Mineral Res. Exp. Bull., 139, 33-49, 2009

PETROGRAPHICAL AND GEOCHEMICAL PROPERTIES OF PLAGIOGRANITES AND GABBROS IN GULEMAN OPHIOLITE

* Ayşe Didem KILIÇ

ABSTRACT.- Petrographical and geochemical properties of gabbros and plagiogranites of Guleman ophiolite are determined. It was concluded that gabbros can be basic rocks on subduction zone and plagioclase rich leucocratic rocks (plagiogranite) are differentiation products of fractional crystallization of a basic magma in the magma chamber.

Key words: Neotethys, supra-subduction zone, plagiogranite, gabbros, Taurides.

INTRODUCTION

Study area is located in a 200 km^2 area surrounding the Hazar village (Maden town) in Eastern Taurus orogenic belt (Figure 1).

When tectonic framework of Turkey is considered, it is located in northeast – southwest trending East Anatolian Fault zone passing from south of Elazığ, and south of Lake Hazar. Guleman ophiolite was formed after the closure

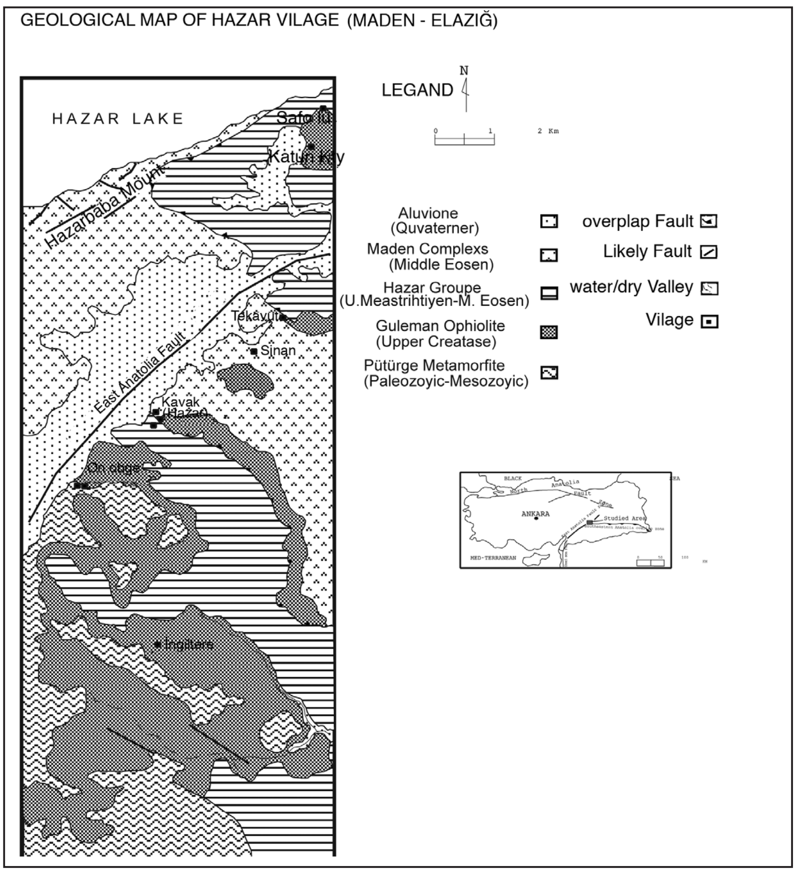

Figure 1- Geoylogic map of studied area (Kılıç, 2005)

* Fırat Üniversitesi Mühendislik Fakültesi Jeoloji Mühendisliği Bölümü, Elazığ

of the Neotethyan ocean as supra-subduction zone ophiolites (Açıkbaş and Baştuğ, 1974; Aktaş and Robertson, 1984; Lytwyn and Casey, 1993; Beyarslan and Bingöl, 2000; Parlak et al., 2008; Robertson, 2002; Kılıç, 2005).

The ophiolites have emplaced in five different zones in Turkey; these are, from south to north, 1) Pontide ophiolites, 2) Anatolide ophiolitic belt, 3) Tauride ophiolite belt, 4) Southeast Anatolian ophiolites, 5) Peri-Arabian ophiolites (Figure 2). All of these ophiolites are the products of subduction zone (Robertson, 2002; Göncüoğlu and Turhan, 1984; Floyd et al., 2000).

There are many researches on the geology, petrography, petrology and ore formations of the Guleman ophiolite (Perinçek 1979b; Perinçek and Özkaya, 1981; Özkan,1982; Erdoğan,1982; Özkan, 1984; Bingöl, 1984; Özkan and Öztunalı,1984; Sungurlu et al., 1985; Yazgan and Chessex, 1991; Kılıç, 2005). The acidic magmatic rocks (trondheimite, tonalite, diorite, etc.) that take place at the plutonic level of the ophiolites or at the sheeted dyke complex provide significant data on the position and origin of the ophiolites (Hebert and Laurent,1990; Floyd et al., 2000). Formations which do not have volcanic units such as Guleman ophiolite have great significance to understand the tectonic positions of the ophiolites. Plagiogranites are the most significant indicators of the arc environments (Floyd et al., 2000). As for the formation of the plagiogranites there are different opinions. It was proposed that, plagiogranites were formed by the differentiation of a tholeiitic magma in the Mid-Oceanic Ridge (Coleman and Peterman,1975; Coleman and Donato, 1979; Pallister and Knight, 1981; Floyd et al., 2000), by partial melting of gabbros (Gerlach et al.,1981; Spulber and Rutherford, 1983; Floyd et al.,2000), and by presence of immiscible liquids found together with mafic solutions (Phillpotts, 1976; Dixon and Rutherford, 1979; Floyd et al., (2000).

This paper aims to examine the petrogenesis, geochemistry and tectonic position of the plagiogranites in Guleman ophiolite, and compare their relation to the gabbros. Defining these properties is significant for revealing the properties of felsic magmatism.

