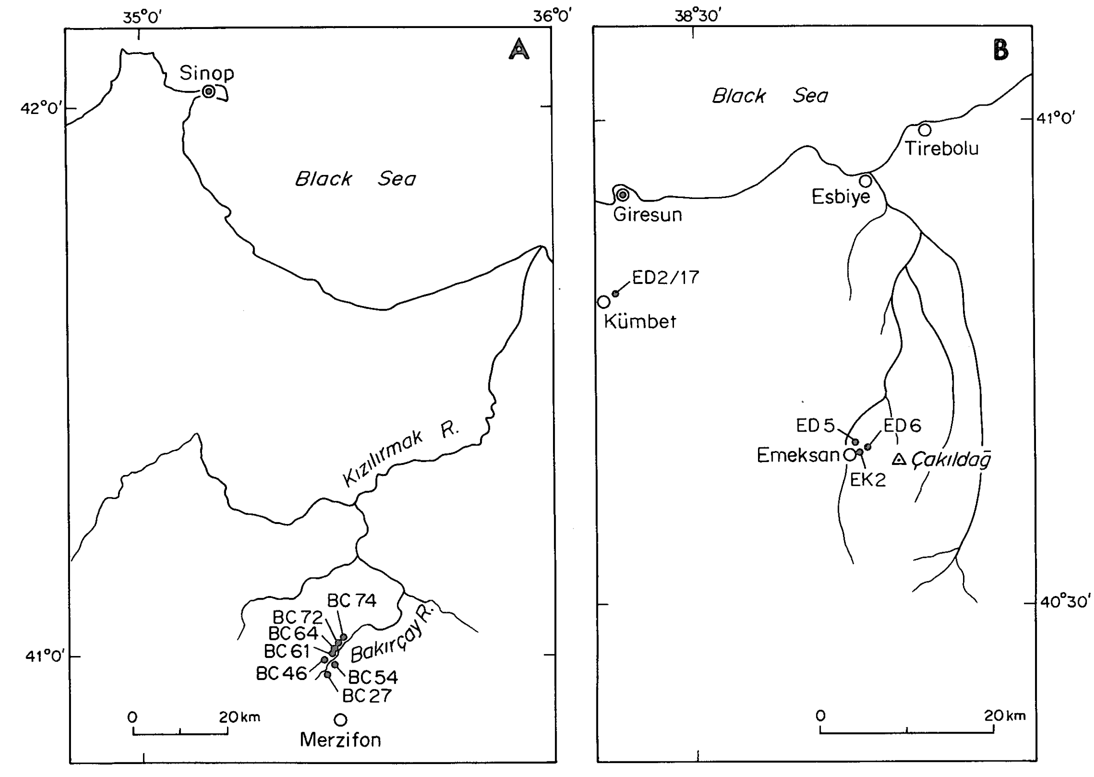

Fig. 3 Sample locality map of the Kümbet, Emeksan areas (B) and the Bakirçay porhyry copper prospect area (A).

gates of quartz and feldspars, indicating a multiple stages of shearing during the crystallization. This type of rocks are moderatery sericitized and large crystals of pyrite occur associated with sericite. Biotite is also partly chloritized.

The sample ED2/17 is medium-grained biotite granodiorite having weak gneissosity and containing sutured quartz, which indicate stress effect. This rock contains no magnetite and is only rock among those studied which belong to the ilmenite-series granitoids (see the following chapter).

In the Bakirçay area, the studied rocks are all fine-grained amphibole-biotite granodiorite. The rocks are more or less porphyritic as shown by phenocrysts of plagioclase and mafic silicates. Plagioclase is often strongly zoned, and zoned one sometimes replaced by later zoned plagioclase, indicating rapid cooling of this rock. Amphibole is common hornblende often actinolitized, then biotitized. The phenocryst of feldspars and mafic silicates have been weakly altered to sericite, carbonate and chlorite. Groundmass of this rock is aphanitic in texture and has the same mineral assemblage as that of the phenocrysts. Porphyry copper-type mineralization (TAYLOR and FRYER, 1980) is known associated with the granodiorite.

In the western, Thrace region (Fig. 4), two types are present in the Derekoy area. One type (C1) is coarse-grained hornblende -bearing biotite monzonite, which contains little interstitial quartz. Hornblende is nearly completely altered to sphene, carbonate and chlorite. This type is so different from the second type that it could belong to the Hercynian cycle.

The other type is quartz monzodiorite porphyry with flowage of amphibole which goes up to 5 by 15 mm. The phenocrysts are zoned plagioclase and mafic silicates. Hornblende has been altered to actinolite and

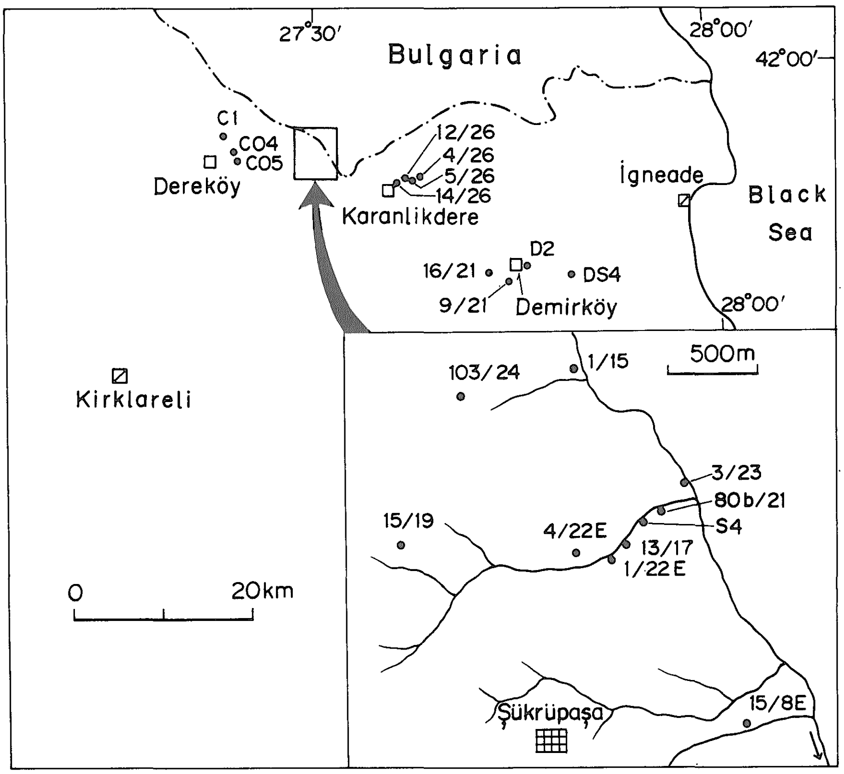

Fig. 4 Sample locality map of the Thrace region, Western Pontids.

biotite; then hydrothermally to chlorite, sphene, carbonate, sericite and pyrite.

In the Sükrüpasa area, the analyzed samples are grouped into two: monzodiorite and granodiorite porphyry. The former (SP103/24, 4/22E) contain clinopyroxene which is replaced partly by actinolite and biotite. Most of the other rocks are amphibole-biotite granodiorite porphyry whose phenocrysts are zoned plagioclase, biotite and hornblende.

