GEOLOGY OF THE BASKİL (ELAZIĞ) AREA AND THE PETROLOGY OF BASKİL MAGMATICS

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ABSTRACT. — The study area which covers the region around Baskil on Eastern Taurus Range comprises of Keban metamorphics and Baskil magmatics overlain by a Tertiary sedimentary cover. The Keban metamorphics are represented by regional and contact metamorphic rocks in the study area. Calc schist and marble associations are widespread on regional scale. Between Baskil granite and Keban metamorphics exomorphism and endomorphism zones have been developed. Metasomatic effects are observed in the contact metamorphic rocks which reflect the pyroxene-hornfels facies. The sedimentary sequence begins with Middle Paleocene (Thanetian) aged rocks in the study area. The same sequence, however, has been deposited starting in Santonian-Campanian in the surrounding area. The sedimentary rock sequence which is composed of Kuşçular conglomerate, Seske formation, Kırkgeçit formation (Paleocene-Plio-Quaternary) are represented by conglomerate, carbonates and flysch kind of sedimentary rocks. Baskil magmatics are an association of plutonic, hypabyssal and volcanic rocks. Of this association, Baskil granite contains dioritic, monzonitic and tonalitic kind of magmatic rocks which are mostly observed as transitional. Baskil granite, in the study area, is frequently cut across by basic and acidic dykes which locally intrudes between the granite and the basaltic, andesitic rocks overlying the granite and are transitional with the volcanics. Chemically, Baskil granite is of calc-alkaline type. It is rich in silica and alkaline. Trace element distribution is quite regular. Baskil granite which is determined as of type 'I' is generally rich in hornblende but poor in muscovite and biotite. It shows the features of continental margin magmatism and is an example of systematic differentiation. Considering their features and under the light of plate tectonics concept, Baskil magmatics may be said to be a product of continental margin magmatism. They are, presumably, the products of an oceanic lithosphere existing between Keban microplate and Arabian platform which later on subducted under Keban microplate.

INTRODUCTION

The study area lies in the west of Eastern Anatolian region. It is surrounded by Keban in the north, Malatya-Elazığ highway in the east and Euphrates River in the west and south. The purpose of the study is to reveal the geology around Baskil and the petrological characteristics of the magmatic rocks in the region. For this purpose, three sheets of 1:25 000 scale maps have been completed in the region (Fig. la, 1b) and the petrographic descriptions and the chemical analyses of the collected samples have been done.

STRATIGRAPHY

In the study area which contains mainly metamorphic, magmatic and sedimentary rocks, the stratigraphic sequence is as follows, from bottom to top: (1) Keban metamorphics; (2) Baskil magmatics; (3) Kuşçular conglomerate; (4) Seske formation; (5) Kırkgeçit formation.

Keban metamorphics

Keban metamorphics are mainly composed of regional and contact metamorphic rocks. Contact metamorphic rock associations are observed in the localities where Keban metamorphics are in contact with plutonic and semi-plutonic rocks of Baskil magmatics. Kipman (1976) divides them into three groups, namely lower schists, Keban marble and upper schist which crop out extensively out of the study area, around Keban and in the surrounding area. Depending on his fossil findings, Glomospira, Ammodiscus, Hemigordius, he proposes the age of the deposition of the metamorphics as Permo-Carboniferous. On the other hand, Özgül (1976, 1981) states that the age of the Keban metamorphics is Permo-Triassic after studying around Munzur mountains and in the surrounding area.

These metamorphics, exhibiting their rough topography and dark colors in the study area, have been tectonized especially during Miocene and have been thrust onto the younger formations.

Under the microscope, in lower and upper schist thin sections, mainly calcite, chlorite, sericite, quartz and locally K-feldspar minerals have been observed. In calcite crystals pressure twinnings and elongation along schistosity are seen. Chlorite and sericite are generally lepidoblastic and show kink band structures. Quartz minerals have also been elongated along schistosity and their wavy extinctions are clearly observable. K-feldspars are locally observed as porphyroblasts.

For these rocks, as protoliths, carbonaceous sandstones may be assumed. As paragenesis, they are in quartz-albite-chlorite subfacies of low degree metamorphism (greenschist) (Winkler, 1974).

Baskil magmatics

This unit which covers the largest part of the study area is represented mainly by plutonic, hypabassal and volcanic rocks. Baskil magmatics, in frame of Eastern Anatolia, has been called Yüksekova formation or Elazığ complex by different researchers (Perinçek, 1979a, 1979b; Naz, 1979; Tuna, 1979; Perinçek and Özkaya, 1981; Bingöl, 1982, 1984; Hempton and Savcı, 1982; Hempton, 1984). During the investigation, a systematic magmatic sequence has been observed rather than a complex, therefore, «Baskil magmatics» which is named first by Yazgan and Asutay, 1981, is preferred. Later, during another investigation (Asutay, 1985), magmatic rocks have been named as Baskil magmatics and the plutonic equivalents of them have been treated as Baskil granite.

Baskil granite has weakly been altered and this is very clear in the hand specimens. This granitic series, in which medium and coarse grained rocks are observed, has been frequently cut by joint systems in NNE and NNW directions. Granitic rocks, especially around Baskil, have been surrounded by dark colored semi-hypabyssal and volcanic rocks. In the study area and in the close vicinity granitic rocks cut Keban metamorphics (Asutay, 1985; Asutay and Turhan, 1986) and contact metamorphism zone is observed in between the rocks. Baskil batholith is an example of shallow-emplaced granite and reflects the epizonal characteristics which have been defined by Read (1957) and Buddington (1958). The most frequent hypabyssal rock in Baskil granite is diabase which is very clear with its dark color especially where they cut white tonalites. Acidic hypabyssals have been emplaced later in the granite and they cut diabases.

All the inclusions in the granitic rocks have cropped out as a kind of granite. This kind of formation is a proof of differentiation in the batholith.

One of the most important features of the Baskil granite is the widespread occurrence of hornblende as melanocratic mineral. Biotite is a rare mineral contrarily to hornblende which is observed almost in every kind of granitic rocks.

Kuşçular conglomerate

Kuşçular conglomerate is a wholly conglomeratic unit which is observed as narrow outcrops in the study area. This unit has been defined as Kuşçular formation since it is very thick around Keban upon the studies made by E.İ.E. Department (1972). The same unit has been named Medik formation by Hakyemez and Örçen (1982) in NW of Malatya. Kuşçular conglomerate overlies Baskil magmatics in the study area. This unit consists mainly of wine colored conglomerates with carbonaceous matrix. It is generally devoid of fossils. The color is due to the iron content of the matrix. Balçık et al. (1978) states that the unit contains low percent manganese, too. The bad sorted and low graded pebbles within the conglomerate wholly belongs to Keban metamorphics. The age of the unit is Middle Paleocene (Asutay, 1985).

Seske formation

This unit which has been named and described by Erdoğan (1975) is quite widespread around Elazığ. It is wholly limestone and is Middle Paleocene (Thanetian) aged. This unit is vertically transitive to Kuşçular conglomerate and is generally medium to thick bedded, light gray and yellowish in color. In the upper levels, there are karstic cavities. Microfossils are abundant in this formation. Under microscope it appears as biomicrite, containing fossils and shell fragments in a micritic matrix. Many specimens have been collected in and around the study area. E. Sirel has determined the following fossils: *Kathina* cf. *selveri* Smout, *Operculina* cf. *heberti* Munier-Chalmas, *Daviesina* sp., *Discocyclina* sp., *Ranikothalia* sp., *Miscellanea* sp., *Rotalia* sp., *Planorbulina* sp., *Kathina* cf. *subsphaerica* Sirel, *Globorotalia* sp., Algae-Bryozoa. According to the above fossil association, the age of the Seske formation, in and around the study area is Middle Paleocene (Thanetian).

Kırkgeçit formation

This formation which is extensively widespread in Eastern Anatolian region is represented mainly by conglomerates, carbonate rocks and flysch in the study area. The distribution and the lower contact relations are locally different. According to Turan (1984), it starts with basal conglomerates but in the study area the formation starts with carbonate rocks which disconformably overlies the Seske formation. On the other hand, the same formation, around Keban transgressively overlies the Seske formation with conglomerates (Asutay and Turan, 1986). Kırkgeçit formation, in the study area, contains a member with olistoliths which overlies the basal carbonate rocks. This member is observed clearly around Marik village and is named after that (Asutay and Turan, 1986). Marik member together with the clasts of Baskil magmatics, contains the blocks of Keban metamorphics. After the Marik member, Kırkgeçit formation gains a typical flysch appearance.

The time interval in which Kırkgeçit formation is observed in Eastern Anatolian region is Middle Eocene (Lutetian)-Oligocene (Perinçek, 1979a). Oligocene materials are mostly in limestone facies and are seen in the upper levels. They are, generally not thick, around Keban maximum 30 m thickness is observed. In the study area, the oligocene deposits are represented by thin to medium bedded, white-grayish sandy carbonate rocks which overlies the Baskil magmatics. For this formation, around Şelil Mountain and Karameşe hill, NW of the study area, samples have been collected and the following fossils have been determined from the lowermost parts of the unit: *Europertia magna* (Le Calvez), *Nummulites* sp., *Discocyclina* sp., *Sphaerogypsina* sp.
Also, the following fossils have been determined from the samples collected from the upper parts of the unit: *Pellatispira* sp., *Heterostegina* sp., *Nummulites* sp., *Discocyclina* sp. *(D. discus* group). According to the above fossils, Lutetian for the lower units, and Upper Lutetian-Upper Eocene for the upper units have been assumed by E. Sirel.

The upper deposits of the Kırkgeçit formation, in the study area, are observed overlying the Baskil magmatics. The fossils collected from these deposits are dated Upper-Middle Oligocene. The following fossils have been determined from the Oligocene unit in the sandy limestone facies: *Nummulites fichteli, Eukpidina* sp., *Amphistegina* sp., *Nephrolepidina* sp.