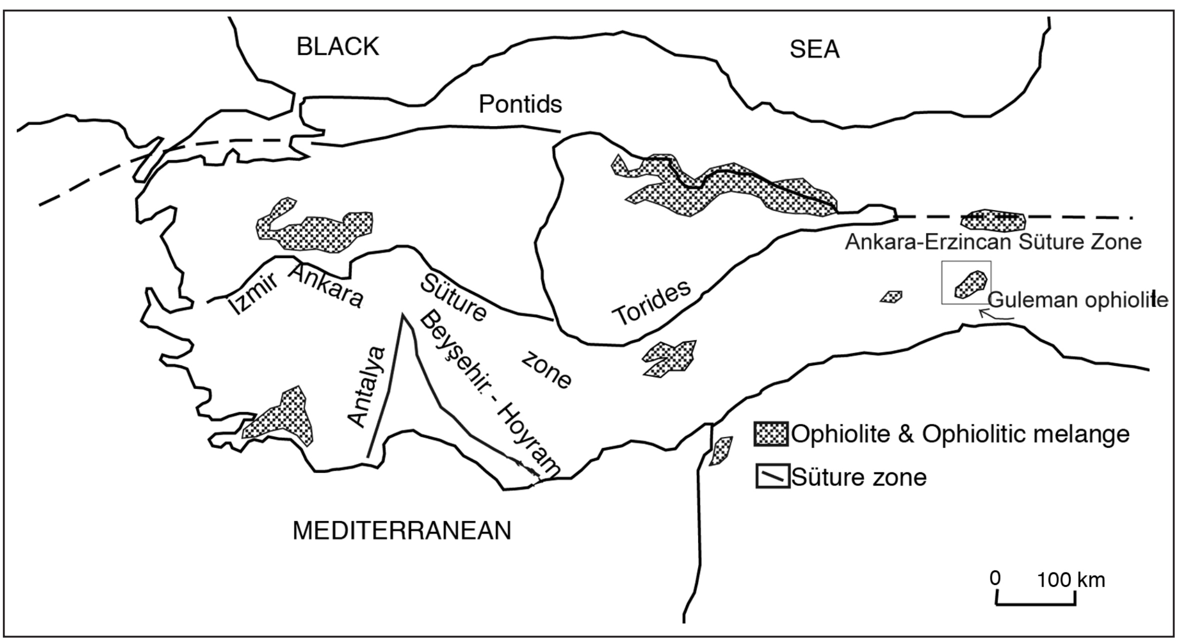

Figure 2- Tectonic units of Turkey and ophiolitic masiffes (changed from Robertson, 2002).

GEOLOGICAL SETTING

An intensive tectonic activity is observed in the study area due to presence of big faults such as the East Anatolian fault and Hazar fault (Figure 1). As for the relation between the lithological units, we observe that Guleman ophiolite is thrusted over the Hazar Group, and Pütürge Metamorphics is thrusted over the Guleman ophiolite and Maden Complex. Hazar Group is thrusted over the Maden Complex as well.

From bottom to top, the following units are observed in the study area (Figure 3): 1) Pütürge Metamorphics, 2) Guleman ophiolite, 3) Hazar Group, 4) Maden Complex, 5) Holocene alluviums (Kılıç, 2005).

Pütürge Metamorphics is composed of Paleozoic-Mesozoic muscovite schists, phyllite, quartzite, calc schist and marbles.

Upper Cretaceous Guleman ophiolite (Erdoğan, 1977; Perinçek and Çelikdemir, 1979) is composed of two main groups, namely tectonites and ultramafic-mafic cumulates. Tectonites are comprised of harzburgite, dunite and podiform chromites in harzburgites. The ultramafic cumulates which have gradual contact with tectonites are represented by dunites with banded or disseminated chromites, wehrlite and clinopyroxenes. A thick layered gabbro level takes place on these rocks. It is possible to differentiate the gabbros as isotope gabbros or as normal gabbros. Isotropic gabros display a equigranular structure in meso and micro investigations whereas the normal gabbros have larger crystals in size. At the upper sections of the isotropic gabbros plagiogranite levels are observed. Ophiolitic units are cut by isolated diabase dykes. Since sheeted dyke complex is not presented in Guleman ophiolite, it is defined as a dismembered ophiolite. Lack of volcanic levels may be explained by tectonic stripping or by a later erosion (Parlak et al. 2008). According to Özkan and Öztunalı (1984), volcanic rocks of Guleman ophiolite is Caferi Volcanics which are

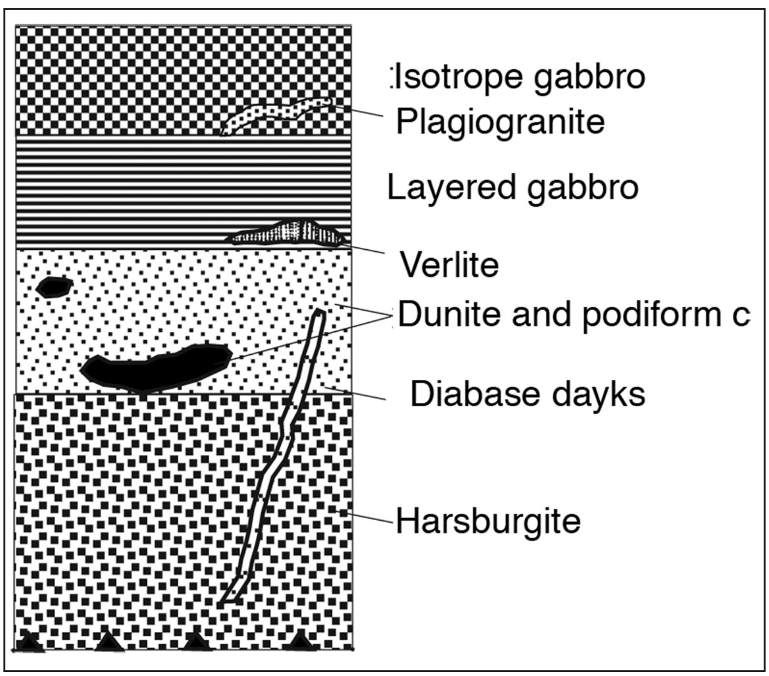

Figure 3- Colon section of The Guleman ophiolite (Kılıç, 2005).

stripped tectonically from ophiolite and rested on Maden Complex. Thickness of diabase dykes which cut the ophiolitic units at different levels is 1 – 1.5 m on average.

Maastrichtian – Lower Eocene Hazar Group (Aktaş and Robertson, 1984) is comprised of an intercalation of conglomerate, sandstone-shale, clayey limestone units.

Middle Eocene Maden Complex is represented by volcanic Karadere Formation (Baştuğ, 1976; Sugurlu et al., 1985; Erdoğan, 1977, 1982) and sedimentary Melefan Formation (Açıkbaş and Baştuğ, 1974; Sungurlu et al., 1985) in the study area. Karadere Formation is composed of agglomerate, tuff, volcanic sandstone, andesite intercalated with mudstone and pillow lava while Melafan formation is composed of marl, mudstone, sandstone and grey limestone.

This study aims to study the petrographical and geochemical properties of gabbros and especially the plagiogranites of Guleman ophiolite and to reveal the character of arc magmatism.

PETROGRAPHY OF GULEMAN OPHIOLITE

Dominant lithology of the Guleman ophiolite is harzburgite. The other rocks are the the mantle tectonites comprised of podiform chromite located in harzburgites and dunites, ultramafic cumulates, gabbros and isolated diabase dykes. The ultramafic cumulates are comprised of wehrlite, dunite and disseminated or banded chromites in dunites. On the cumulate level thick gabbro (isotope gabbro, layered gabbro) is located. Between the two gabbroic level plagiogranites are observed. Isolated diabase dykes cut the whole succession of Guleman ophiolite at different levels.

Harzburgites constitute 40% of the whole ophiolitic rocks. They are serpentinized at tectonic levels and appear as greenish, bright rocks in the field. The main minerals of the harzburgite are olivine (50-60%), enstatite (50-40%) and chromite (less than 1%). Structural and textural features such as recrystallization, partial melting and plastic deformation were preserved in tectonites (harzburgites and dunites) (Özkan and Öztunalı, 1984).