The porphyry has been partly altered to secondary biotite whose aggregate cut plagioclase as minute veinlets (e. g., SP-S4, 15/8E), then to carbonate, sericite, chlorite and pyrite (e. g., SP-S4, 3/23). The altered rocks contain abundant apatite occasionally and microveinlet of zeolite. Carbonatization is distinct in the altered rocks of this area.

In the Karanlikdere area, the sample KD14/26 is also amphibole granodiorite porphyry but the groundmass is flooded by quartz. This rock is partly altered to sericite, chlorite, carbonate and pyrite (KD4/26). The sample KD5/26 is a hollocrystalline rock of medium-grained hornblende-biotite granodiorite.

In the Demirköy area, the granitoids are biotite-hornblende monzodiorite to granodiorite. Some rocks (e. g., DK16/21, DS4) are strongly altered; hornblende has been actinolitized, then altered to carbonate and epidote. No opaque minerals are present in this rock, due to the hydrothermal alteration.

Magnetic Susceptibility

Magnetic susceptibility was measured on hand specimen by the Geoinstruments ky TH-1 magnetic susceptibility meter. The results are listed in Tables 2 through 4 and are shown in Fig. 5. Granodioritic stock of the Medet porphyry copper deposit in Bulgaria is plotted in the figure for comparison. Almost all of the studied granitoids have magnetic susceptibility of the magnetite-series granitoids of Japan.

In the eastern region, four out of 27 samples give the values of the ilmenite-series granitoids. Among these, ED2/17 of the Kümbet area is only true ilmenite series, because the rock is fresh and contains no magnetite. The others were originally magnetite-series granitoids, but have lost their magnetic susceptibility by later hematitization (CB37/22) or pyritization (ED5, UD11/24) of the original magnetite during hydrothermal alteration. The sample Y2/22 has a low magnetic susceptibility for its mafic composition, because of oxidation and pyritization of the original magnetite.

In the Thrace region, four out of 21 samples have the values of ilmenite-series grani-

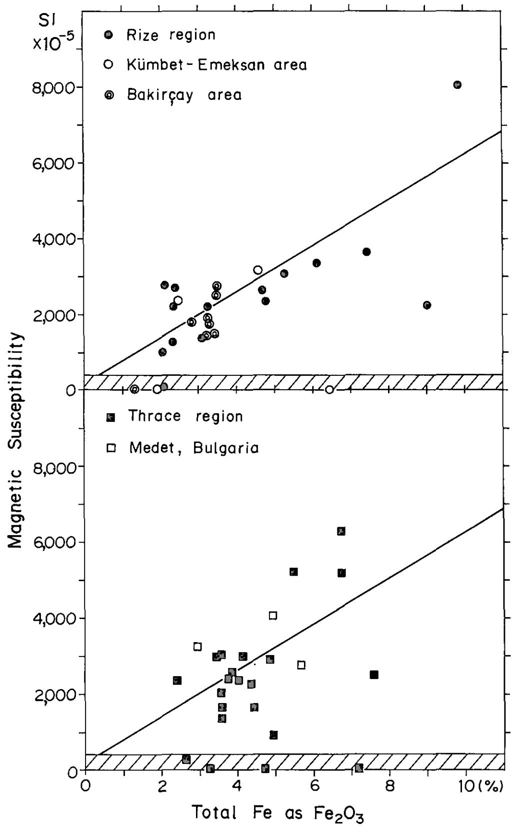

Fig. 5 Magnetic susceptibility of the studied granitoids. The original data are given in Tables 2-4. Straight line is the average magnetite-series granitoids of Japan (ISHIHARA *et al.* unpublished data). Shaded is the area for ilmenite-series granitoids.

Table 2 Analytical data for the Rize Plutonic rocks (see Fig. 2 for the Sample locality).

Sample No.	Yolgeçen area		Balcili area			İkizdere-Cimilbaşköy area				
	Y1/22	Y2/22	B8/21	B7/21	B6/21	56	43	287	280	296
SiO_2(%)	48.75	50.42	67.04	·····	71.83	53.50	73.43	74.65	72.89	74.30
TiO_2	.90	.85	.55	·····	.36	.90	.25	.28	.36	.25
Al_2O_3	19.60	19.45	14.86	·····	13.77	18.43	13.73	13.28	13.22	13.42
Fe_2O_3	4.47	4.27	2.54	7.38	1.69	2.51	1.43	2.20	1.29	.65
FeO	4.84	4.29	2.42	·····	1.40	6.65	1.55	.61	1.79	1.78
MnO	.19	.15	.10	.14	.06	.16	.02	.01	.08	.06
MgO	5.03	4.56	1.88	2.72	.97	3.97	.48	.47	.74	.56
CaO	9.95	7.92	3.58	3.97	2.80	8.84	3.20	2.28	3.07	2.53
Na_2O	2.80	2.48	2.97	2.53	3.35	2.60	4.91	4.32	4.64	4.02
K_2O	.98	1.52	2.58	2.11	3.20	.07	.14	.09	.73	1.58
P_2O_5	.37	.41	.11	·····	.07	.10	.06	.05	.07	.04
H_2O+	1.56	2.49	.89	·····	.25	1.20	.77	1.23	.62	.63
H_2O-	.22	.31	.06	·····	.03	.11	.13	.26	.03	.08
Others	.09	.94	.57	·····	.06	1.40	.16	.11	.05	.08
Total	99.75	100.06	100.15	18.85	99.84	100.44	100.26	99.84	99.58	99.98
T. C. (ppm)	100	160	100	590	130	600	1,350	820	220	580
S	30	7,900	5,030	60	170	12,960	10	30	50	20
Cu	24	635	211	186	12	152	1	3	15	2
Zn	67	53	57	52	26	33	2	6	28	24
Pb	15	10	13	10	8	17	2	3	5	6
Li	1	3	4	6	2	1	1	1	1	1
Rb	22	60	69	38	88	5	4	-	10	30
Sr	591	543	179	183	140	250	186	198	128	99
Be	1.2	1.0	1.4	1.3	1.4	.3	1.0	.7	.7	.8
Kai	8,030	2,250	3,070	3,640	2,200	·····	·····	·····	·····	·····
Q (%)	1.02	6.10	28.99	·····	32.61	10.49	36.45	43.73	35.18	37.62
C	-	.31	.94	·····	-	-	-	2.05	-	.59
or	5.79	8.98	15.25	·····	18.91	.41	.83	.53	4.31	9.34
ab	23.69	20.98	25.13	·····	28.35	22.00	41.55	36.55	39.26	34.02
an	38.02	36.61	17.04	·····	13.08	38.41	15.01	10.98	13.09	12.29
wo-di	3.73	-	-	·····	.15	2.00	.20	-	.70	-
en-di	2.58	-	-	·····	.10	1.02	.09	-	.35	-
fs-di	.84	-	-	·····	.03	.93	.10	-	.34	-
en-hy	9.94	11.36	4.68	·····	2.31	8.86	1.10	1.17	1.49	1.39
fs-hy	3.22	3.22	1.62	·····	.66	8.02	1.19	-	1.44	2.43
mt	6.48	6.19	3.68	·····	2.45	3.64	2.07	1.19	1.87	.94
hm	-	-	-	·····	-	-	-	1.38	-	-
il	1.71	1.61	1.04	·····	.68	1.71	.47	.53	.68	.47
ap	.86	.95	.25	·····	.16	.23	.14	.12	.16	.09
Q+or+ab	30.50	36.06	69.37	·····	79.87	32.90	78.82	80.82	78.75	80.97

Abbreviation for Tables 2 through 4: Others, total minor elements; T. C. total carbon; Kai, magnetic susceptibility in SI unit ($\times 10^{-5}$).