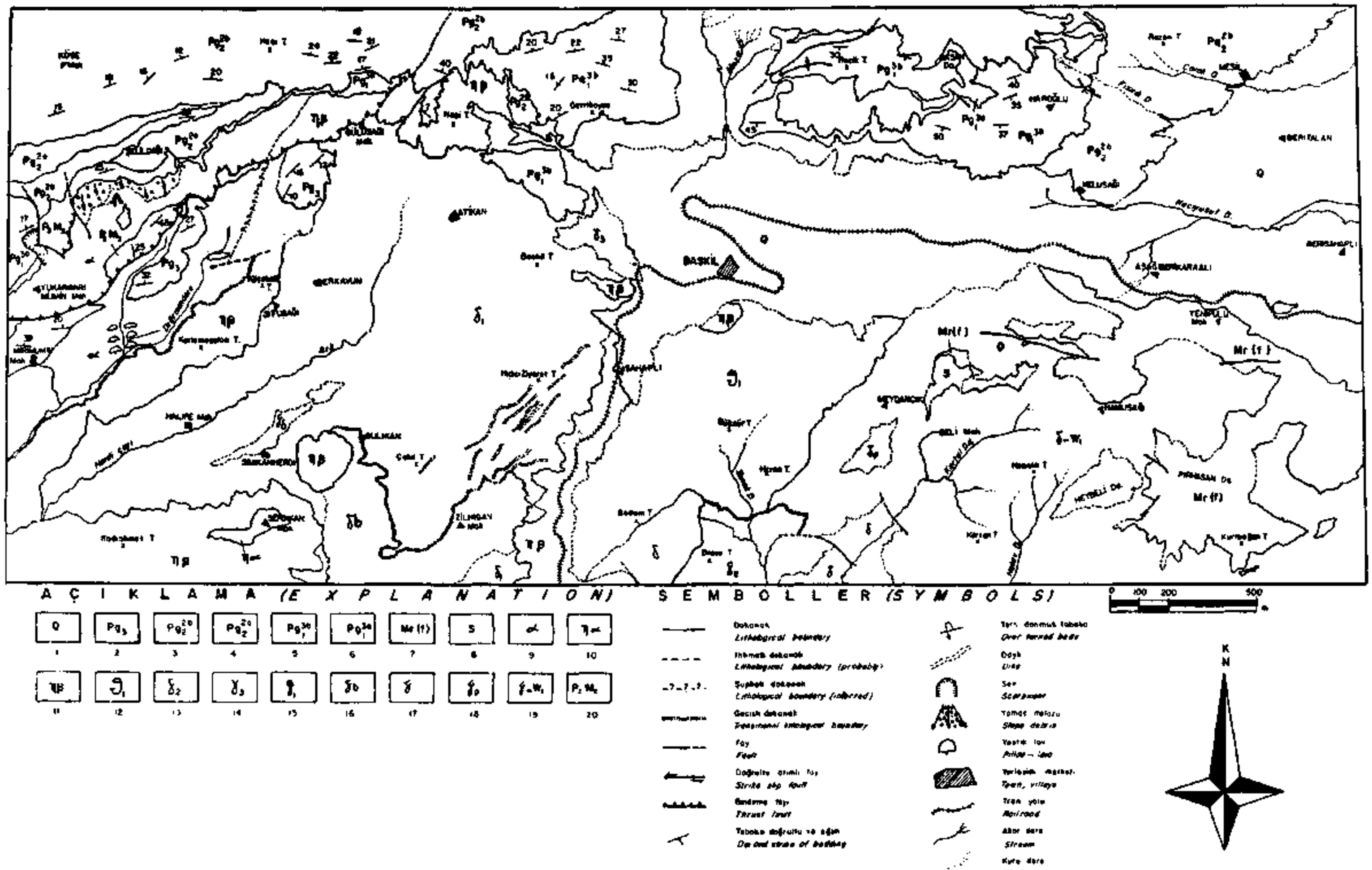

Fig. 1a - The geological map of Baskil (Elazığ) area.
1 - Quaternary, 2,3,4 - Kırkgeçit formation; 5 - Seske formation; 6 - Kuşçular conglomerate; 7 - Marble, contact metamorphic; 8 - Skarn; 9 - Volcanic rocks; 10 - Asidik hypabassal rock; 11 - Basic hypabassal rocks; 12 - Quartz monzonite; 13 - Quartz monzodiorite; 14 - Granodiorite; 15 - Tonalite; 16 - Transitional rocks; 17 - Pegmatitic monzodiorite; 18 - Quartz diorite; 19 - Diorite, monzodiorite; 20 - Keban metamorphics.

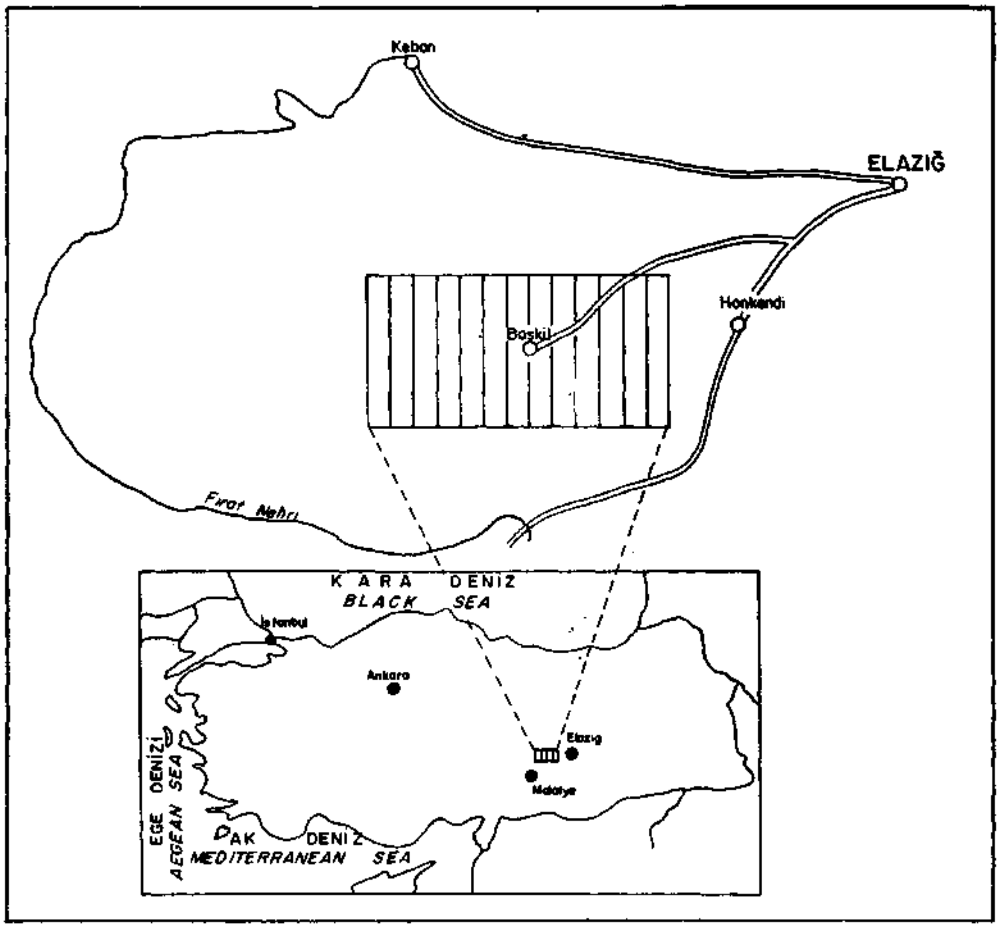

Fig. 1b - Location map.

PETROGRAPHY OF BASKİL MAGMATICS

Baskil magmatics are mainly composed of plutonic, hypabyssal and volcanic rocks. The plutonics, Baskil granite, are divided into four according to some certain characteristics. These are, from older to younger in the emplacement order, are as follows: (1) Diorite-monzonite group; (2) Transition rocks; (3) Tonalite-granodiorite group; (4) Monzonite group (Fig. 2).
In the close vicinity of the study area, Baskil magmatics start with gabbros and end up with syenites (Asutay and Turan, 1986). This implies that magmatism has started rich in plagioclase and has enriched in quartz and ended up with an increase in K-feldspars.

Baskil granite

7. *Diorite-monzonite group.*— This is the first group emplaced in the study area. It is subdivided into two groups:

a. Monzodiorite-quartz monzodiorite: When a monzodiorite from the study area is studied by naked eye, it is seen that the rock is dark gray and includes some mineral associations having different grain sizes. These minerals are plagioclases, 2-3 mm in length and whitish, K-feldspars, 1-2 mm in length and pink, and dark green-black amphiboles dominant all over the rock. Quartz is less abundant than the other minerals, 2-3 mm in length and glassy in appearance.

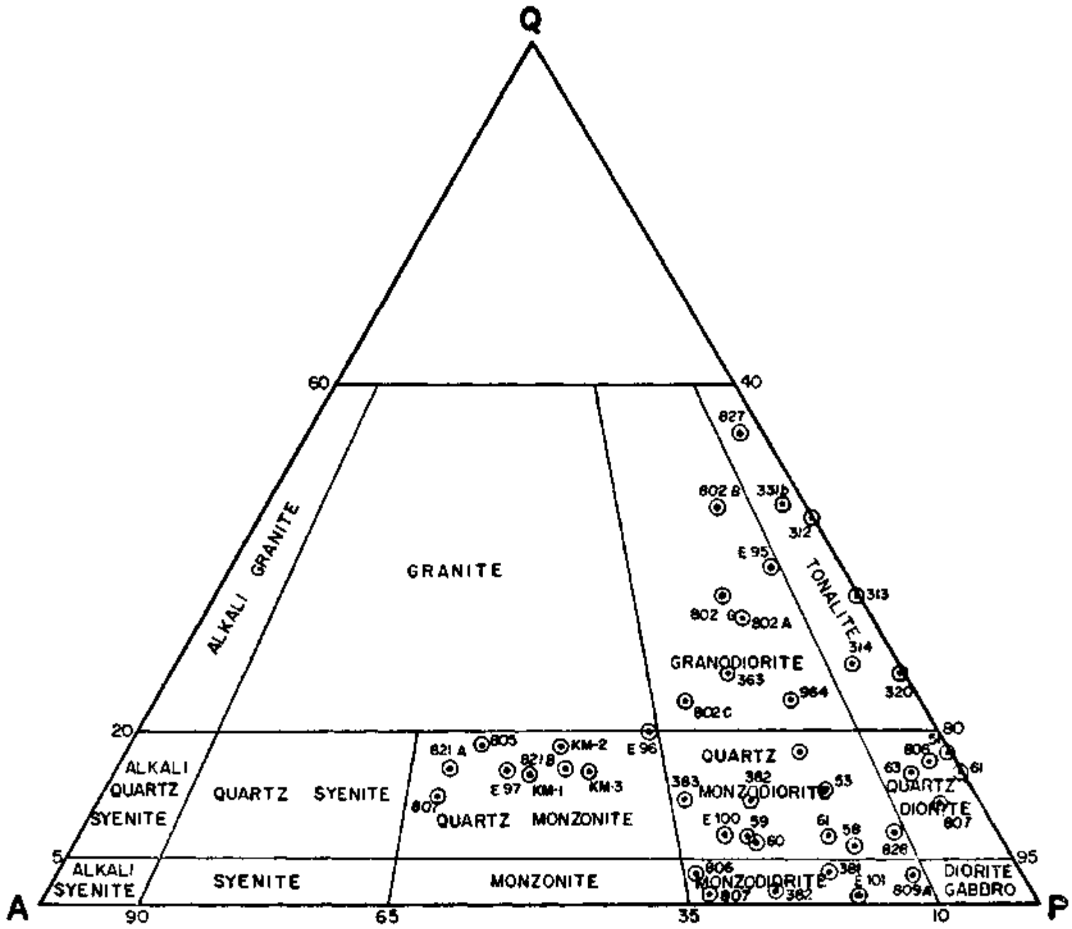

Fig. 2 - Distribution of Baskil granitic rocks in Streckeisen (1976) diagram.