Harzburgites and dunites are laterally transitive. Dunites display fabric texture and/or granular texture. Their modal mineralogical components are olivine (90-97%), clinopyroxene (5-2%) and magnetite (5%).

Thick cumulates are observed on the tectonite level. The ultramafic cumulates and tectonites are laterally transitive. The rocks which much more affected by alteration are wehrlite and clinopyroxene. Wehrlite has mesocumulate texture and forms clinopyroxene (augite) and plagioclase cumulus minerals; on the other hand, olivine forms intercumulus minerals. Intercrystal deformations such as kink banding and plastic flow are not observed. The thick gabbro layer which overlie the cumulate level is represented by isotope gabbro, normal gabbro and plagiogranites at the upper levels.

Layering in gabbros are defined by the change of rate of olivine, plagioclase and pyroxene in layered gabbros. Isotrope gabbros or equigranular gabbros are the upper section of the gabbro level and they have subophitic texture. They are comprised of clinopyroxene (30-35%), olivine (30%) and plagioclase (40-45%). On the other hand, normal gabbros have mesocumulate texture. The most significant property that differs isotope gabbros from layered gabbros is the anorthite content in plagioclases, besides the textural difference (Beccaluva et al., 1994). As a result of microscopic study, the anorthite content of plagioclases is found as 10%.

Plagiogranites are located between the isotope gabbros and normal gabbros. These light colored acidic rocks can easily be observed ingabbros in macroscopic scale. These rocks which display fine granular texture have a modal mineralogical composition of plagioclase (An20-25) (60-65%), quartz (>20%) and biotite (10-15%) (changed into chlorite) and magnetite. Zoning is observed in the euhedral and subeuhedral plagioclases in plagiogranites.

Thickness of isolated diabase dykes whch cut the ophiolitic rocks at different levels is 0.5-1m. They display intersertal texture. Modal mineralogical composition of unaltered diabases is plagioclase (60-80%), clinopyroxene (20-40%) and secondary minerals. Plagioclases have prismatic shapes. They display albite, albite-carlsbad twinning.

GEOCHEMISTRY

Main oxide and trace element (including rare earth elements) analyses of gabbros (7 samples) and plagiogranites (3 samples) of Guleman ophiolites were conducted in ACME Analytic Laboratories in Canada. Total amount of major oxide and minor elements were analysed by ICP-MS method and by acid digestion and lithium metaborate/tetraborate fusion method on 0.2 gr samples. The results are shown in table 1.

When the results of analyses of the gabbros and plagiogranites of Guleman ophiolites were studied in table 1, it was observed that the gabbros have 48.33-54.88 SiO_2, 5.73-11.84 MgO, and the plagiogranites have 60.21-69.19 SiO_2 and 1.22-2.34 MgO values. LOI values of these rocks are between 1.0 – 4.5 and the rocks display hydrothermal alteration in less amounts.

Gabbros have affected from this alteration even if less and in mafic element chemistry this effect is observed. Due to alteration the Na_2O+K_2O value is 1.52-4.90%. K_2O value is less than that of Na2O. Enrichment of Na might be due to spilitization of mafic rocks as a result of low gade hydrothermal ocean floor metamorphism.

In AFM diagrams it is observed that some gabbros fall into an area of non-cumulate gabbro related to arc (Figure 4). This indicates the formation of the primary fraction of solutions in depleted mantle which typicaly occurs at the

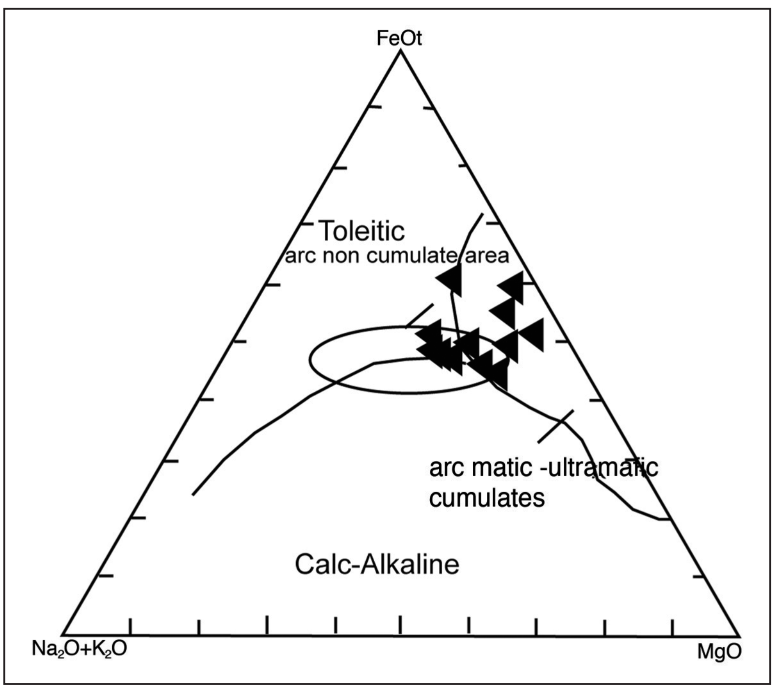

Figure 4- AFM diagrams of gabbros (Beard, 1986).

Table 1-Major and trace element analysis of the gabbros and plagiogranites of Guleman ophiolite.

Lihology	*Plagiogranite*			*Gabbro*						
Sample No	**Pl-1**	**Pl-4**	**Pl-12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
SiO_2	60.21	69.19	62.52	49.30	53.40	54.88	52.17	48.33	53.77	51.29
Al_2O_3	12.84	13.57	15.56	9.63	14.60	11.56	15.85	12.23	12.56	7.8
TiO_2	0.71	0.38	1.23	0.70	1.37	1.05	0.46	0.60	1.51	0.47
Fe_2O_3	6.19	3.81	8.24	13.76	9.92	8.42	8.98	12.76	8.24	15.09
MnO	0.09	0.08	0.04	0.26	0.13	0.13	0.14	0.16	0.15	0.23
MgO	2.34	1.22	1.48	11.66	5.73	6.74	7.22	11.26	6.48	11.84
CaO	13.46	3.35	6.03	11.78	6.64	10.84	9.75	11.18	10.42	9.98
Na_2O	0.19	4.51	3.92	1.46	4.86	3.15	2.85	2.47	3.61	0.51
K_2O	0.03	0.23	0.34	0.06	0.04	0.66	0.20	0.04	0.06	0.03
P_2O_5	0.07	0.08	0.07	0.07	0.15	0.15	0.04	0.08	0.14	0.07
LOI	3.7	3.4	1.0	1.0	2.8	4.1	2.0	1.7	2.9	2.3
Total	99.88	99.84	99.43	99.68	99.64	99.92	99.66	99.77	99.81	99.61
Mg#	56	55	57	59	49	57	57	54	58	55
Rb	0.4	2.6	1.3	<5	1.1	8.2	3.3	3.8	0.5	1
Sr	310	166	193	134	115	166	176	122	155	141
Y	19	26	30	33.5	32	25.2	15.7	31	27	16.8
Zr	45	26	39	18.6	92.7	66.0	25.5	19	51	83.7
Nb	1.1	2.8	2.1	0.7	2.1	1.5	0.5	1	1.7	1.4
Ba	12	62	73	7	26	69	28	45	32	56
Hf	1	1.9	1.3	0.7	2.4	1.8	0.8	1.6	0.9	2.1
Ta	0.1	0.2	<0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1
Pb	0.7	2.6	1.8	0.4	0.3	0.5	0.5	0.3	0.4	0.3
Th	0.2	1.1	0.12	1.1	0.7	0.2	0.3	0.6	0.2	0.7
U	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
La	3.9	4.4	3.83	2.0	2.5	2.3	1.4	2.1	4.1	1.8
Yb	1.8	2.61	1.73	0.08	0.13	0.16	0.49	1.01	0.52	2.01
Eu/Eu*	0.89	1.13	1.08	0.02	0.02	0.02	0.07	0.02	0.07	0.02
$(La)_N/(Sm)_N$	0.90	0.95	0.92	0.52	0.78	0.95	0.8	0.75	0.94	0.91
$(La)_N/(Yb)_N$	**1.04**	**0.97**	**1.03**	**0.46**	**1**	**1.14**	**5.40**	**1.13**	**3.28**	**1.1**