Table 2 (continued)

Sample No.	İkizdere-Cimilbaşköy area												
	CD11/23	CD10/23	CD8/23	CD6/23	CD4/23	CD3/23	CD2/23	CB10/19	CB11/21	CB37/22	KD-5	2/74	2/2
SiO_2 (%)	·····	67.89	73.61	62.42	68.74	·····	71.93	63.60	·····	·····	72.40	69.71	68.50
TiO_2	·····	.29	.18	.67	.25	·····	.25	.39	·····	·····	.25	.24	.30
Al_2O_3	·····	16.14	14.05	17.15	15.65	·····	14.20	15.98	·····	·····	13.10	15.22	15.23
Fe_2O_3	2.29	.95	.70	2.32	1.26	2.40	1.16	2.33	4.68	2.05	1.75	1.16	1.38
FeO	·····	1.95	1.21	3.42	1.03	·····	.86	2.18	·····	·····	.49	1.35	2.59
MnO	.05	.07	.05	.15	.11	.09	.07	.11	.12	.01	.05	.08	.18
MgO	.51	.66	.40	1.80	.56	.67	.54	1.86	2.00	.64	.64	.62	.49
CaO	2.80	2.79	2.70	4.98	1.80	2.01	1.88	4.92	4.17	1.64	1.70	2.30	2.40
Na_2O	4.38	3.61	4.20	4.05	4.27	4.14	4.00	3.66	3.40	3.55	3.55	4.10	3.81
K_2O	1.44	4.50	2.12	1.88	5.53	4.23	4.28	2.62	2.58	2.90	3.78	4.01	3.18
P_2O_5	·····	.09	.04	.21	.08	·····	.06	.13	·····	·····	.09	.08	.10
H_2O+	·····	.60	.79	.33	.31	·····	.25	1.51	·····	·····	1.19	.58	1.18
H_2O-	·····	.02	.07	.05	.07	·····	.07	-	·····	·····	.02	.02	.14
Others	·····	.07	.07	.15	.10	·····	.47	.28	·····	·····	1.50	.10	.20
Total	11.47	99.63	100.19	99.58	99.76	13.54	100.02	99.57	16.95	10.79	100.51	99.57	99.68
T. C. (ppm)	400	220	440	260	600	120	4,030	2,200	5,400	70	510	500	1,300
S	30	30	20	700	30	10	300	10	30	12,200	13,840	40	130
Cu	7	10	11	32	9	4	23	13	35	100	186	2	7
Zn	18	35	15	93	39	40	18	46	46	13	23	39	82
Pb	4	27	8	26	29	25	25	20	22	27	33	24	66
Li	5	1	10	15	16	14	12	14	20	5	7	27	20
Rb	30	132	47	63	141	106	128	50	85	90	96	128	147
Sr	108	280	132	285	162	206	181	443	416	176	271	217	224
Be	.6	2.1	1.0	2.2	2.3	2.0	2.1	1.4	1.5	2.6	2.3	2.6	2.8
Kai	1,270	1,390	1,000	3,340	2,170	2,680	2,750	2,340	2,640	22	·····	·····	·····
Q (%)	·····	21.85	34.14	17.35	18.24	·····	27.64	19.48	·····	·····	32.94	24.31	27.00
C	·····	.47	.03	-	-	·····	-	-	·····	·····	.29	.14	1.40
or	·····	26.59	12.53	11.11	32.68	·····	25.29	15.48	·····	·····	22.34	23.70	18.79
ab	·····	30.55	35.54	34.27	36.13	·····	33.85	30.97	·····	·····	30.04	34.69	32.24
an	·····	13.25	13.13	23.06	7.20	·····	8.15	19.44	·····	·····	7.85	10.89	11.25
wo-di	·····	-	-	.11	.50	·····	.33	1.72	·····	·····	-	-	-
en-di	·····	-	-	.06	.32	·····	.24	1.17	·····	·····	-	-	-
fs-di	·····	-	-	.05	.15	·····	.06	.41	·····	·····	-	-	-
en-hy	·····	1.64	1.00	4.42	1.07	·····	1.11	3.46	·····	·····	1.59	1.54	1.22
fs-hy	·····	2.45	1.44	3.49	.49	·····	.28	1.22	·····	·····	-	1.27	3.45
mt	·····	1.38	1.01	3.36	1.83	·····	1.68	3.38	·····	·····	1.02	1.68	2.00
hm	·····	-	-	-	-	·····	-	-	·····	·····	1.05	-	-
il	·····	.55	.34	1.27	.47	·····	.47	.74	·····	·····	.47	.46	.57
ap	·····	.21	.09	.49	.19	·····	.14	.30	·····	·····	.21	.19	.23
Q+or+ab	·····	78.99	82.21	62.73	87.05	·····	86.77	65.93	·····	·····	85.32	82.70	78.04

Table 3 Analytical data for the granitoids from the Kümbet, Emeksan and Bakirçay areas, (see Fig. 3 for the sample locality)