Under the microscope, a hypidiomorph granular texture is observed. The results of the modal analyses of the rock are as follows:

	%
Quartz	1.9
Plagioclase	49.5
K-feldspar	5.8
Amphibole	40.3
Other minerals	2.5
Total	100

Quartz content in the rock is always changing, therefore, it is difficult to differentiate monzodiorite and quartz-monzodiorite during mapping. In the quartz-monzodiorites, the increasing quartz rate is clearly visible in the result of the modal analysis:

	%
Quartz	4.2
Plagioclase	37.8
K-feldspar	5.7
Amphibole	45.0
Other minerals	7.3
Total	100

b. Quartz diorite: They are located in the south of the study area and are easily distinguished from the other rocks by their darker colors. When their hand specimens are studied amphiboles, 1-2 mm in length and dark green in color, white-beige plagioclases and less abundant quartz minerals are seen. Amphiboles, which give their color to the rock, are the minerals with the highest percentage. The results of the modal analyses are as follows, averagely:

	%
Quartz	7.6
Plagioclase	40.6
K-feldispar	2.9
Amphibole	47.0
Other minerals	1.9
Total	100

2. Transition rocks. — This group of rocks are in between diorite-monzodiorite and tonalite-granodiorite groups. The best outcrops can be seen south of study area and locally in tonalites like small islands. The quartz-rich rocks of Baskil granite starts with this unit. Their appearance also is different than the other group of rocks. They are generally gray and dark gray in the study area but locally include less dark parts which are the result of differentiation in magma chamber.

When the hand specimens or the outcrops of the transition rocks are studied, two main different parts are differentiated. First part, as in quartz-diorites, is composed of plagioclase needles and mafic minerals in between them and light colored or transparent quartz. Second part is composed of elliptic or round quartz crystals whose radii or long axes are approximately 1 cm (Fig. 3). No apparent orientation is observed in elliptic quartz crystals and they are randomly distributed. On the outcrops quartz minerals surrounding the plagioclases gather together and appear as white spots on tonalites which are situated on top of transition rocks.

These small islands locally get denser and surrond the melanocratic parts and therefore make them appear as «autoliths». This formation is especially observed in a zone passing south of Zilhigan quarter.

The results of the modal analyses are different. This is simply because of the coarse quartz grains. In the thin sections which are taken from the quartz rich parts quartz content is very high. If the thin sections which are not rich in quartz were studied, it would have been seen that the rocks would fall into the quartz-diorite area in Streckeisen (1976) diagram. The results of such thin sections are as follows:

	%
Quartz	8.2
Plagioclase	42.5
K-feldspar	1.0
Amphibole	40.0
Other minerals	8.3
Total	100

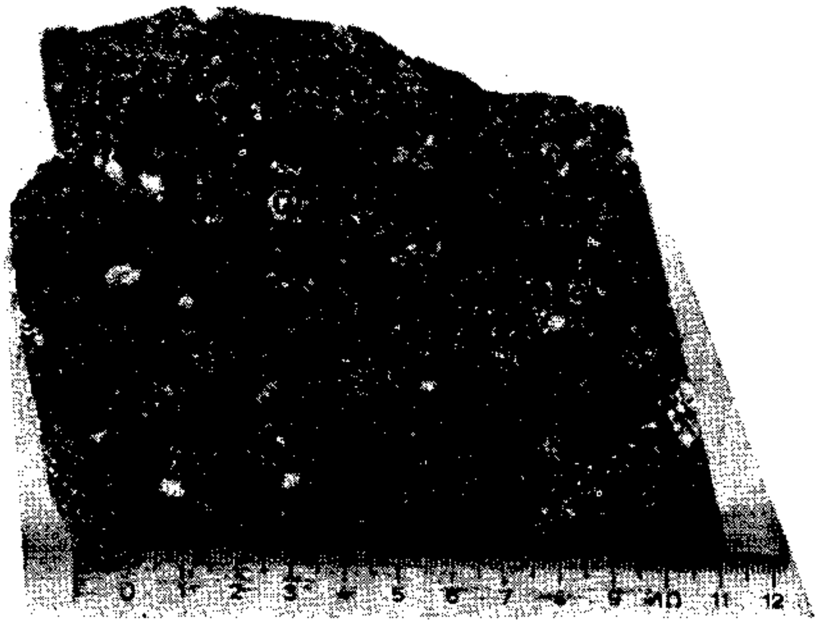

Fig. 3 - Quartz minerals within transitional rock.

It is deduced from these results that the transition rocks are mainly composed of quartz -diorites. When the coarse quartz crystals are abundant the rate changes and the rock falls into tonalite group.

3, *Tonalite-granodioritegroup.* — This group is divided into two groups:

a. Tonalite: Tonalites are the most extensively widespread unit in Baskil plutonic rocks. Both their appearance in the field and their features under microscope are quite different than the other group of rocks. The round and elliptical quartz grains in the rock provide a different appearance. The striped appearance of light colored tonalites when they were cut by diabase dykes is another characteristic of the rock.

Of the plutonic rocks in the study area, tonalites are the rocks in which leucocratic minerals are highly dense. This unit is transitive to granodiorites with a local increase in the rate of K-feldspars. In hand specimens and in the outcrops they are grayish-white or whitish in color. Coarse, mostly round and elliptical quartz grains are striking with their glassy appearance. Sericitized and clayed parts indicate plagioclases. Between all of these leucocratic minerals, dark colored epidotesand chlorites are the secondary minerals. Tonalites are richer than the other rocks in having secondary minerals since they have frequently been cut by basic dykes. Also, amphibole may be observed as a melanocratic mineral. In some specimens amphibole is very scarce, therefore they are very light in color.

Tonalites which are observed in hypidiomorphic texture locally have porphyritic features. The results of the modal analyses are as follows:

	%
Quartz	48
Plagioclase	39
K-feldspar	1
Amphibole (chl. + epi.)	12
Total	100

b. Granodiorite: Tonalites, with increasing K-feldspar rate pass into granodiorites. In the study area granodiorites cover a limited area with respect to the other units. They are quite similar to tonalites in appearance. If hand specimens are carefully studied according to the following features of granodiorites, they can be distinguished from tonalites: No porphyritic texture, bright biotite crystals, existence of pink K-feldspars. The rates of-mineral distribution in the rock are as follows:

	%
Quartz	33.7
Plagioclase	49.0
K-Feldspar	12.7
Biotite	2.8
Amphibole	1.0
Other minerals	0.8
Total	100

4. Monzonite group. — This group which forms the last members of Baskil plutonic rocks is mainly divided into two sections:

a - Quartz-monzodiorite

b - Quartz-monzonite

The quartz-monzodiorites which are included in monzonite group are different than previously mentioned quartz-monzodiorites. These differences, in turn, are:

— The rocks in monzonite group have been formed after the other group of rocks. This has been verified by field observations.

— The color, texture and the structural features of the rocks of this group are quite different.

— The K-feldspar content and the rate of these rocks are higher than Baskil plutonic rocks and they show idiomorphic crystals. As a result, the quartz-monzodiorites in diorite-monzodiorite group and the quartz-monzodiorites in monzonite group characterize the different emplacement phases of Baskil granite.

a. Quartz-monzodiorite: They are observed in north of the study area. The following result is obtained from the modal analysis:

	%
Quartz	3.0
Plagioclase	40.0
K-feldspar	15.0
Amphibole	35.0
Other minerals	7.0
Total	100

b. Quartz-monzonite: It is the last member of Baskil plutonic rocks in the study area. It has clear contacts with the other rock groups. Its pinkish color is a distinguishing feature than the other rocks. It is the richest rock in K-feldspar in the study area. The coarse idiomorphic K-feldspar minerals are easily observed in hand specimens. The distribution of minerals is as follow:

	%
Quartz	15.0
Plagioclase	38.0
K-feldspar	40.0
Amphibole	4.0
Other minerals	3.0
Total	100

Hypabyssal rocks

One of the characteristic features of Baskil magmatics is the abundance of hypabyssal rocks. They are observed in various forms and compositions of basic and acidic rocks. Except for their mineral paragenesis and texture, another characteristic feature is their appearance in the field.

Around Baskil, the geommetrical system of hypabyssal rocks is of two types. First of them is basic dykes (locally acidic) which cut the plutonic rocks and observed up to one km in length (especially in tonalites). In the field, almost all the dykes show chilled margins. These dykes trend in NNE direction (Fig. 4).

Fig. 4 - Diabase dike, cutting granodiorites.

The second type is the cover rocks which overlie almost all the granitic rocks and are very easily seen by their dark colors. They are transitive to the overlying volcanic rocks.

Main hypabyssal rocks observed in the area are as follows:

a. Orbicular gabbro. — These rocks have formed in rare places in the world, including Baskil and have the features of natural monuments. In the study area, they are observed on the left flank of Hısırlık Dere, east of Haroğlu village and they are not mappable in 1:25 000 scale. The main outcrop is few meters wide and 5 m long. Orbicular gabbros are mainly altered and have soil appearance. Locally they are seen as nodules as big as egg or fist if not altered yet.

Some fragments which can reflect the overall features of the rock can be found in Hısırlık Dere as blocks. When observed closely, they are seen consisting two parts. First part is the matrix which contains coarse grains and the second part consists spherical nodules whose longitudinal axes are 5-15 cm (Fig. 5). in the matrix, melanocratic minerals, green amphiboles and yellowish-greenish pyroxene crystals are more abundant.

Fig. 5 - Orbicular gabbro.

When the nodules are observed a different structure is seen. In the cores of what called orbicule, generally mafic and coarse minerals are seen. Around the core there is a surrounding radial ring. In this ring extended plagioclase and olivine minerals are observed (Fig. 6). With respect to the volume of the orbicule, the number of the rings may increase. The composition of the ring is troctolite whereas the core is olivine-gabbro-norite. The results of the modal analysis of the core is as follows:

	%
Plagioclase	38.0
Orthopyroxene	12.0
Clinopyroxene	18.0
Olivine	21.0
Other minerals	11.0
Total	100

The matrix has pegmatitic features. Asutay (1985) states that the orbicules may reach the temperature up to 535±20°C, after the formation, related to metamorphism.

b. Diabase. — Most of the hypabyssal rocks in the study area are diabases. They are mainly observed as cutting the granites and as overlying the granites. They are transitive to overlying volcanic rocks when they are observed as parallel dykes. Chilling margins can clearly be observed in the dykes. The general trend is in NNE direction and sometimes they cut each other.

Under the microscope, diabases show ophitic, subophitic and porphyritic textures. Besides, plagioclase, augite, amphibole, secondary minerals such as chlorite, epidote and also magnetite as an opaque mineral can be seen.

Fig. 6 - The outer circulars texture of orbicular gabbro.

c. Granite porphyry. — Granite porphyry is locally observed in the study area. Its red color, resulted from the alteration is a distinguishing feature. In hand specimens, in a fine grained matrix, coarse quartz crystals are easily observed. Under the microscope, in a cryptocrystalline silicified matrix, clayish K-feldspar and also quartz minerals effected by magmatic corrosion is seen. Compositionally it can be classified as a semi-hypabyssal derivative of dacitic rocks.

d. Granophyry. — This is the youngest dyke system in the study area. It is seen everywhere in the region but is not frequently. Generally, they cut the diabase dykes. They are rich in leucocratic members and their grain sizes are variable. Coarse grained hand specimens are similar to granites whereas the fine grained ones resemble aplites. K-feldspars and quartz can be studied by naked eye. Some of them does not contain melanocratic minerals and some contains biotite even if it is in less amounts.

In thin sections granophyric texture is typical which is formed by K-feldspars and quartz.

e. Quartz veins. — Quartz veins are observed less than the other rocks in the study area. They are denser in the contacts of the quartz monzonites and the other rocks. Under the microscope, together with hypidiomorphic quartz crystals, chlorite and idiomorphic pyrite formations can be observed. No economical mineral formation is observed.