floor of the magma chamber of mafic cumulate gabbros (Hopson et al., 1981). Plagiogranites are accepted as a product of a later differentiation of such a magma (Hopson et al., 1981).

TiO_2 value of the gabbros are between 0.46-1.37 and their Ti content is between 4000-8000 ppm which is consistent with the 5000 ppm Ti content of the island arc tholeiites as indicated by Pearce and Gale (1977). Low trace element values such as Nb, Y, Zr besides Ti, low Nb/Y amount indicate a subalkaline environment (Floyd and Winchester, 1975, Figure 5).

Clustering of rock samples in Ti/V (<20) area in Ti/1000-V diagram which is one of the discriminant diagrams of tectonic environment indicate an island arc tholeiite environment (Figure 6). Similar low Zr amount and low Zr/Y rate (0.5-2.94 in gabbros and 1.0-2.36 in plagiogranites) is typical for island arc (IAT) (Beccaluva et al., 1994; Spulber et al., 1983). When the samples are in studied in Nb/Th-Y diagram similarly, it is observed that the rock sampes fall in island arc area (Figure 7).

The effects of metamorphism observed as a result of petrographic and chemical analyses, the samples variable in MORB-normalized multi-element spider diagrams and the gabbros variable in respect to LILE (Sr, K, Rb, Ba) (Figure 8) reflect ocean flor metamorphism. The most reliable indicator element in LILE which is affected by alteration is Th, which indicates enrichment. Th enrichment is an indicator of emplacement of subduction zone (Wood et al., 1979; Pearce et al., 1990). In (Nb/Zr)n-Zr diagram, it was observed from the distribution of gabbros and plagiogranites that they take place in subduction zone area (Figure 9), and some samples located out of the area indicate the presence of processes of contamination in evolution of magmas (Jenner et al., 1991).

The Th/Y rate, which is the indicator of enrichment of magma with the solutions separated from the subductiong plate (Pearce et al., 1990; Edwards et al., 1991) is 0.04-0.012 and this value is more than MORB (0.03). The low Ti and Zr rates of the samples point out a low melting. Low melting also indicates low crustal thick-

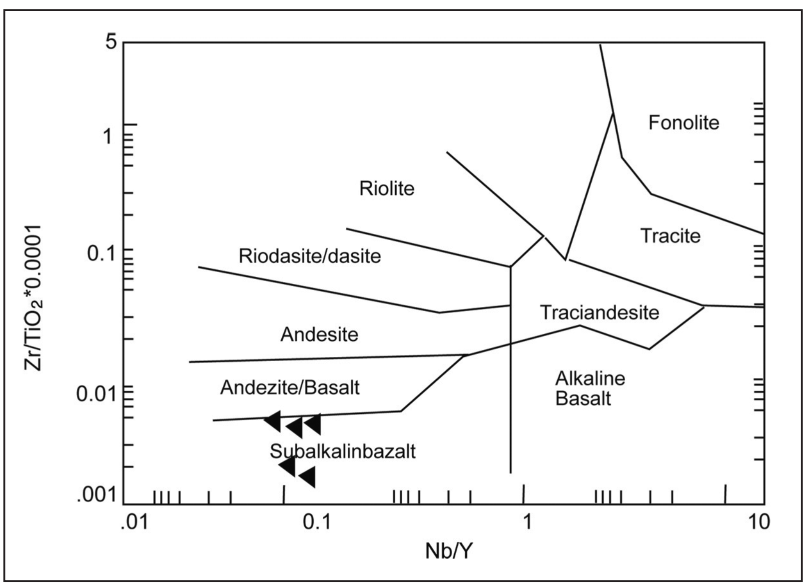

Figure 5- Nb/Y-Zr/TO2*0.0001 diagrams of gabbro (Winchester and Floyd, 1975).

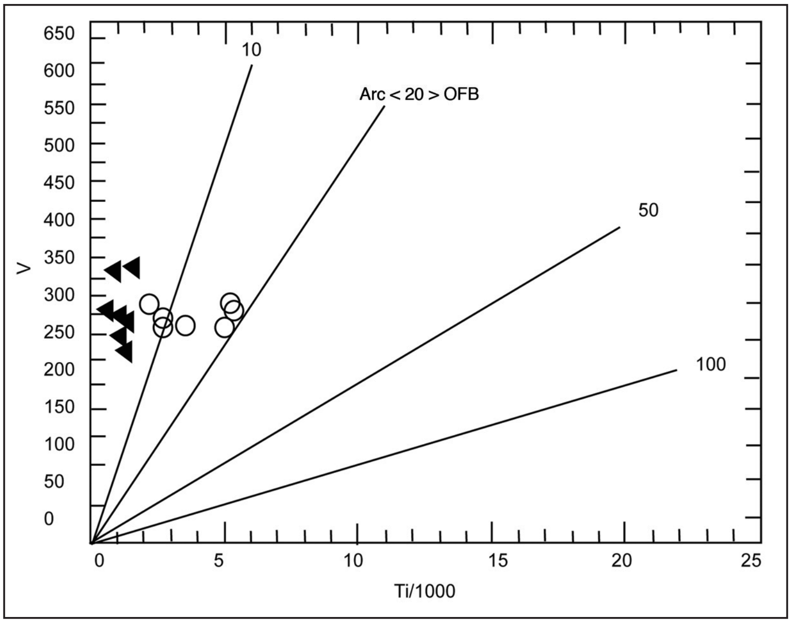

Figure 6- Tectonic diagrams of Plajiogranites (circle) and gabbros (triangle) (Floyd and Winchester, 10975). OFB: Oceanic Floor Basalts