Sample No.	Kümbet	Emeksan area			Bakirçay area							Uludağ
	ED2/17	EK 2	ED 6	ED 5	BC27	BC46	BC54	BC61	BC64	BC72/1	BC74	UD11/24
SiO_2 (%)	62.32	62.88	70.11	·····	·····	·····	67.12	67.74	66.32	67.28	·····	70.95
TiO_2	.80	.63	.32	·····	·····	·····	.57	.50	.57	.54	·····	.24
Al_2O_3	15.81	16.56	14.82	·····	·····	·····	15.62	15.63	16.00	15.62	·····	15.31
Fe_2O_3	1.12	2.32	1.19	1.93	3.25	3.30	1.85	1.57	1.88	1.19	2.82	.47
FeO	4.80	2.09	1.15	·····	·····	·····	1.47	1.41	1.44	1.84	·····	.76
MnO	.12	.07	.04	.03	.03	.03	.06	.02	.06	.06	.05	.03
MgO	2.93	2.60	1.04	1.07	1.61	1.60	1.65	1.53	1.70	1.83	1.52	.70
CaO	4.40	3.20	1.35	.88	2.70	2.81	3.62	2.60	4.00	3.74	3.37	1.66
Na_2O	2.32	3.09	3.36	3.41	4.42	3.79	3.98	4.08	4.35	3.94	3.77	3.96
K_2O	2.84	3.76	4.88	5.91	2.60	2.74	2.48	2.68	2.49	2.38	2.76	4.15
P_2O_5	.14	.15	.11	·····	·····	·····	.17	.17	.20	.18	·····	.11
H_2O+	1.42	1.69	.93	·····	·····	·····	.70	1.40	.76	.91	·····	1.04
H_2O-	.12	.25	.17	·····	·····	·····	.12	.57	.25	.24	·····	.25
Others	.18	.21	.12	·····	·····	·····	.07	.10	.07	.10	·····	.13
Total	99.32	99.50	99.59	13.23	14.61	14.27	99.48	100.00	100.09	99.85	14.29	99.76
T. C. (ppm)	590	1,430	520	160	80	120	70	110	80	380	80	270
S	760	250	250	6,750	300	30	20	200	20	40	10	360
Cu	27	6	11	168	220	235	32	177	20	12	84	1
Zn	87	45	25	24	12	14	33	6	38	25	30	26
Pb	22	23	19	25	14	9	10	8	10	4	9	38
Li	25	7	11	9	20	20	13	22	12	18	11	41
Rb	71	70	158	202	75	74	63	68	58	78	67	156
Sr	174	274	243	225	440	434	452	401	502	441	404	378
Be	2.3	2.7	2.9	2.9	1.7	1.8	1.5	1.7	1.5	1.6	1.8	4.4
Kai	24	3,100	2,350	29	1,910	1,520	2.780	1,440	2.530	1,820	1,800	10
Q (%)	21.46	19.75	27.45	·····	·····	·····	24.59	26.15	21.21	24.28	·····	27.44
C	1.25	1.95	1.82	·····	·····	·····	.21	1.70	-	.19	·····	1.55
or	16.78	22.22	28.84	·····	·····	·····	14.66	15.84	14.71	14.06	·····	24.52
ab	19.63	26.15	28.43	·····	·····	·····	33.68	34.52	36.81	33.34	·····	33.51
an	20.91	14.90	5.98	·····	·····	·····	16.85	11.79	16.78	17.38	·····	7.52
wo-di	-	-	-	·····	·····	·····	-	-	.73	-	·····	-
en-di	-	-	-	·····	·····	·····	-	-	.61	-	·····	-
fs-di	-	-	-	·····	·····	·····	-	-	.04	-	·····	-
en-hy	7.30	6.48	2.59	·····	·····	·····	4.11	3.81	3.63	4.56	·····	1.74
fs-hy	6.79	1.01	.67	·····	·····	·····	.34	.50	.22	1.61	·····	.67
mt	1.62	3.36	1.73	·····	·····	·····	2.68	2.28	2.73	1.73	·····	.68
hm	-	-	-	·····	·····	·····	-	-	-	-	·····	-
il	1.52	1.20	.61	·····	·····	·····	1.08	.95	1.08	1.03	·····	.46
ap	.32	.35	.25	·····	·····	·····	.39	.39	.46	.42	·····	.25
Q+or+ab	57.88	68.11	84.72	·····	·····	·····	72.92	76.51	72.73	71.69	·····	85.47

Table 4 Analytical data for the granitoids from the Thrace region (see Fig. 4 for the sample locality).

Sample No.	Dereköy area			sükrüpasa area (sp)									
	C 1	CO 4	CO 5	103/24	1/15	15/19	4/22E	1/22E	13/17	S 4	80b/21	3/23	15/8E
SiO_2 (%)	60.89	59.44	62.71	55.50	66.23	65.84	56.25	64.36	·····	·····	65.62	·····	68.89
TiO_2	.57	.43	.46	.80	.37	.41	.77	.46	·····	·····	.38	·····	.28
Al_2O_3	18.61	18.32	16.54	17.27	15.88	16.02	16.83	17.16	·····	·····	16.80	·····	16.16
Fe_2O_3	1.80	1.99	1.88	3.22	1.78	2.17	2.88	1.78	3.62	3.25	1.83	2.64	1.24
FeO	1.58	2.64	1.74	3.20	1.51	1.44	3.49	2.03	·····	·····	1.54	·····	1.21
MnO	.06	.11	.05	.11	.06	.09	.12	.07	.05	.03	.06	.04	.05
MgO	1.30	3.05	2.14	3.66	1.49	1.52	4.12	1.68	1.47	1.27	1.19	1.52	.95
CaO	3.01	6.62	4.16	6.08	3.22	3.52	5.76	3.90	3.55	3.22	3.33	3.28	2.92
Na_2O	4.58	3.45	4.26	4.34	4.13	4.05	4.25	4.25	4.09	3.59	4.10	4.00	4.43
K_2O	6.07	1.35	3.58	4.46	3.15	3.10	4.14	2.97	3.45	3.41	3.21	3.35	3.14
P_2O_5	.36	.07	.22	.42	.15	.16	.34	.18	·····	·····	.16	·····	.11
H_2O+	.49	1.74	1.36	.31	1.21	.95	.61	.85	·····	·····	.98	·····	.37
H_2O-	.05	.18	.26	.11	.20	.16	.21	.11	·····	·····	.25	·····	.08
Others	.16	1.09	.31	.44	.07	.09	.14	.09	·····	·····	.54	·····	.07
Total	99.53	100.48	99.67	99.92	99.45	99.52	99.91	99.89	16.23	14.77	99.99	14.83	99.90
T. C. (ppm)	510	950	1,260	3.260	50	80	250	100	200	1,960	780	1,300	90
S	160	9,300	1,020	10	20	70	50	80	840	12,320	3,910	4,580	20
Cu	39	210	8	105	25	42	96	6	103	775	51	1,985	6
Zn	34	33	23	72	29	50	65	25	22	12	25	26	22
Pb	56	19	23	44	15	20	35	16	15	15	14	15	14
Li	12	18	7	28	14	16	13	16	8	14	12	14	12
Rb	203	40	68	154	85	96	129	95	117	120	80	144	113
Sr	600	356	710	730	500	528	740	560	554	430	502	506	431
Be	3.9	.4	2.8	4.5	2.4	2.6	3.6	2.5	2.5	2.3	2.5	2.4	2.9
Kai	3,030	900	2,520	6.250	2,940	2.450	5,180	2,350	1,345	54	2,060	275	2,330
Q (%)	3.44	14.85	13.12	-	21.09	20.92	-	17.18	·····	·····	20.66	·····	23.37
C	-	-	-	-	.18	-	-	.29	·····	·····	.91	·····	.43
or	35.87	7.98	21.16	26.36	18.62	18.32	24.47	17.55	·····	·····	18.97	·····	18.56
ab	38.75	29.19	36.05	35.71	34.95	34.27	35.96	35.96	·····	·····	34.69	·····	37.49
an	12.29	30.51	15.44	14.47	14.99	16.38	14.62	18.17	·····	·····	15.47	·····	13.77
ne	-	-	-	.55	-	-	-	-	·····	·····	-	·····	-
wo-di	.12	.78	1.57	5.41	-	.02	4.90	-	·····	·····	-	·····	-
en-di	.09	.53	1.19	3.98	-	.01	3.47	-	·····	·····	-	·····	-
fs-di	.02	.19	.22	.92	-	.00	1.01	-	·····	·····	-	·····	-
en-hy	3.15	7.07	4.14	-	3.71	3.77	4.98	4.18	·····	·····	2.96	·····	2.37
fs-hy	.57	2.51	.76	-	.80	.34	1.45	1.63	·····	·····	.80	·····	.83
fo-ol	-	-	-	3.60	-	-	1.27	-	·····	·····	-	·····	-
fa-ol	-	-	-	.91	-	-	.41	-	·····	·····	-	·····	-
mt	2.61	2.88	2.73	4.67	2.58	3.15	4.18	2.58	·····	·····	2.65	·····	1.80
il	1.08	.82	.87	1.52	.70	.78	1.46	.87	·····	·····	.72	·····	.53
ap	.83	.16	.51	.97	.35	.37	.79	.42	·····	·····	.37	·····	.25
Q+or+ab	78.07	52.02	70.32	62.62	74.65	73.50	60.43	70.69	·····	·····	74.33	·····	79.41