Volcanic rocks

Volcanic rocks which are not widespread around Baskil region are generally seen in forms andesitic lava flows. Sometimes the lava flows are seen as pillow lavas. When examined, they are seen to be highly altered. In some localities where they are in contact, it is difficult to distinguish the plutonic and volcanic rocks. Under the microscope, they are seen to be carbonatized and containing clays.

CHEMISTRY OF BASKİL GRANITIC ROCKS

From some selected samples of Baskil granitic rocks main element oxides (Table 1), trace elements (Table 2) and CIPW norms of the rocks (Table 3) have been determined. Only the sample No. 64 belongs to the gabbros of Kömürhan ophiolite (Yazgan and Asutay, 1981) which is out of the study-area. This sample has been analysed to show the difference between.

Baskil granitic rocks are wholly subalkaline rocks (Fig. 7) and they are rich in aluminium (Fig. 8) but not rich in iron as in the tholeiitic rocks (Fig. 9). The Baskil granitic rocks which are poor in femic minerals, fall into calc-alkaline field in diagrams (Fig. 10).

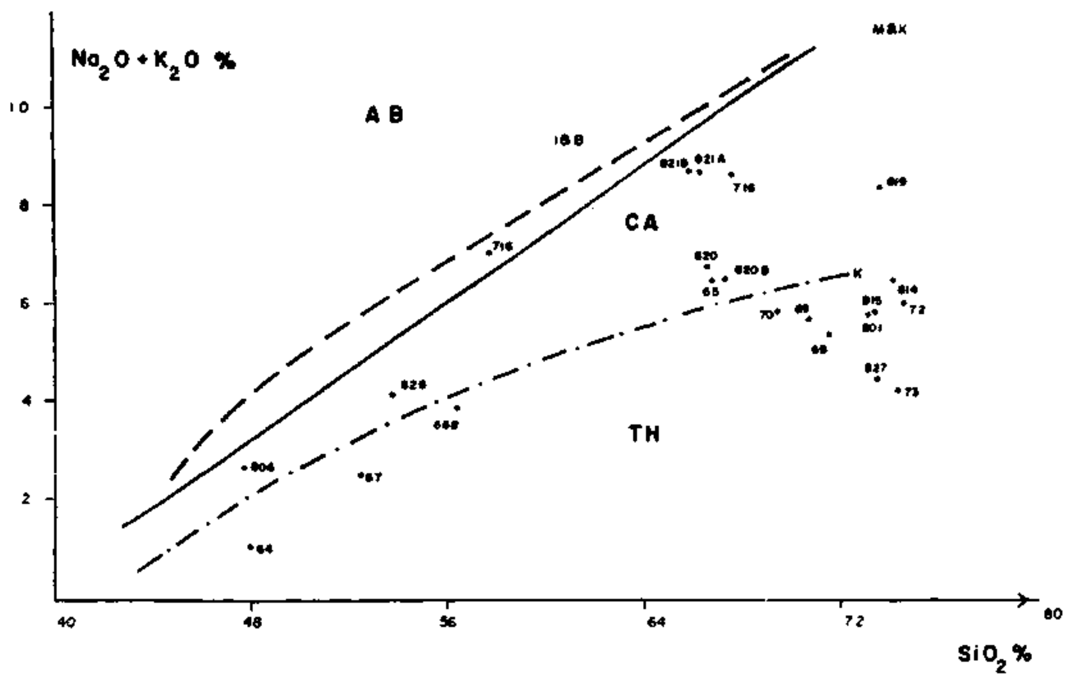

Fig. 7 - Distribution of Baskil magmatic rocks in $Na_2O + K_2O/SiO_2$ diagram.
I & B - Irvine and Baragar (1971); M & K - MacDonald and Katsura (1964); K - Kuno (1960).

PETROGENESIS OF BASKİL MAGMATIC ROCKS

Baskil magmatism is a very rare magmatic event so that in Turkey any similar magmatism may not be present. It reflects some characteristic features. There is a clear and regular interrelation between the plutonic, hypabyssal and volcanic rocks. These relations are shown in the field, under the microscope, and by chemical analyses.

Most of the contacts between the plutonic rocks are transitive. Clear contacts between the units are not observed. They are seen only between monzonite group and the adjacent rocks. Between diorite-monzonite and the tonalite-granodiorite groups, the transition is observed in a special group of rocks which are called transitive rocks. Mineralogical features of this group changes in between

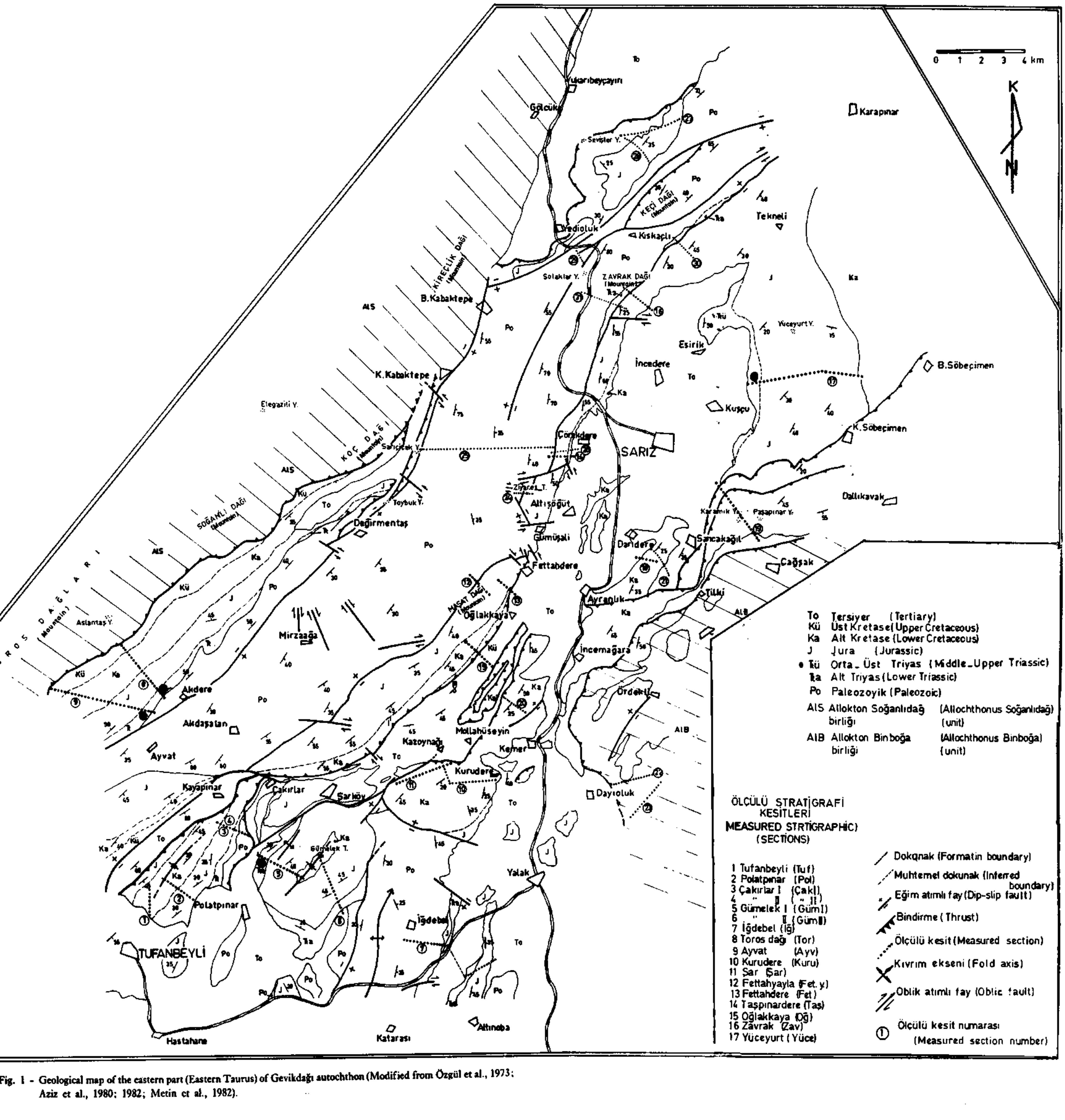

Fig. 1 - Geological map of the eastern part (Eastern Taurus) of Gevikdağı autochthon (Modified from Özgül et al., 1973; Aziz et al., 1980; 1982; Metin et al., 1982).

Table 1 - Variation of major elements in Baskil magmatic rocks

Sample no.	*64*	*65*	*66 B*	*67*	*68*	*69*	*70*	*71 G*	*71 C*	*72*	*73*	*802*	*806*	*814*	*815*	*819 A*	*820*	*820 B*	*821 A*	*821 B*	*826*	*827*
Rocks	*Gabbro*	*Gr.Dio.*	*Tonalite*	*Diorite*	*Granophyre*	*Granophyre*	*Gr. Dio.*	*Q. Mon.*	*Q. Mon.*	*Gr. Dio.*	*Tonalite*	*Gr. Dio.*	*Q. Dio.*	*Granophyre*	*Tonalite*	*Granophyre*	*Gr. Dio.*	*Gr. Dio.*	*Q. Mon.*	*Q. Mon.*	*Diabase*	*Tonalite*
SiO_2	48	66.8	56.4	52.5	71.6	70.7	69.4	67.6	57.7	74.6	74.3	73.41	47.64	74.06	73.22	73.75	66.54	67.15	66.71	65.94	53.90	73.57
Al_2O_3	21.09	15.3	15.3	10.8	14.2	13.8	14.3	14.5	15.6	13.0	12.1	13.19	16.96	13.73	13.93	14.92	15.67	16.23	15.42	15.16	14.58	12.87
F_2O_3	2.7	3.5	9.9	9.4	1.4	1.2	2.5	9.6	8.7	3.0	2.4	3.19	9.99	1.99	3.09	0.65	3.25	3.37	4.43	4.57	8.92	2.70
MgO	8.39	1.07	4.74	11.0	0.76	0.69	0.35	0.86	2.05	0.75	0.85	0.82	7.35	0.39	1.10	0.34	1.05	0.99	1.03	0.97	3.98	0.84
CaO	15.9	4.7	8.9	13.3	5.6	5.6	4.8	3.2	5.8	3.0	3.3	2.85	11.55	2.25	2.08	1.32	3.96	4.24	3.30	3.29	4.51	3.29
Na_2O	1.14	4.13	3.08	2.14	5.14	4.84	5.58	4.21	5.85	4.05	3.91	3.96	2.30	6.11	5.10	6.98	4.01	4.02	4.21	4.09	3.36	4.14
K_2O	0.17	2.36	0.75	0.37	0.29	0.23	0.33	4.43	1.34	1.91	0.28	1.89	0.88	0.38	0.57	1.38	2.71	2.54	4.43	4.52	0.85	0.26
Mn_3O	—	—	—	—	—	—	—	—	—	—	—	0.18	0.22	0.10	0.07	0.05	0.09	0.09	0.13	0.15	0.15	0.09
Mn_3O_4	0.064	0.071	0.186	0.145	0.028	0.024	0.031	0.096	0.226	0.087	0.051	—	—	—	—	—	—	—	—	—	—	—
TiO_2	0.07	0.21	0.66	0.34	0.26	0.24	0.26	0.22	0.51	0.24	0.25	0.26	0.62	0.10	0.44	0.10	0.23	0.24	0.30	0.29	0.87	0.27
BaO	>0.01	0.23	>0.01	>0.01	>0.01	>0.01	>0.01	0.04	>0.01	0.02	>0.01	—	—	—	—	—	—	—	—	—	—	—
S_2O	0.01	0.09	0.01	0.01	0.04	0.04	0.04	0.02	0.08	0.01	0.01	—	—	—	—	—	—	—	—	—	—	—
H +	2.62	0.77	0.94	1.34	0.59	1.10	0.74	0.22	0.69	0.27	1.02	—	—	—	—		—	—	—	—	—	—
P_2O_5	—	—	—	—	—	—	—	—	—	—	—	0.05	0.08	0.03	0.07	0.08	0.07	0.11	0.96	0.09	0.12	0.04
Total	**100.97**	**99.23**	**100.87**	**101.39**	**99.91**	**98.47**	**98.69**	**104.99**	**98.49**	**100.93**	**99.08**	**99.75**	**97.04**	**99.14**	**99.67**	**98.57**	**97.57**	**98.98**	**100.42**	**99.07**	**91.24**	**98.07**