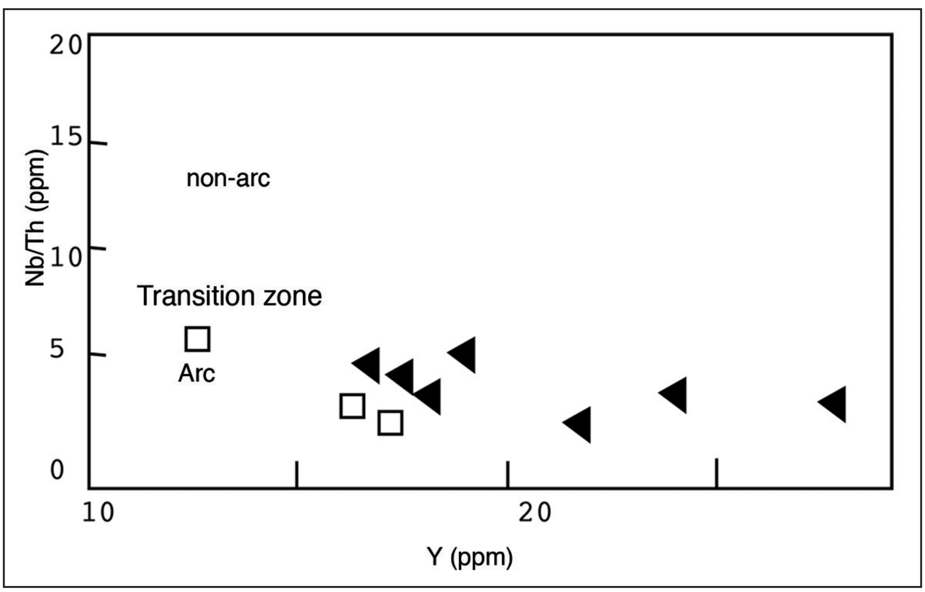

Figure 7- Nb/Th-Y diagram of gabbro and plagiogranites (Jenner et al., 1991 partly changed from). Gabbro (triangle), plagiogranite (square).

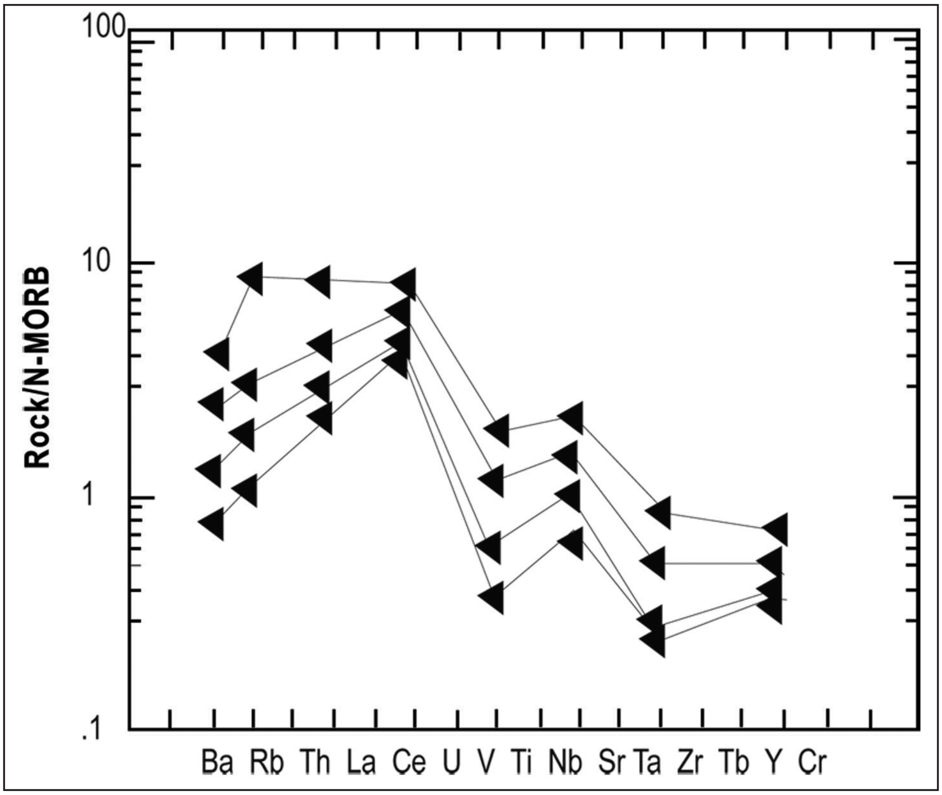

Figure 8- N-MORB normalized diagram of gabbros.

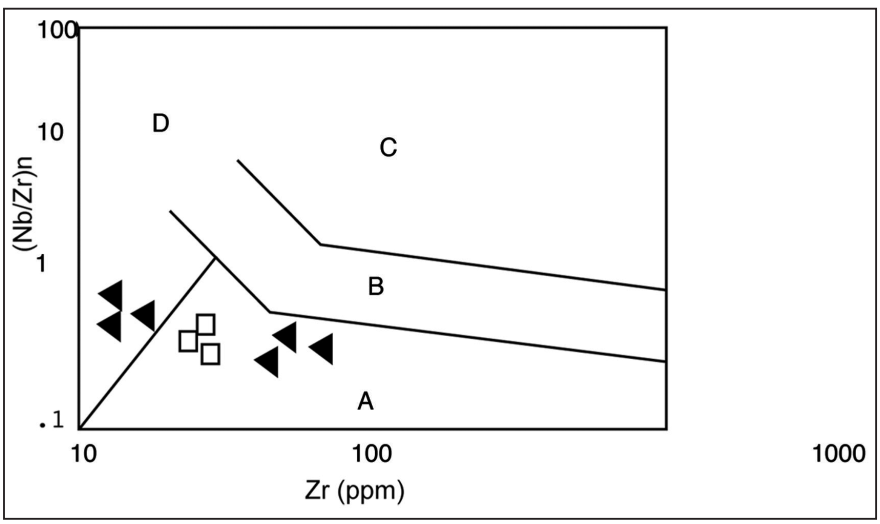

Figure 9- (Nb/Zr) n-Zr diyagrams of gabbros (triangle) and plagiogranites (sqare). A: Subduction zone volcanic and plutonic area, B: Continent-continent corossion area. C: Plate interior plutone and lava area, D: Continent-continent collosion peralümina rocks (Jenner et al., 1991)

ness (Rheid and Jackson, 1981) and change in composition of magma is related to interaction of subducting plate and mantle, composition of subducting plate, enrichment by components coming from the mantle, and depletion rate of mantle. Low concentration of elements coming from the mantle such as Nb, Ti, Y and Yb indicate a depleted mantle resource.

When trace element contents of the plagiogranites observed at the upper levels of the gabbros the most conspicuous property is their low Rb contents. On Rb/Sr diagram, the whole samples are below the line which defines the 0.1 ratio. This ratio is used by Pedersen and Malpas (1984) for discrimination of the plagiogranites formed by partial melting and the plagiogranites formed by fractional crystallization (Figure 10). In all plagiogranites which were assumed to have formed by differentiation of basic magma the Rb/Sr is less than 0.1 (Göncüoğlu and Türeli, 1993).

When the rock/chondrite diagram of the gabbros and plagiogranites of the Guleman ophiolite was studied, it is seen that the plagiogranites are richer in Rare Earth Elements (REE) compared to gabbros (Figure 11). Observing the gabbros along a rather flat curve compared to plagiogranites can be explained by rather less decomposition of the hornblend and/or opaque minerals (Rao et al., 2004).