Table 4 (continued)

Sample No.	Karanlikdere area (KD)				Demirköy area(DK)				
	4/26	12/26	14/26	5/26	16/21	9/21	D 2	D 3	DS 4
SiO_2 (%)	·····	·····	64.48	65.60	55.87	56.53	63.33	66.96	·····
TiO_2	·····	·····	.43	.40	.67	.61	.45	.41	·····
Al_2O_3	·····	·····	17.22	16.41	17.92	16.07	16.44	16.10	·····
Fe_2O_3	4.88	4.27	1.74	2.00	1.02	2.91	2.59	1.88	7.18
FeO	·····	·····	2.15	2.19	3.30	4.22	2.62	1.54	·····
MnO	.12	.11	.11	.11	.10	.15	.11	.07	.15
MgO	2.51	1.86	2.11	1.91	4.45	5.06	2.00	1.32	3.10
CaO	5.32	5.00	5.15	5.21	8.11	8.23	5.64	3.42	6.60
Na_2O	2.90	3.35	3.42	3.41	3.10	3.12	3.31	4.22	3.11
K_2O	2.03	1.91	1.98	1.96	3.72	1.60	2.02	3.05	1.23
P_2O_5	·····	·····	.13	.11	.16	.16	.13	.14	·····
H_2O+	·····	·····	1.11	.63	.90	.72	.73	.46	·····
H_2O-	·····	·····	.13	.07	.04	.04	.03	.05	·····
Others	·····	·····	.07	.08	.17	.09	.06	.09	·····
Total	17.76	16.50	100.23	100.09	99.53	99.51	99.46	99.71	21.37
T. C. (ppm)	630	410	90	70	890	100	50	200	3,900
S	3,810	30	160	150	80	160	20	30	150
Cu	86	6	20	86	8	8	20	4	264
Zn	59	40	40	49	35	72	50	23	68
Pb	9	12	9	12	14	16	12	20	15
Li	7	6	6	11	2	4	11	16	16
Rb	58	44	23	35	68	30	43	114	34
Sr	342	396	341	356	554	499	380	498	484
Be	.5	.7	.5	.8	1.1	.9	.9	2.5	1.0
Kai	2,940	2,240	2,980	1,640	33	2,540	5,200	1,680	68
Q (%)	·····	·····	22.28	24.00	1.37	8.60	21.34	21.52	·····
C	·····	·····	.40	-	-	-	-	-	·····
or	·····	·····	11.70	11.58	21.98	9.46	11.94	18.02	·····
ab	·····	·····	28.94	28.85	26.23	26.40	28.01	35.71	·····
an	·····	·····	24.70	23.68	23.99	25.12	24.03	15.98	·····
wo-di	·····	·····	-	.60	6.34	6.12	1.29	.03	·····
en-di	·····	·····	-	.40	4.23	4.14	.84	.02	·····
fs-di	·····	·····	-	.16	1.64	1.52	.36	.00	·····
en-hy	·····	·····	5.26	4.36	6.85	8.46	4.14	3.27	·····
fs-hy	·····	·····	2.00	1.75	2.65	3.10	1.77	.72	·····
fo-ol	·····	·····	-	-	-	-	-	-	·····
fa-ol	·····	·····	-	-	-	-	-	-	·····
mt	·····	·····	2.52	2.90	1.48	4.22	3.75	2.73	·····
hm	·····	·····	-	-	-	-	-	-	·····
il	·····	·····	.82	.76	1.27	1.16	.85	.78	·····
ap	·····	·····	.30	.25	.37	.37	.30	.32	·····
Q+or+ab	·····	·····	62.92	64.44	49.58	44.45	61.29	75.26	·····

toids. Magnetic susceptibility is low in oxidized (DK-DS4) and pyritized (SP-S4, SP3/23, KD4/26) rocks. The magnetic susceptibility values are consistent with general high ratio of Fe_2O_3/FeO of the studied granitoids (Tables 2-4).

Alkali Ratio

The studied granitoids have some variation in the alkali ratio. In the İkizdere area of the eastern region in particular, the rocks along the river İkizdere are very depleted in K_2O, and five samples are plotted in the field of typical island arc tonalite in the K_2O-Na_2O-CaO diagram (Fig. 6), while those occurring along the southeastern tributary of the river Cimil have a normal K_2O/Na_2O ratios of island arc calc-alkaline rocks.

Granitoids of the Bakirçay area are plotted in the field between the two types of granitoids mentioned above. Granitoids of Kümbet and Emeksan areas are most potassic in the diagram (Fig. 6).

Granitoids of the Thrace region have normal K_2O/Na_2O ratio and show no areal variations.

Normative Qz–Or–An+Ab

The studied granitoids reveal a wide variation in the normative quartz-orthoclase-plagioclase diagram (Fig. 7). Low-K granitoids of the eastern region are as a matter of fact plotted along the quartz-plagioclase side-line. The majority are distributed from gabbro to granodiorite-monzogranite boundary through quartz monzodiorite field. One sample CD4/23 is plotted at the boundary between quartz monzonite and monzogranite.

Granitoids of the Thrace region are plotted in a similar field to that of the main rock type of the eastern region (Fig. 7). But four samples are alkalic being either quartz-free (SP4/22 E, 103/24) or containing little quartz (C1, DK16/21). These rocks have plagioclase/orthoclase ratio plotted around quartz monzodiorite-monzonite boundary.

Minor Elements

Minor element distribution of the studied rocks are similar to that of magnetite-series granitoids in general, i. e., contents of Pb, Li, Be and Rb are relatively low as compared with those of ilmenite-series (Ishihara and Terashima, 1977). Within individual granitic areas of the eastern region, there are some local variations (Fig. 8). The low-K granitoids are lower in all the components mentioned above than the calc-alkaline granitoids. Granitoids of the Bakirçay area are high in Sr content.