Table 2 - Variation of trace elements in Baskil magmatic rocks

								TRACE		ELEMENTS												
Sample no.	*Nb*	*Zr*	*Y*	*Sr*	*U*	*Rb*	*Th*	*Pb*	*Ga*	*Zn*	*Cu*	*Cr*	*Ni*	*Co*	*Nd*	*Sm*	*Pr*	*Ce*	*Ba*	*La*	*Ti*	*V*
64	—	—	3	132	—	—	—	—	—	44	36	969	—	—	—	—	—	—	58	—	0.07	48
65	—	—	17	893	—	—	—	—	—	10	47	18	—	—	—	—	—	—	2527	—	0.21	46
66 B	—	—	41	153	—	—	—	—	—	78	107	96	—	—	—	—	—	—	87	—	0.66	269
67	—	—	20	153	—	—	—	—	—	51	5	518	—	—	—	—	—	—	43	—	0.34	194
68	—	—	20	374	—	—	—		—	2	10	2	—	—	—	—	—	—	58	—	0.26	26
69	—	—	18	351	—	—	—	—	—	2	5	2	—	—	—	—	—	—	54	—	0.24	25
70	—	—	22	387	—	—	—	—	—	21	11	16	—	—	—	—	—	—	79	—	0.26	27
716	—	—	22	204	—	—	—	—	—	43	12	2	—	—	—	—	—	—	394	—	0.22	39
71 C	—	—	43	206	—	—	—	—	—	94	68	154	—	—	—	—	—	—	99	—	0.51	105
72	—	—	20	104	—	—	—	—	—	25	10	2	—	—	—	—	—	—	208	—	0.24	34
73	—	—	33	115	—	—	—	—	—	11	7	2	—	—	—	—	—	—	76	—	0.25	41
802	2	109	24	103	0	59	3	7	14	33	7	122	5	8	0	0	0	20	216	12	—	—
806	2	30	20	237	0	19	0	9	16	91	113	148	25	32	0	0	0	0	113	6	—	—
814	8	141	11	257	7	17	27	15	19	25	16	174	5	11	18		0	33	53	26	—	—
815	2	96	37	168	0	12	0	5	15	19	6	117	0	9	0	0	0	30	82	10	—	—
819 A	7	61	20	174	0	20	7	10	17	7	64	84	15	6	0	0	0	33	464	22	—	—
820	4	147	18	798	16	88	28	37	21	25	26	79	5	8	0	0	0	45	2212	41	—	—
820 B	3	154	20	849	5	84	30	41	19	28	33	84	3	9	0	0	0	41	2312	40	—	—
821 A	19	165	36	202	4	183	18	22	19	49	8	70	0	10	29	0	0	42	411	26	—	—
821 B	19	168	36	192	5	190	30	23	20	53	10	67	6	10	17	0	0	67	399	54	—	—
826	2	66	33	124	0	18	0	14	17	106	74	34	0	22	15	0	0	0	107	0	—	—
827	2	99	33	123	0	5	0	5	13	21	4	130	0	11	0	0	0	15	71	0	—	—

Table 3 - CIPW norms which are calculated from chemical analyses of samples

No.	*IL*	*OR*	*AB*	*AC*	*AN*	*TN*	*HT*	*WO*	*DI*	*HY*	*OL*	*NE*	*CS*	*LC*	*PF*	*Q*	*HM*	*A*	*F*	*M*	*CI*	*AD*
802	0.49	11.17	33.51	0.00	12.63	0.00	1.73	0.00	1.24	3.32	0.00	0.00	0.00	0.00	0.00	35.28	0.00	61.32	30.09	8.59	6.78	SACA
814	0.19	2.25	51.70	0.00	8.92	0.00	0.46	0.00	1.91	2.32	0.00	0.00	0.00	0.00	0.00	31.09	0.00	74.87	20.63	4.50	4.89	SACA
82.08	0.46	15.01	34.01	0.00	18.74	0.00	2.69	0.00	1.79	1.64	0.00	0.00	0.00	0.00	0.00	23.98	0.35	62.01	28.64	4.36	6.91	SACA
821/A	0.57	26.18	35.62	0.00	10.09	0.00	2.23	0.00	5.22	2.97	0.00	0.00	0.00	0.00	0.00	16.15	0.00	63.27	29.19	7.54	11.00	SACA
826	1.65	9.02	28.43	0.00	22.19	0.00	2.68	0.00	0.15	18.55	0.00	0.00	0.00	0.00	0.00	11.58	0.00	25.96	49.49	24.55	23.04	SATH
827	0.51	1.54	35.03	0.00	15.77	0.00	1.23	0.00	0.46	3.77	0.00	0.00	0.00	0.00	0.00	37.45	0.00	57.41	31.64	10.96	5.77	SACA
806	1.18	1.95	19.46	0.00	34.78	0.00	4.51	0.00	17.99	12.29	3.69	0.00	0.00	0.00	0.00	0.00	0.00	13.87	47.39	38.75	39.66	SATH
815	0.84	3.37	43.15	0.00	10.32	0.00	2.52	0.00	0.00	2.80	0.00	0.00	0.00	0.00	0.00	35.25	0.00	39.40	29.08	11.52	6.16	SACA
819 A	0.15	8.15	59.06	0.60	5.30	0.00	0.00	0.00	0.91	0.43	0.00	0.00	0.00	0.00	0.00	24.81	0.57	10.06	6.28	3.66	2.05	SACA
820	0.44	11.01	33.93	0.00	11.32	0.00	2.60	0.00	0.00	3.14	0.00	0.00	0.00	0.00	0.00	24.00	0.00	62.92	27.35	9.74	6.17	SACA
821 B	0.55	26.71	34.61	0.00	9.66	0.00	2.44	0.00	5.55	2.56	0.00	0.00	0.00	0.00	0.00	16.48	0.00	52.88	30.03	7.08	11.09	SACA

SA — Subalkaline; CA — Calc-alkaline; TH — Tholeiitic.

diorites and tonalites for which quartz is responsible. Together with the anhedral minerals which have clear contacts with the other minerals there are round or elliptic quartz crystals whose roundness increase towards tonalites. The inclinations from formerly emplaced plutonic rocks to the rocks rich in quartz is a feature of Baskil magmatism. This inclination ceases from tonalite and granodiorite and passes into a magma rich in K-feldspar. The forms seen in the quartz crystals which gives a porphyritic texture to the tonalites are related to the events in the magma chamber. These forms may be due to the movements during the formation and these movements are not in large scale and may be because of the changes in the inclination in the magma chamber. The quartz-feldspathic solution whose density increases with the advance of differentiation locally surrounds the dioritic and quartz-dioritic remnants (Fig. 3). This event is the increase of quartz rich solution in the magma chamber and it, as an autolith, surronds the previously formed magma products which are rich in melanocratic minerals. No heat transfer between remnant magmatic rocks is seen. Their contact is not clear. In some outcrops the relics of the newly formed rocks are observed in remnant rocks.

The events we have observed in transitive rocks may not be considered as assimilations but the proofs of the changing conditions in the same magma chamber.

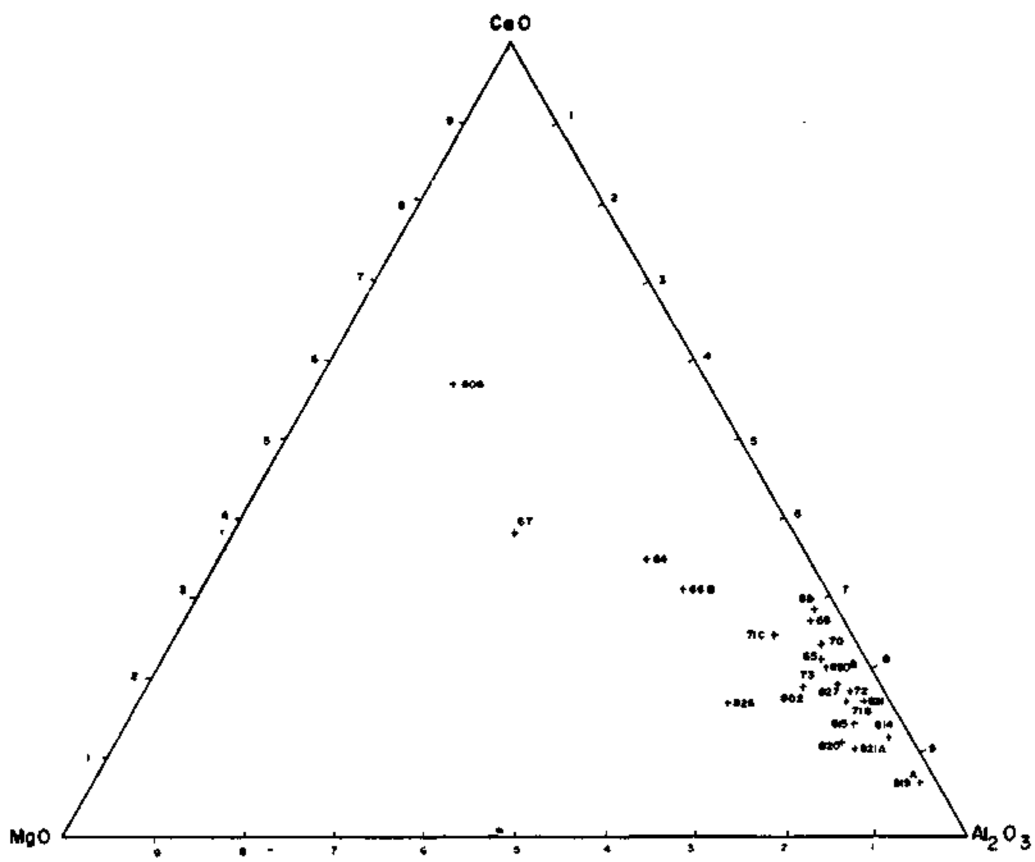

Fig. 8 - Distribution of Baskil magmatic rocks in CaO-MgO-Al_2O_3 triangular diagram.