In ORG (ocean ridge granites)-normalized diagram of plagiogranites (Figure 12) it is observed that the Nb and Ta values are negative. Besides Nb and Ta, negative values of Eu indicate subduction zone (Schilling et al., 1984; McCullough and Gamble, 1991). It is observed that these rocks have been depleted by high

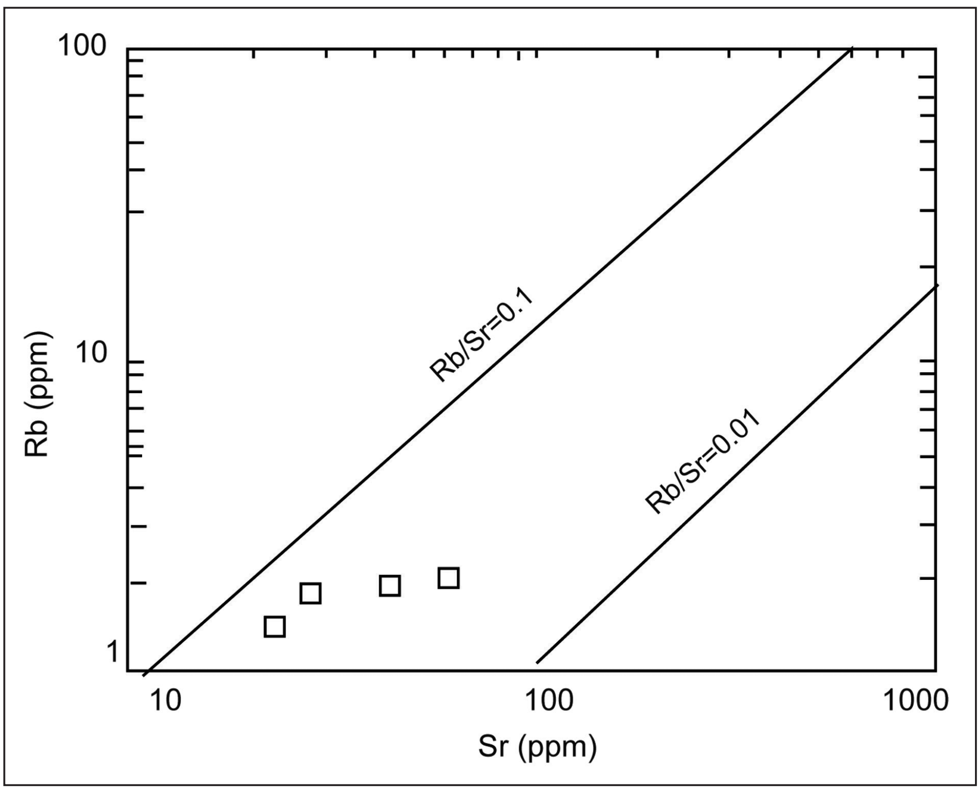

Figure 10- Rb-Sr diagrams of plagiogranites (Pedersen and Malpas, 1984).

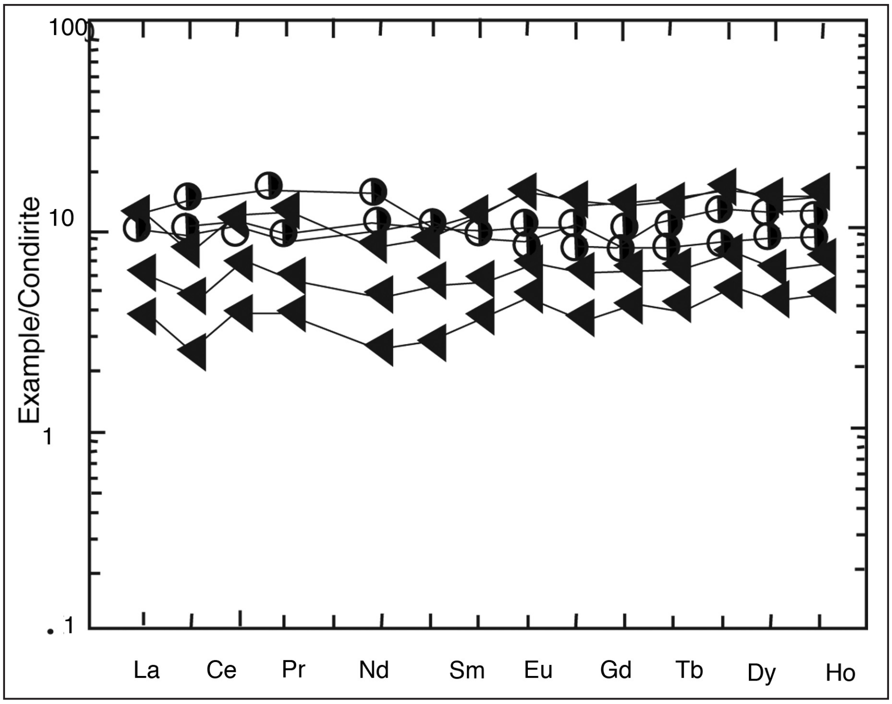

Figure 11- Normalized diagrams of gabbros (triangle) and plagiogranites (circle). (Sun and McDonough, 1989).

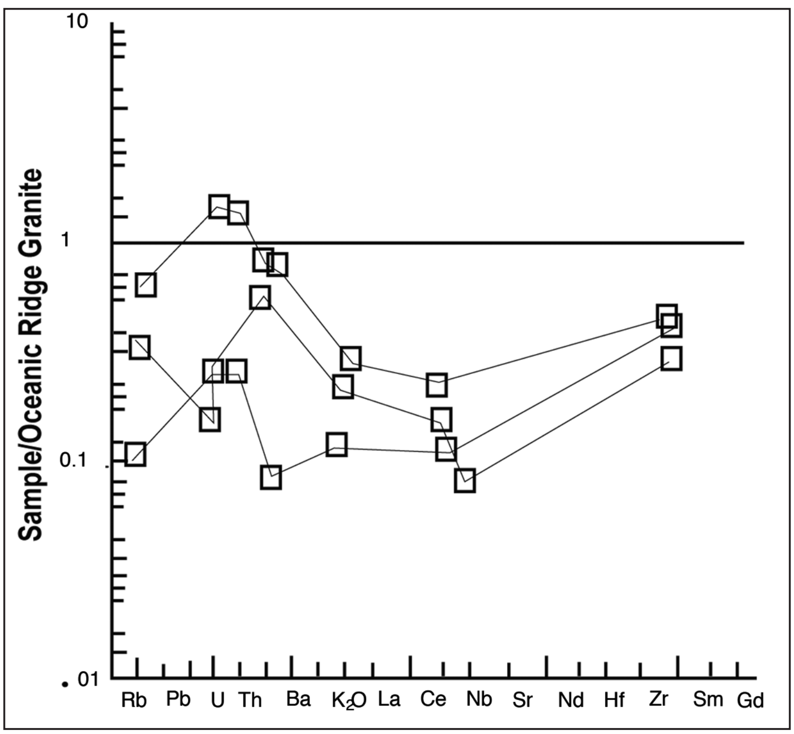

Figure 12- Incompatible elements according to occean ridge granites (from Pearce, 1982).

fastness elements (HFSE) and enriched in large ion radius elements (LILE). This depletion and enrichment is interpreted as a consequence of subduction by Pearce (1982) and Hawkesworth et al. (1977). Another possibility for LILE enrichment is the process of contamination (Wilson, 1989). Zr/Nb-Y/Nb and Rb/Y-Nb/Y diagrams (Figure 13) define the contamination processes. These data indicate the addition of crust components to the solution to separated from the subducting slab. Because the negative Eu anomali also indicate the contamination (Pearce and Parkinson, 1993).