In the Thrace region, the contents of Sr are higher than those in the eastern region (Fig. 8). Large variations are observed among rock types and individual areas. The alkaline granitoids are rich in Pb, Be, Rb and Sr. The calc-alkaline granitoids can be grouped into two: those of the Karanlikdere and Demirköy areas are generally poor in all the components, while those of the Dereköy and Sükrüpasa areas are rich in these elements. The Medet rocks of Bulgaria are very high in Sr.

Sulfur and copper contents of the studied rocks are generally high exceeding the average contents of the Japanese magnetite-series granitoids of 84 ppm S and 12.7 ppm Cu (at normative Q + Or + Ab 80%) or the average contents of the Kitakami Cretaceous granitoids (89 ppm S and 26 ppm Cu at normative Q + Or + Ab 64.3%, Terashima and Ishihara, 1983). As mentioned previously, the Turkish rocks have been altered various degrees. When the rocks are moderate to strongly altered, the sulfur contents exceed 5,000 ppm and copper more than 100 ppm. Even weakly altered rocks contain sulfur between 100 and 5,000 ppm, indicating high sulfur activity of the Turkish rocks during the deuteric stage.

The high copper characteristic is best shown on the altered granodiorite porphyry in the Sükrüpasa area (SP3/23), which has

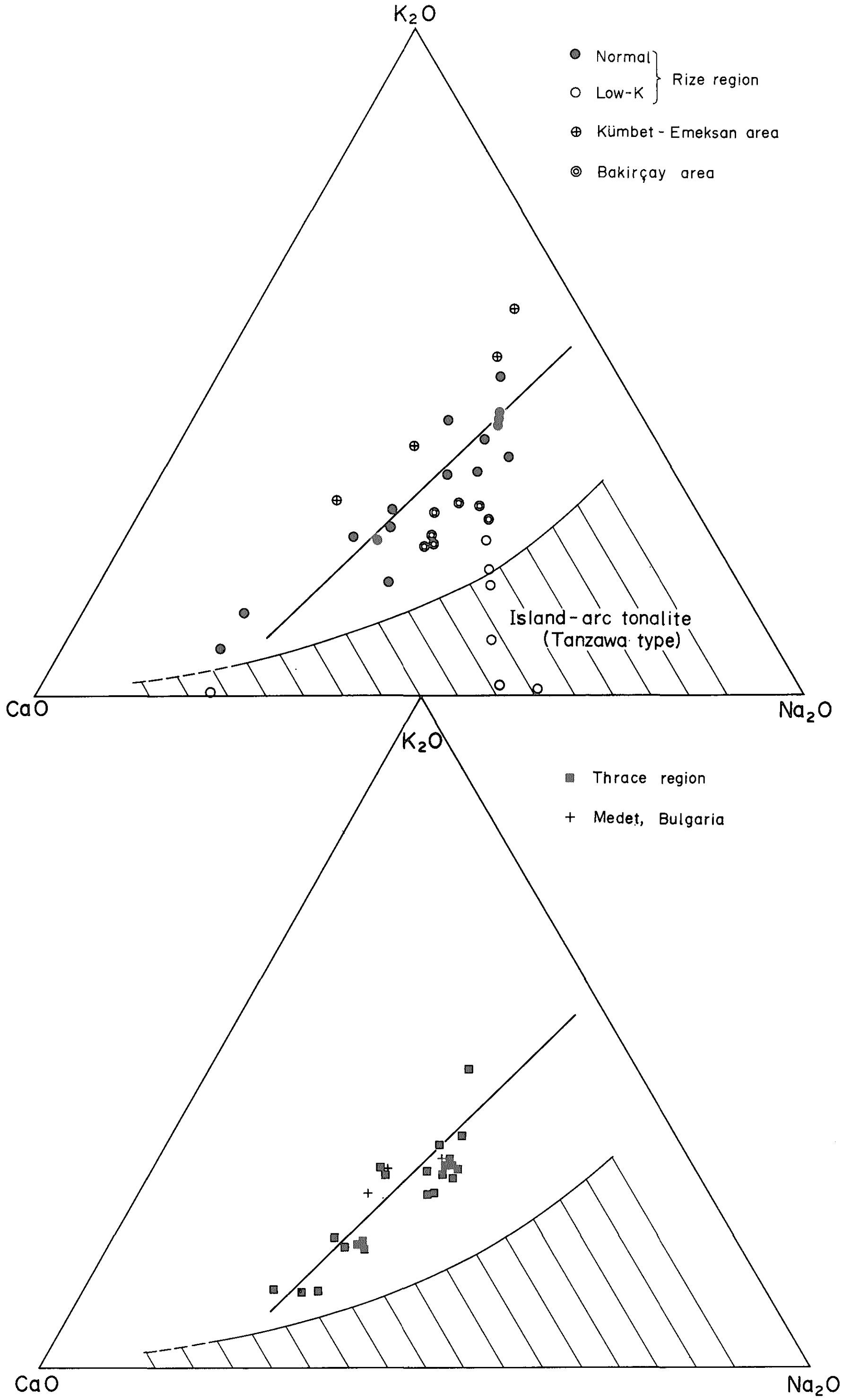

Fig. 6 Alkali-lime variation of the studied granitoids. Straght line is the average magnetite-series granitoids of Japan between the norm Q+Or+Ab 30 and 90%.