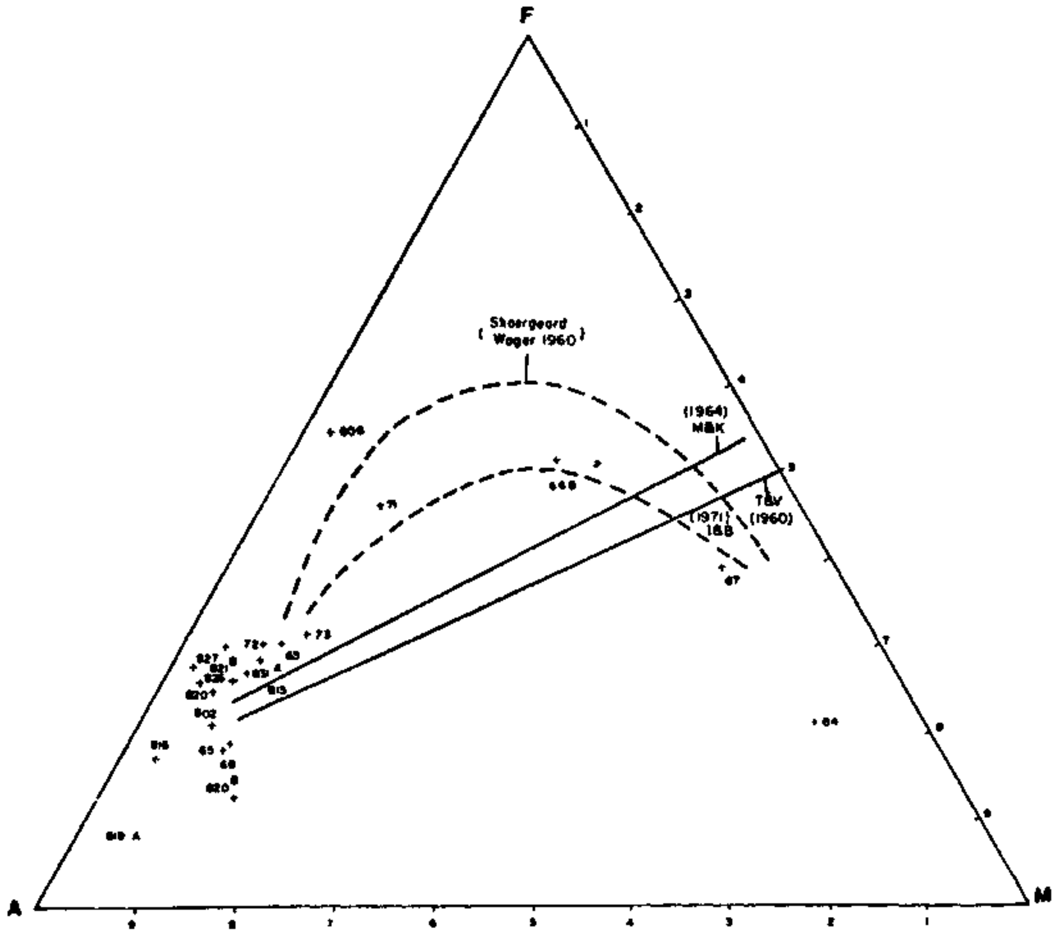

Fig. 9 - Distribution of Baskil magmatic rocks in AFM diagram. After, Wager (1960); M & K (1964) - MacDonald and Katsura (1964); I & B - Irvine and Baragar (1971); T & V - Turekian and Vedepahl (1961).

Quartz-monzonites are the last emplaced rocks in the Baskil plutonic rocks and they have quite clear contacts with the other rocks. In regional scale (especially around Keban) the last emplaced rocks are syenites (Asutay and Turan, 1986). This shows the increase of K-feldspars in magma after a certain time. This feature is also visible in the granitic rocks of the Divriği region. The results of the modal analyses of Gysin (1943), when applied to the Streckeisen diagram shows that Divriği plutonic rocks are almost, 99 %, under the line of 20 %. When the granitic rocks of the two regions are compared, it is seen that the Baskil granites are richer in quartz. When the increase of K-feldspar in Baskil magmatics after a certain time and the regional positions of Baskil and Divriği are considered, it may be concluded that both events may have the same genesis.

THE TYPE AND AGE OF BASKİL GRANITE

The features of the Baskil granite has been studied and has been compared with the descriptions (Appendix 1) of the various researchers and its type has been determined. These features are as follows:

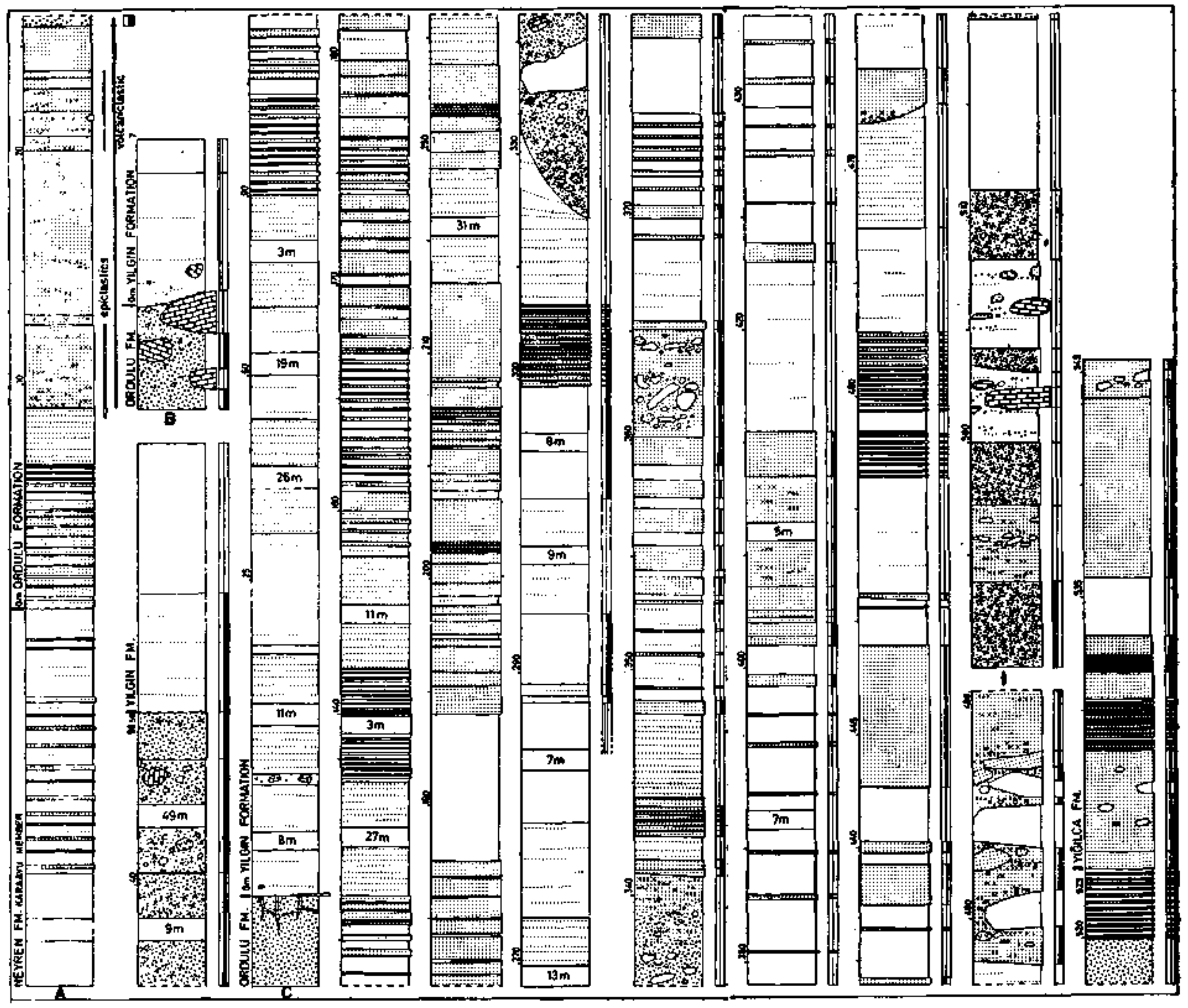

Fig. 10 - A - Complete type section of the Ordular formation; B, C - unconformity between the Yılgın and Ordulu formations, complete composite type section of the Yılgın formation.

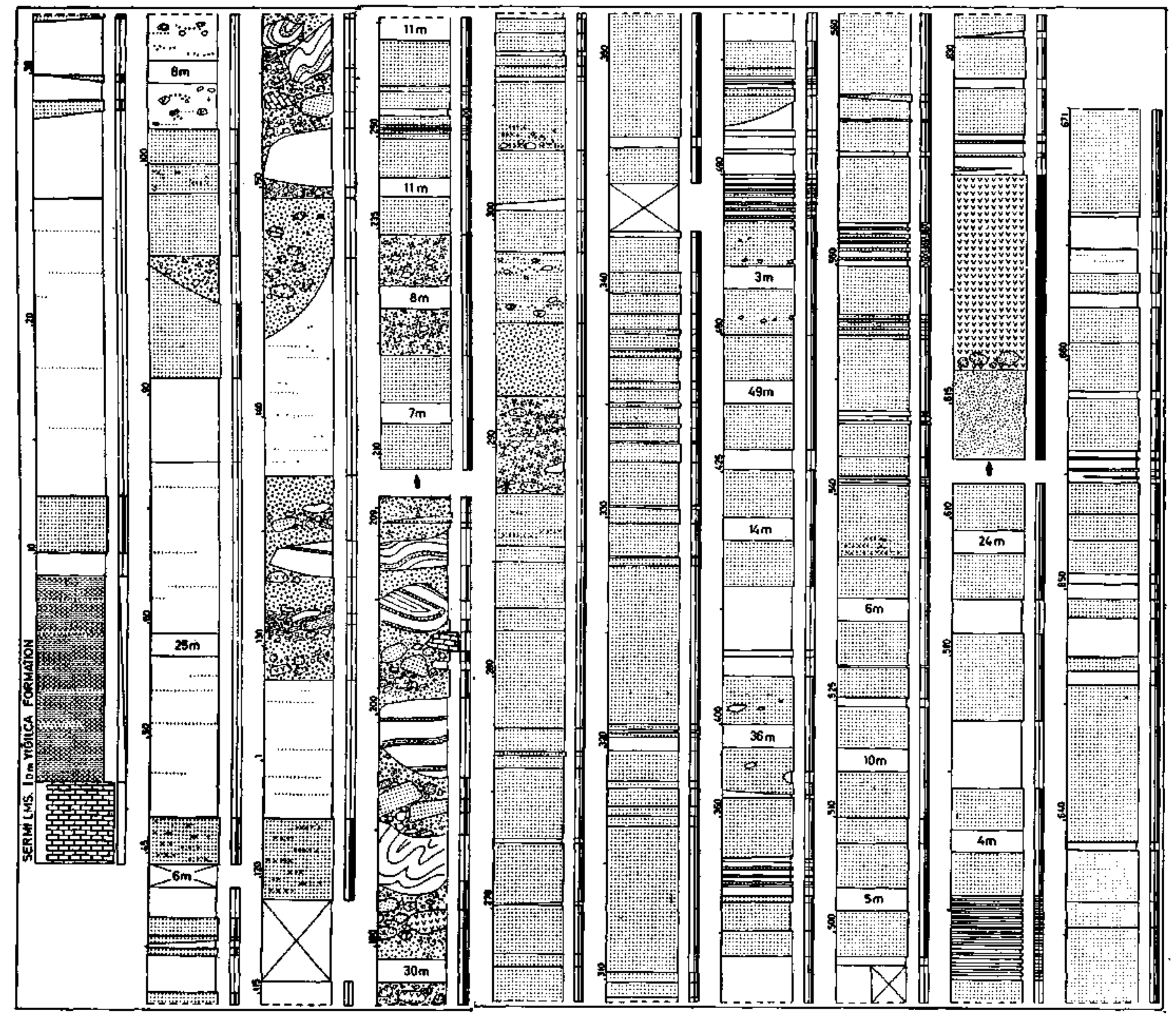

Fig. 11 - Partial composite type section of the Yığılca formation.