In the Rb-Y+Nb diagram prepared for acidic origin rocks by Pearce (1982) (Figure 14) the plagiogranites take place in volcanic arc granite (VAG) area. The structural position of the gabbros in the Guleman ophiolite and acidic rocks which are collected under the name of plagiogranite, and the Rare Earth element (REE) content show that they have formed by partial melting of some basic rocks located at the upper levels of the subduction zone below the island arc with the effect of the solutions separated from the subducted slab and water (Luchitskaya et al., 2005; Li et al., 1997). The most significant

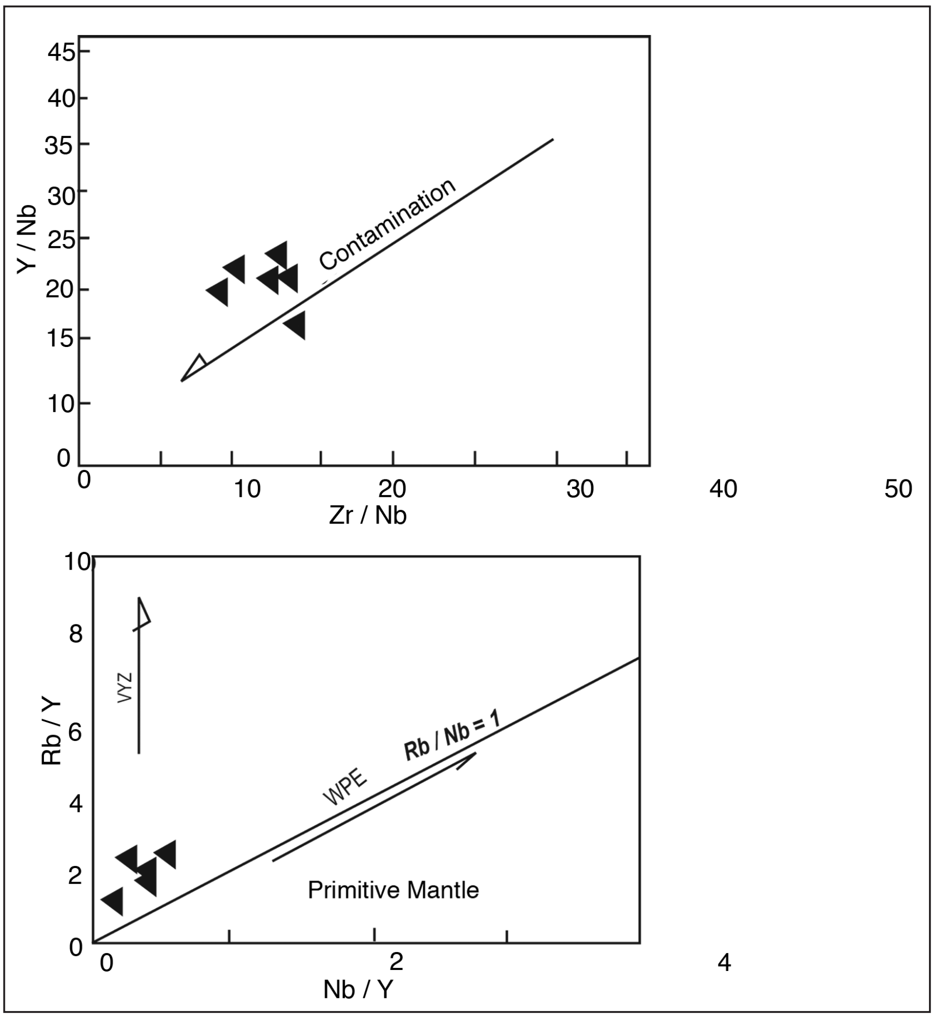

Figure 13- Gabbros of The Guleman ophiolite. Zr/Nb-Y//Nb (changed from Edwards et al., 1991) and Nb/2-Zr-Y (Mechede, 1986). Plate iunterior mid-plate enrichment ((WPE), are enrichment (VYZ.)

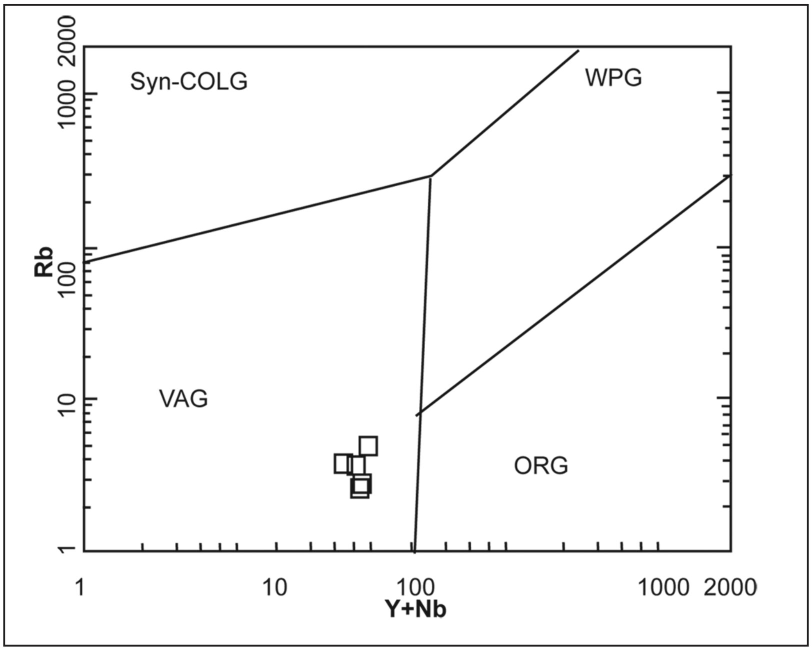

Figure 14- Tectonic environment examine diagrasof plagiogranites (interior spare square) (Pearce ve diğerleri, 1984). ORG: oceanic ridge granite, VAG: volcanic are granite, WPG: plate interior granite, syn-SCOLG: collision granite

evidences for the formation by partial melting of the basaltic rocks are the depletion of these rocks by Rare Earth Elements (REE), high La/Yb and Sr values and low Y value.

Therefore, when all the geochemical data were studied, it is seen that the REE concentrations of the gabbros of the Guleman ophiolite is 2-9x chondrite and that of the plagiogranites is 6-75x chondrite; and they have high REE values. As in Semail (Oman) and Troodos ophiolites, based on the similarity in REE distribution, it is possible to say these two rock types are cogenetic.