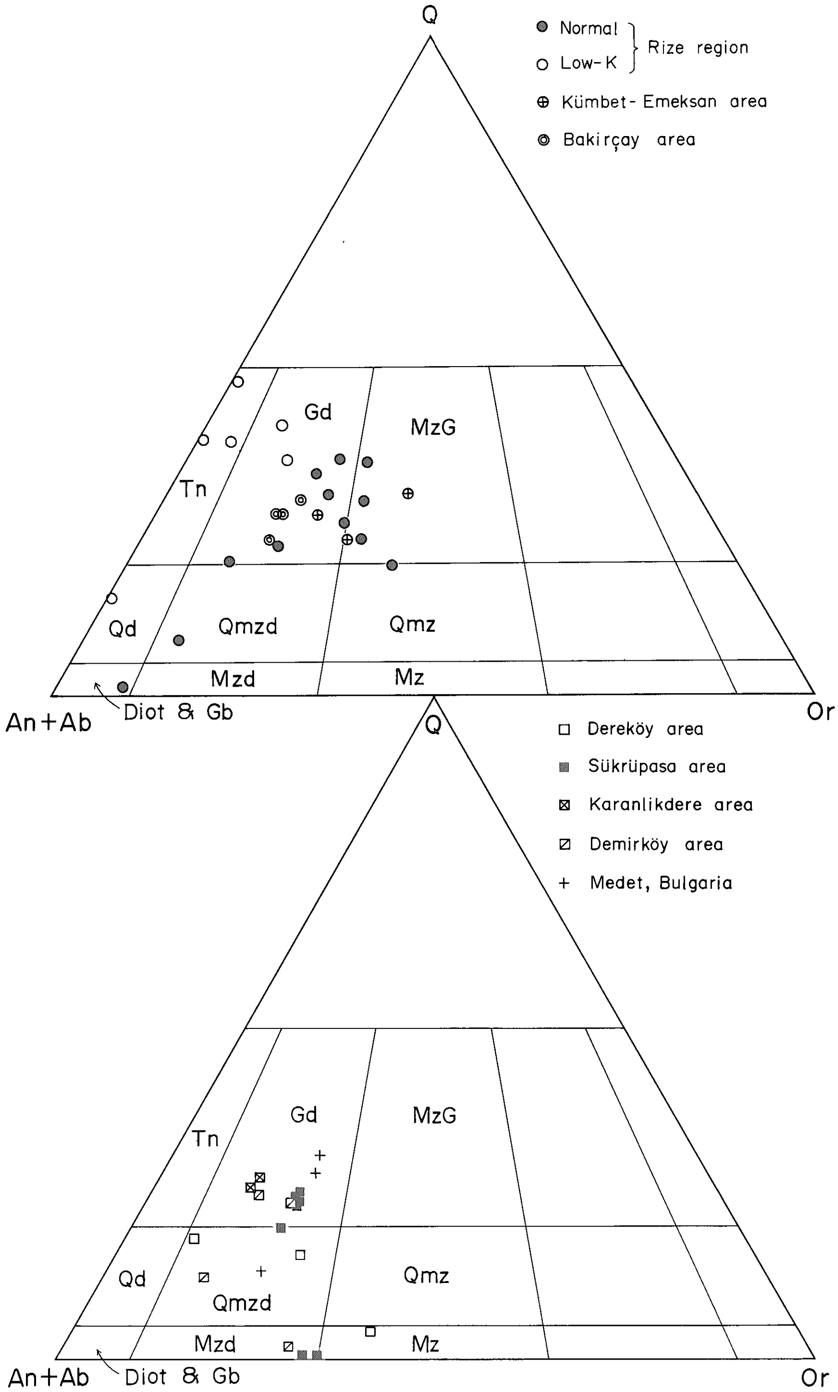

Fig. 7 Normative quartz-plagioclase-orthoclase ratio of the studied granitoids. Names of the granitoids, after STRECKEISEN *et al.* (1973). Diot: Diorite, Gb: Gabbro, Gd: Granodiorite, Mz: Monzonite, Mzd: Monzodiorite, MzG: Monzogranite, Qd: Quartz diorite, Qmz: Quartz monzonite, Qmzd: Quartz monzodiorite, Tn: Tonalite.

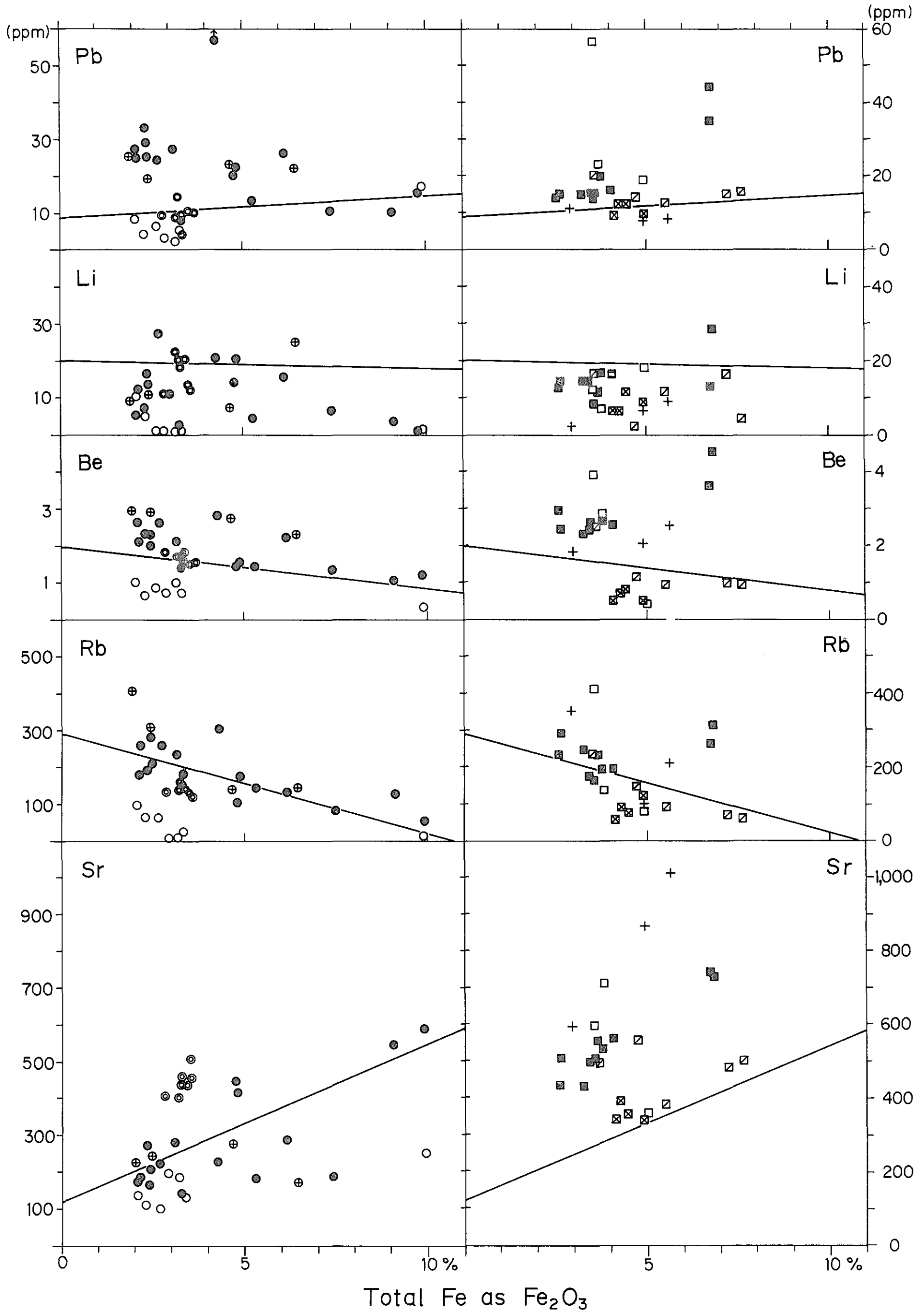

Fig. 8 Minor component variation of the studied granitoids. Straight line is the average magnetite-series granitoids of Japan. Symbols are the same as in Fig. 7.

an ore grade value (0.2% Cu) in the sense of porphyry copper mining. Besides, some rocks have Cu/S ratios higher than that of chalcopyrite (Fig. 9). This is one of the characteristics of Cu-sulfide rich terrane like the Chilean Andes (ISHIHARA *et al.*, 1984). Thus, the studied rocks appear to belong to granitoids of copper-rich terrane in the Alpine orogenic belts.

Concluding Remarks

The studied granitoids which would belong mostly to the Alpine orogenic cycle in Turkey, have the characteristics of magnetite-series granitoids of calc-alkaline suite. However, low-K calcic granitoids are locally present in the volcano-plutonic region of the eastern Pontids. High K alkaline granitoids occurs in the western Pontids, but the rock may be Hercynian in age.