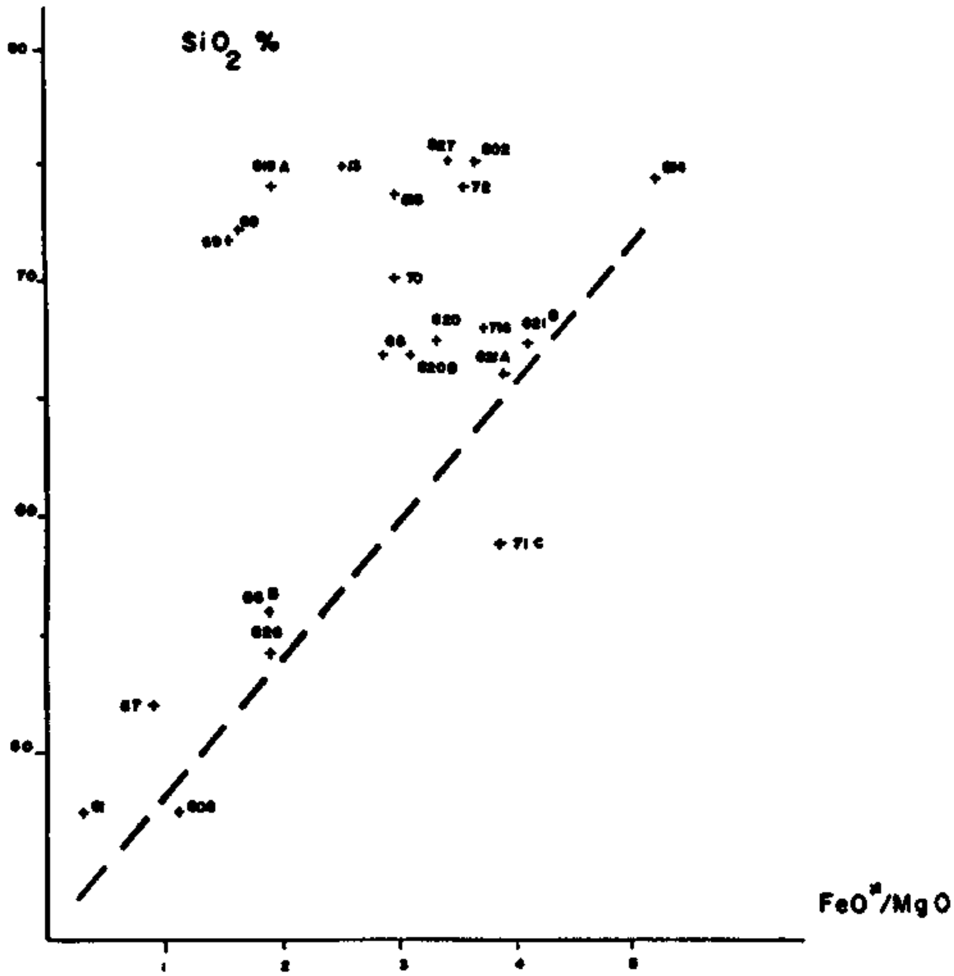

Fig. 10 - Distribution of Baskil magmatic rocks in SiO_2/FeO/MgO diagram. (After, Miyashiro, 1975). FeO - Total iron.

1. Baskil granite is of type 'I', because the descriptions made for this type is suitable (+marked features in Appendix 1).

2. According to Nb/SiO_2 diagram (Fig. 13), low Nb magma is dependent to subduction zones (Pearce and Gale, 1977).

3. According to geochemical data, Baskil granite is calc-alkaline, it has no similarities alkaline or per-alkaline granites (Fig. 13a).

4. It has been formed in a compactional environment, because in the region, a continental collision has taken place in Upper Cretaceous (Yazgan, 1984).

5. The distribution of trace elements points out a regular magmatic crystallization for Baskil granitic rocks (Asutay, 1985).

6. A regular relation with the andesites which are only seen in subduction zones is observed. The oldest unit with which Baskil granite has contact is Keban metamorphics. In these contacts well developed skarn zones are always observed. Now that the sedimentation age of the metamorphic rocks

is Upper Paleozoic-Lower Mesozoic (Özgül, 1976, 1981) it can be said that Baskil granite is younger than Triassic age. However, the age of the granitic rocks is determined only when the age of the Baskil magmatic rocks are studied. The volcanics related to Baskil magmatic rocks are the distal flysch deposits and its interbeds of Sağdıçlar formation which crops out well around Hamzikan village and Ciban quarter (Asutay and Turan, 1986). The age of the flysch is determined as Santonian-Campanian by M. Serdaroğlu. The samples from the formation includes the following fossils: *Dicarinella concavata* (Brontzen), *Globotruncana lapparenti* (Qr), *Globotnmcana area* (Cushman), *Marginotruncana marginata* (Reuss).

Fig. 11 - Diyoritic restits in transitional rocks.

When the above data and the relation between the granitic rocks and hypabyssal rocks are considered, it is deduced that the age of the Baskil granite is older than Santonian. The granitic pebbles of the conglomerate in the base of the Maestrichtian limestones present around Keban supports the age of magmatism (Asutay and Turan, 1986). On the other hand, Yazgan (1984) determines the age of the granitic rocks as Coniacian (Appendix 2).

CONTACT METAMORPHISM

Keban metamorphics has experienced contact metamorphism due to presence of Baskil plutonic rocks. In the study area, contact metamorphism is observed in two ways:

a - Endomorphism: Metamorphism occurred inside the magmatic rock.

b - Exomorphism: Metamorphism observed in the rock which is intruded by magmatic rock. Different minerals have been determined in both kind of metamorphisms.

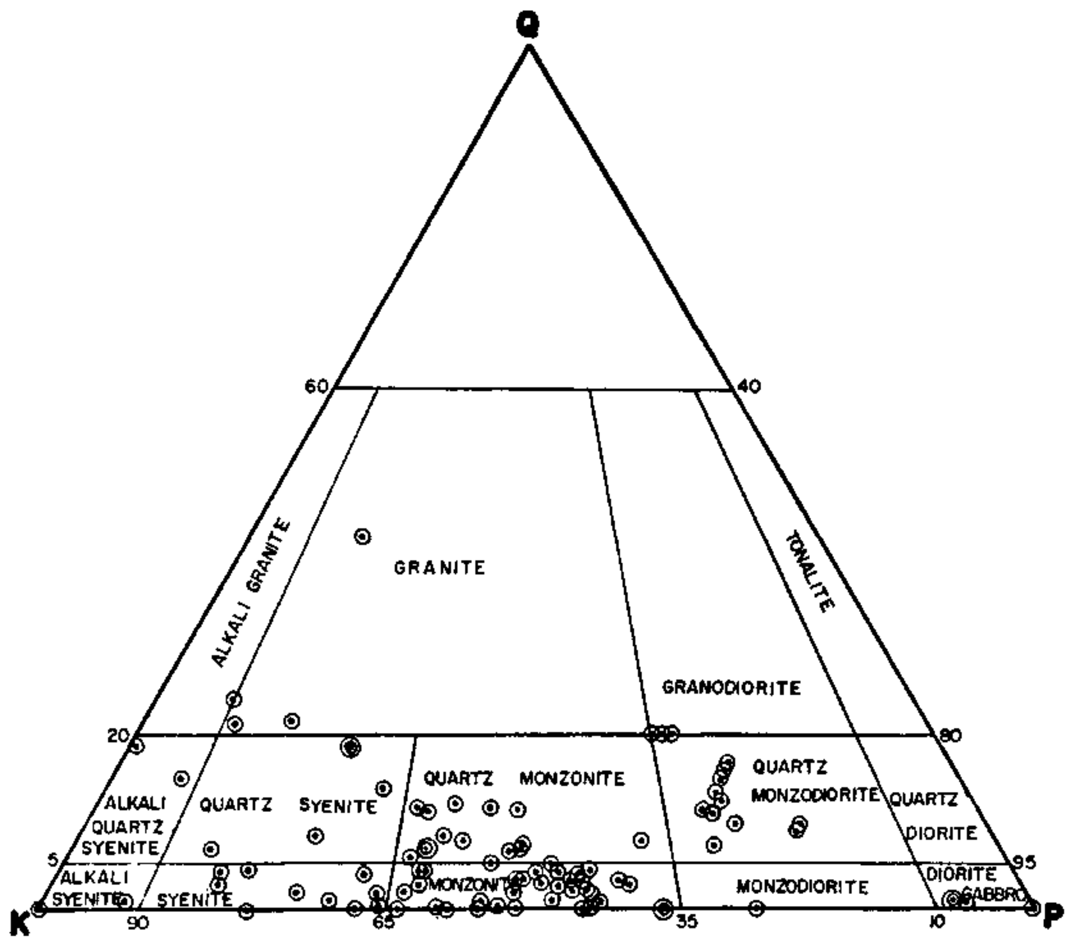

Fig. 12 - Distribution of Divriği granitic rocks in Streckeisen diagram (1976).

Endomorphism

Endomorphism is observed in the plutonic rocks when they are close to the Keban metamorphics. The rocks experienced this metamorphism are generally diorite-monzodiorite group and quartz-monzonites. The following minerals have been determined from the samples in which endomorphism is observed:

Garnet. — Generally idiomorphic, yellowish-light brown under single nicol and hexagonal. It has clear contacts with the other minerals. As a result of the qualitative analyses (microprobe) «grandite» composition has been determined (Asutay, 1985).

Clinopyroxene (diopside). — Pyroxenes, together with short prismatic sections locally display (001) sections and are generally green and shows pale green pleochroism. In the thin sections whose double birefringence is high, extinction angle is determined as 37°. 2V is 60° and it is optically positive.

Amphibole., — It is generally in prismatic forms and green-brownish, green in color. Pleochroism formula is (determined as light green (x), green (y) and dark green (z). Its pseudohexagonal sections are observed with their typical cleavages.

Sphene. — It is easily known by its very high double birefringence and idiomorphic minerals. Its rhombic sections are widespread.

Appendix 1 - Differences of 'I' type and 'S' type granites

Data	*I type granites*	*S type granites*
Field	+ Generally large-scale intrusions	Generally small-scale intrusions
	+ Wide composional distribution. Gabbro-diorite 15 %; Granodiorite 50 %; Granite 35 %	Limited compositional distribution. Gabbro-diorite 2 %; Granodiorite 18 %; Granite 80 %
	+ Genetic and spatial relation with volcanites	No synchronologic volcanism.
Mineralogic	+ Hornblende more dominant than biotite	Biotite more dominant than hornblende
	+ Little muscovite (in too felsic rocks)	Muscovite and double-mica granite dominant
	+ Magnetite being the most dominant iron-oxide	Ilmenite being the most dominant iron-oxide
	+ Allanite and sfen. No accessory cordierite, garnet, andalusite or sillimanite	Monozite and cassiterite. Accessory cordierite, garnet, andolusite and sillimanite may be present
Chemical	+ Mol. $Al_2O_3/Na_2O.K_2O.CaO$ 1.1 SiO_2 65% very widespread	Mol. $Al_2O_3/Na_2O.K_2O.CaO$ 1.1 SiO_2 65%
	+ Na_2O in normal levels (3.2% in felsic rocks and 22% in mafic rocks)	Na_2O may be low. (in rocks bearing 5% K_2O 3.2%)
	+ Regular element distribution. Normative diopside or normative corundum less than 1% in CIPW norms.	Distribution diagrams irregular. Always contains normative corundum.
	+ $Fe^3/(Fe^3+Fe^2)$ generally high and bigger than 0.2	$Fe^3/(Fe^3+Fe^2)$ generally low.
Isotopic	Low $Sr^{87/86}$ ratio (<0.706)	High Sr^{87}/Sr^{86} ratio (<0.706)

After, Chappell and White (1974), Coleman (1980), Hine and others (1978), Ishira (1978) O'neil and others (1977), Pankhurst (1980), Pitcher (1979-1980), White and Chappell (1977).

Appendix 2 - Some radiometric ages of Baskil magmatics

Sample no. *Rock type* *Location*	*System*	*K_2O (wt%)*	*^{40}Ar. rad. (10^{-11} mol/g)*	*100× ^{40}Ar. rad. / ^{40}Ar. total*	*Numbering age (±σ) (Million year)*
Sanidine-bearing microsyenite intruded into Keban marble (Northern Keban) 30/80	Sanidine and other feldspars	3.98	45.98	79	78.5 ± 2.5
31/80	Sanidine	11.90	133.2	82	76.0 ± 2.5
Amphibole-gabbro intruded into Keban marble (Elazığ-Keban highway) 124/81	Hornblende	274	3.129	26	77.5 ± 4.5
Granodiorite (SW Baskil) 95/79	Biyotite	6.12	78.00	90	86.5 ± 2.5
Quartz-monzodiorite (Southern Baskil) 96/79	Hornblende	941	11.55	87	83.5 ± 2.5
Quartz-monzodiorite (Southern Baskil) 100/79	Hornblende	11.080	13.71	87	86.0 ± 2.5
Quartz-monzodiorite (Southern Baskil) 101/79	Hornblende	901	11.16	87	84.0 ± 2.5
Diorite (Southern Baskil)	Amfibol	1.50	16.71	92	76 ± 2.5
9/2-78	Biotite	6.68	73.94	94	75.5 ± 2.5

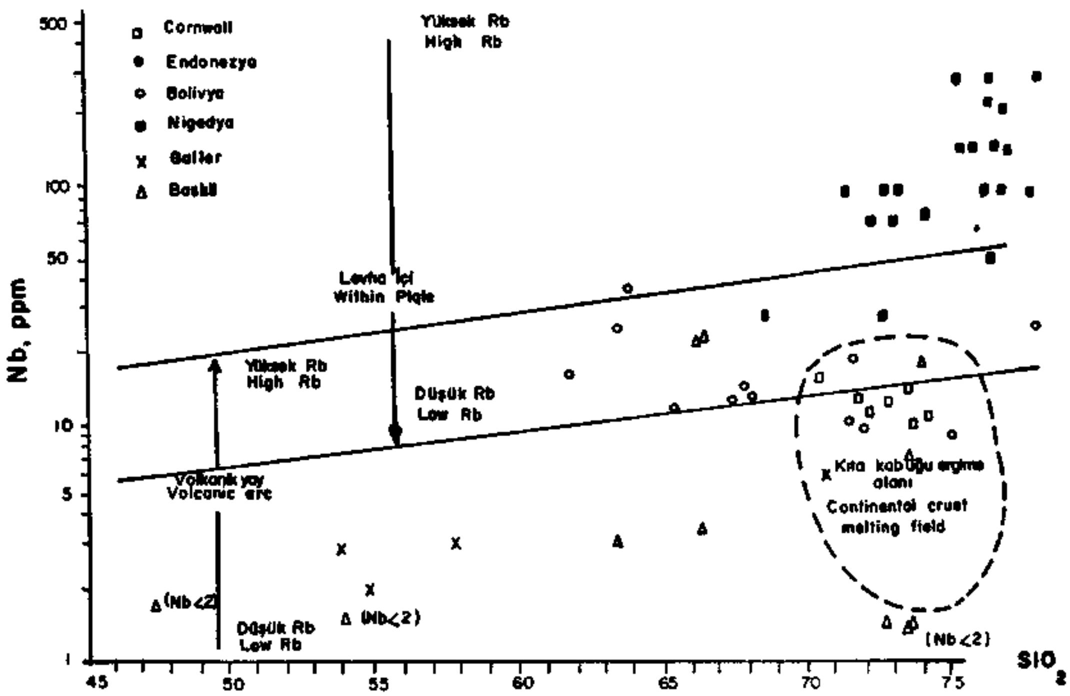

Fig. 13 - Distribution of Baskil magmatic rocks in Nb/SiO_2 diagram and comparison of some other granites of the world.

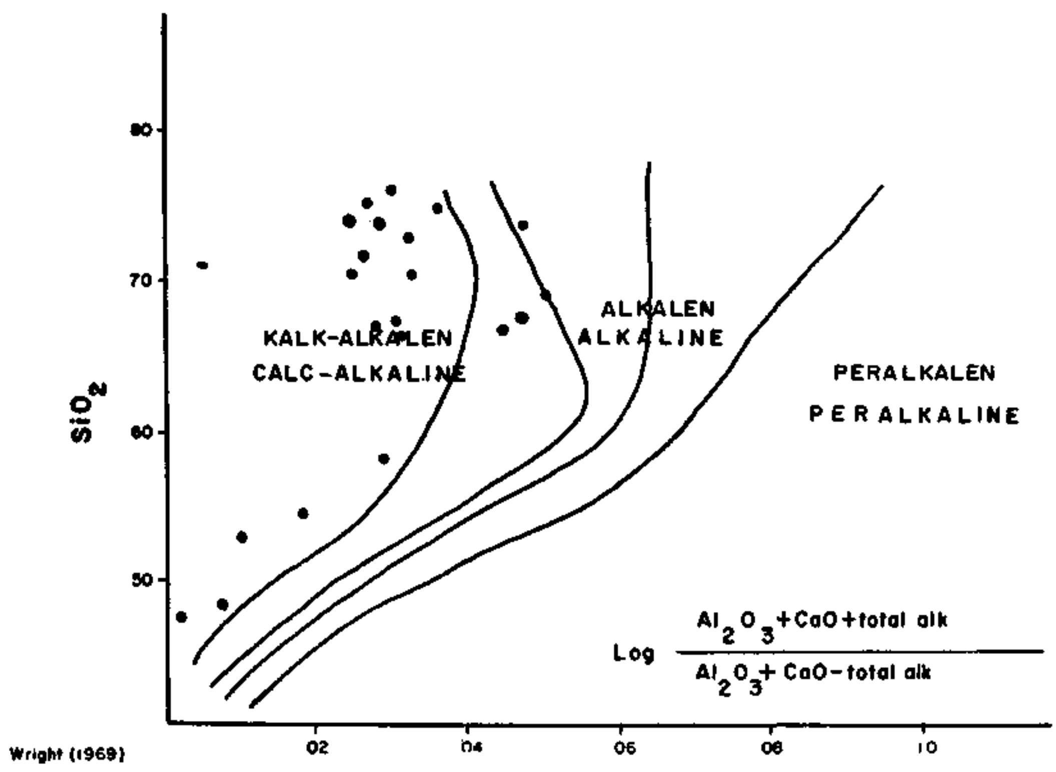

Fig. 13a - Distribution of Baskil magmatic rocks in Wright (1969) diagram.

As will be seen from the above mentioned minerals an endomorphism rich in Ca and Mg is displayed. In the surrounding rocks there are no minerals which would experience this metamorphism except for the Keban metamorphics. The existing ones are younger than the magmatism. The minerals in the rocks reflecting endomorphism have formed as a result of the assimilation of the marbles of Keban metamorphics, containing dolomite and calcite, by the Baskil magmatic rocks. The mineral paragenesis in the rocks corresponds to the pyroxene-hornfels facies conditions. Together with this paragenesis, alteration in the same magmatic rocks and sausaritization in feldspars are observed. This formation, in a way, is a clear result of Ca metasomatism. A similar endomorphism is observed also in Akdağmadeni by Sağıroğlu (1982).

Exomorphism

Exomorphism is observed in Keban metamorphics in which magmatic rocks are intruded. Around Baskil, both plutonic and hypabyssal rockshave experienced contact metamorphism. Of these, the hypabyssal ones are orbicular gabbros. In Keban metamorphics which have contacts with orbicular gabbros minerals such as quartz, garnet (andradite), clinopyroxene (diopside) are observed.

In the contacts of plutonic rocks with Keban metamorphics locally the melanocratic minerals of contact metamorphism and mostly calcite are observed. The size of calcite minerals are smaller when they are away from the contact. In such rocks saccaroid texture has developed, they are easily breakable into pieces. These rocks are like islands in the magmatics around Keban and Elazığ. In Keban metamorphics such marbles are not seen. Some researchers, since they have not seen any mafic mineral in these marbles, have not differentiated them from Keban metamorphics. These marbles are the raw materials of the limestone quarries. As mafic minerals, in the contact metamorphism, minerals such as magnetite, olivine (forsterite), spinel have been determined (Asutay, 1985). Aşvan iron ore displays contact metasomatic iron mineralization which is a result of the exomorphism between Keban metamorphics and Baskil magmatics.

RESULTS AND DISCUSSION

The main results obtained from the above study are as follows:

a. Baskil magmatic rocks form a regular sequence and cannot be interpreted as a complex;

b. Baskil magmatics have been derived from a calc-alkaline magma which has continental margin magmatism characteristics;

c. Between Baskil magmatics and Keban metamorphics always contact metamorphism is observed;

d. No ophiolitic rocks are observed in Baskil magmatics.

Together with these results the following results obtained from some observed phenomena around the area studied:

The first sedimentary unit deposited on the Baskil magmatics is Santonian-Campanian aged Sağdıçlar formation (Asutay and Turan, 1986). Upper Maestrichtian aged Harami formation overlies both Keban metamorphics and Sağdıçlar formation in the close vicinity of the study area. The trend of the axes (NNE) of the great asymmetrical folds observed in the Keban metamorphics are coinciding with the diabase dykes cutting the Baskil granite. It is known that the first compaction in the region has started in Turonian (Yazgan, 1984), therefore Keban carbonates have been metamorphized possibly in Turonian-Lower Maestrichtian. When the structural features with granitic rocks are regarded, this age may change up to Coniacian-Lower Maestrichtian. In Lower Maestrichtian the tectonic style of the region has greatly changed. Because, the carbonates of Harami formation overlies the folded Sağdıçlar formation in a quiet and uniform way (Asutay and Turan, 1986).

Baskil magmatics may be said to be a product of continental margin magmatism. They are presumably, the products of an oceanic lithosphere existing between Keban microplate and Arabian platform which later on subducted under Keban microplate.

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