Some of the studied rocks have high Cu/S ration, similarly to granitoids of the Chilean Andes. Copper and sulfur contents increase in the weakly altered rocks, indicating that these components were concentrated toward the deuteric stage during the cooling history of the granitic magmatism. The Turkish granitoids in general appear to have a high potentiality for porphyry copper-type mineralization.

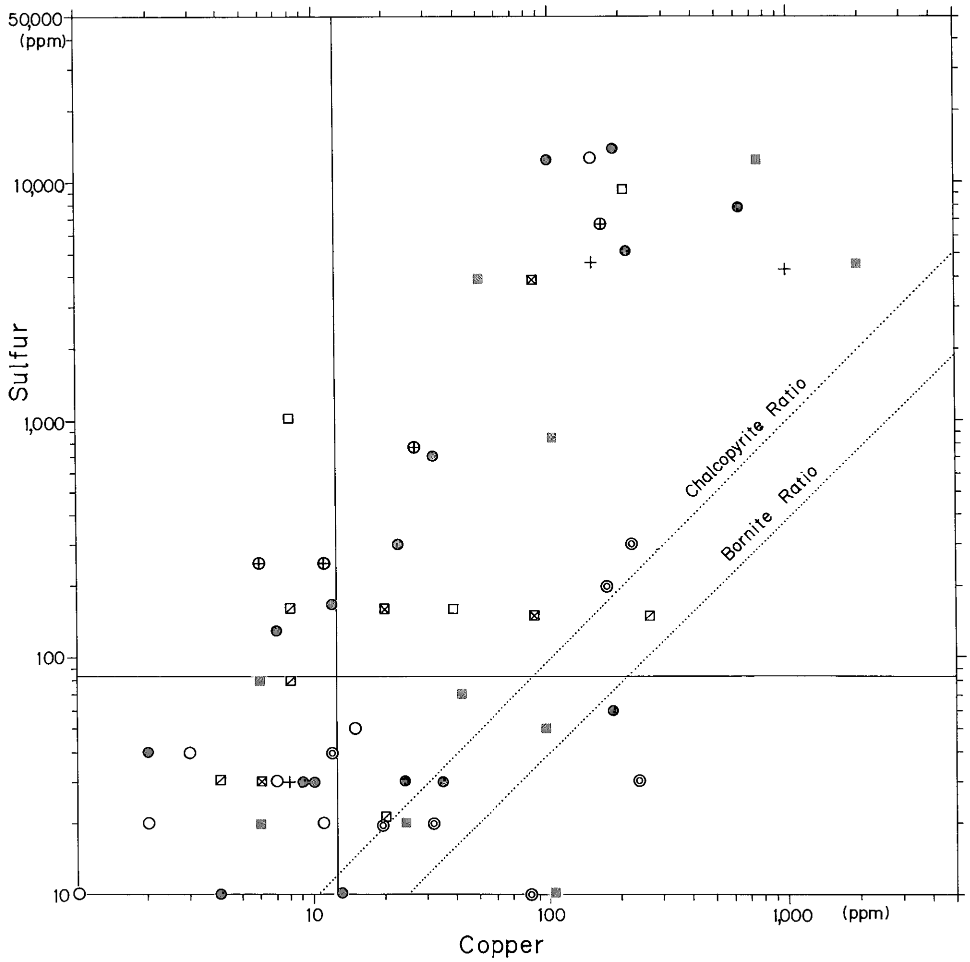

Fig. 9 Sulfur-copper variation of the studied granitoids. Straight line is the average content for sulfur and copper of the Japanese magnetite-series granitoids. Symbols are the same as in Fig. 7.

References

HIRANO, H. (1981) Geotectonic division of Turkey. *Magma*, no. 62, p.22–27.

ISHIHARA, S. and TERASHIMA, S. (1977) Chemical variation of the Cretaceous granitoids across southwestern Japan — Shirakawa-Toki-Okazaki transection —. *J. Geol. Soc. Japan*, vol. 83, p.1–18.

———, ULRIKSEN, C. E., SATO, K., TERASHIMA, S., SATO, T. and ENDO, Y. (1984) Pultonic rocks of North-central Chile. *Bull. Geol. Surv. Japan*, vol. 35, p.503–536.

KAMITANI, M. and AKINCI, O. (1979) Alpine granitoids and related tungsten-molybdenum deposits in Turkey. *Mining Geol.*, vol. 29, p.341–350.

KETIN, I (1966) Tectonic units of Anatolia. *M. T. A. Bull.*, vol. 66, p.22–34.

MOOR, W. J., MCKEE, E. H. and AKINCI, O. (1980) Chemistry and chronology of plutonic rocks in the Pontid mountains, northern Turkey. Symp. European Copper Deposits-Belgrade, p.209–216.

STRECKEISEN, A. L. *et al.* (1973) Plutonic rocks — Classification and nomenclature recommended by the IUGS subcommission on the systematics of igneous rocks. *Geotimes*, vol. 18, Oct., p.26–30.

TANER, M. F. (1977) Etude géologique et pétrographique de la région Güneyce-Ikizdera, située au sud de Rize (Pontides orientales, Turquie). Thése Dr. Sci., Genève, 180 p.

TAYLOR, R. P. and FRYER, B. J. (1980) Multiple stage hydrothermal alteration in porphyry copper systems in northern Turkey. *Canada. J. Earth Sci.*, vol. 17, p.901–926.

TERASHIMA, S. and ANDO, A. (1987) Elemental concentration in nine new Japanese rock reference samples. *Geostandards Newsletter*, vol. 11, p.75–77.

——— and ISHIHARA, S. (1983) Copper, lead, zinc, arsenic and sulfur of the Japanese granitoids (1) Kitakami Mountains and Abukuma Highland. *Bull. Geol. Surv. Japan*, vol. 34, p.443–453.

———, YAMASHIGE, T. and ANDO, A. (1984) Determination of major and minor elements on the six GSJ rock reference samples. *Bull. Geol. Surv. Japan*, vol. 35, p.171–177.

トルコのポンチッド帯花崗岩類の化学組成

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要　旨

トルコ北部，黒海沿岸のポンチッド帯から得られた主としてアルプス造山期の花崗岩類57試料について主成分と微量成分（C, S, Cu, Pb, Zn, Rb, Sr, Li, Be）を定量すると共に岩石帯磁率を測定し，その特徴を明らかにした．ほとんどの試料はカルクアルカリ岩系に分類され，その帯磁率は磁鉄鉱系花崗岩類の値を示す場合が多かった．東部の火山岩地域の一部には，カリウム量が極めて少なく，カルシウムに富む花崗岩類が分布し，また西部のトラキア地方には少数ではあるが高カリウムのアルカリ花崗岩も存在することがわかった．

微量成分の含有量について，日本の磁鉄鉱系花崗岩類のそれと比較すると，銅，硫黄，鉛，ストロンチウム等は本地域の花崗岩類中に多く含有される傾向がある．特に銅含有量や銅/硫黄の存在比は，ポーフィリー型銅鉱床地帯として著名なチリ中北部の花崗岩類と同程度に高い値も得られた．

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