DISCUSSION AND RESULTS

The study area is located in tectonically most active region in Turkey. The region has undergone many changes by tectonic movements that have occurred since the Upper Triassic. The most significant and relevant to this work is the subduction process that began with the closure of the Neotethys (Şengör and Yılmaz, 1981; Tüysüz, 1993) and formation of a wide ophiolitic basin that began to open between the Keban and Pütürge massifs (Yazgan, 1984; Yazgan and Chessex, 1991). According to these researchers, the Guleman and Kömürhan ophiolites were formed in this basin and these ophiolites were thrusted over the Arabian platform during Campanian. Some researchers indicate that the ophiolite formation in the region can not be explained only by a an oceanic opening (Perinçek and Özkaya, 1981; Şengör and Yılmaz, 1981; Aktaş and Robertson, 1984; Turan and Bingöl, 1991). These researchers claim that these ophiolites might have formed in two different subduction zones. While the Guleman ophiolite has formed in a small ocean opened between Keban and Pütürge Metamorphics, the other ophiolites (e.g. Koçali ophiolite) have formed on the oceanic crust located between Pütürge and Arabian platform.

Bingöl (1984) states that Guleman, Kömürhan and İspendere ophiolites, since the Upper Triassic, have formed on an oceanic floor that has opened between Bitlis-Pütürge massifs with a high rate and, since the Upper Cretaceous this oceanic floor has first broke up to form a subduction northward and as a consequence of this subduction Baskil granitoid was formed and by the end of the Upper Cretaceous, Baskil granitoids and the ophiolites emplaced on the Bitlis-Pütürge massifs southward. Yılmaz et al. (1992) claims that these Late Cretaceous ophiolites (Göksun, Kömürhan, İspendere, Guleman, etc.) are similar in age, lithology and metamorphism and they all formed by the gradual extinction of the south branch of the Neotethys on the oceanic subduction zone dipping northward. Şengör and Yılmaz (1981), Yılmaz et al. (1992), Parlak et al. (2008), Robertson et al. (2007) state that, although these ophiolites display differences in metamorphism grades, distributions, existence or inexistence of sheeted dyke complexes and volcanic rocks, they all have formed as consequences of thrusts during the orogenic movements between Late Cretaceous and Late Miocene.

Rocks related to Late Cretaceous arca re the basic, neutral and acidic extrusive and intrusive rocks. While the extrusive rocks were defined as "Elazığ unit" by Robertson et al. (2007) the intrusive rocks were defined as "Baskil Magmatic Rocks" by Aktaş and Robertson (1984) and Yazgan (1984) and as"Elazığ Volcanic Complex" by Hempton (1984, 1985) and as "Elazığ Granitoid" by Turan and Bingöl (1991) and Beyarslan and Bingöl (2000). The intrusive rocks known as Baskil granitoid are the I-type calcalkaline rocks that cut the Taurid platform, ophiolites and the extrusive rocks in the north. These rocks are And type active continental margin rocks (Yazgan, 1984; Yazgan and Chessex,1991; Beyarslan and Bingöl, 2000; Robertson et al., 2007). The gabbros in the study area are the extensions of the opholitic series, their mineralogical and geochemical features indicate that these gabbros do not belong to Baskil granitoid.

Presence of harzburgites as mantle rocks in Guleman ophiolite and, presence of thick gabbros with different textural and mineralogical composition, the geochemical features, indicate that this ophiolite is of "Harxburgitic Type Ophiolite" which is one of the supra-subduction zone ophiolites which developed based on the opening of the upper section of the crust as a result of the subduction.

As a result of the petrographical and geochemical study of the plagioclase-rich leucocratic rocks located at the upper levels of the gabbros and isotrope gabbros of the Guleman ophiolite, it was found out that these rocks are products of island arc magmatism related to subduction zone. Besides, presence of acidic rocks and location of the samples in volcanic arc granitic area (VAG) (Figure 14) indicate island arc activity.

The leucocratic rocks we define under the name of plagiogranite are interpreted to have formed as a result of the activity in the upper levels of the magma chamber (Floyd et al., 2000). Plagiogranites may form by the partial melting (5-15%) of the gabbroic source rocks or by fractional crystallization (Floyd et al., 2000).

REFERENCES

Açıkbaş, D. and Baştuğ, C. 1974. Sason-Kozlu şarj yöresi jeolojik raporu. Türkiye Petrolleri Anonim Ortaklığı Raporu,795s (unpublished).

Aktaş, E. and Robertson, A. H. F., 1984. The Maden Complex, SE Turkey: Evolution of the Neotethyan Continental Active Margin. In: Dixon, J.E and Robertson, A.H.F.(eds). Geological Evolution of the Eastern Mediterranean, The Special Publication of Geological Society No:Blackwell Scientific Publication, Edinburg, 375-402.

Baştuğ, C., 1976. Bitlis napının stratigrafisi ve Güneydoğu Anadolu sütur zonunun evrimi. Yeryuvarı ve İnsan, 1/3, 55-61.

Beard, J. S., 1986. Characteristic mineralogy of arc-related cumulate gabbros: implications for the tectonic setting of gabbroic plutons and for andesite genesis, Geology, 14, 848-851.

Beccaluva, L., Coltorti, M., A.,Premti, I., Saccani, E., Siena, F. and Zeda, O., 1994. Mid-ocean ridge and suprasubduction affinities in the ophiolitic belts of Albania. Ofioliti, 19/1, 1-77.
Beyarslan M. and Bingöl, A.F., 2000. Petrology of a supra-subduction zone ophiolite (Kömürhan-Elazığ -Turkey). Canadian Journal of Earth Sciences. 37, 1411-1424.
Bingöl, A. F., 1984. Geology of the Elazığ area in the Eastern Taurus region: In: Tekeli, O., Göncüoğlu, M. C.(eds). Geology of the Taurus Belt, Proceedings of the International Symposium. Mineral Research and Exploration Institute of Turkey (MTA), Ankara, 209-216.
Coleman, R.G. and Peterman, Z.E., 1975. Oceanic plagiogranite. Journal of Geophysical Research, 80, 1099-1108.
______ and Donato, M. M., 1979. Oceanic plagiogranite revised. In: Barker, F. (ed). Trondhjemites, dacites, and related rocks. Development in Petrology, 6, 149-168. Elesevier Scientifics Publication Corporation New York.
Dixon, S. and Rutherford, M. J., 1979. Plagiogranites as late stage immiscible liquids in ophiolite and mid-ocean ridge suites: An experimental study. Earth and Planetary Science Letters, 45, 45-60.
Edwards, C., Menzies, M., and Thirlwall, M., 1991. Evidence from Muriah, Indonesia, for the interplay of supra-subduction zone and intraplate processes in the genesis of potassic alkaline magmas. Journal of Petrology, Vol.32,No:3, 555-592.
Erdoğan, B., 1977. Geology, geochemistry and genesis of the sulphide deposits of the Ergani-Maden region SE Turkey, Ph. D. Thesis, University of New Brunswick.
______, 1982. Ergani – Maden yöresindeki Güneydoğu Anadolu Ofiyolit Kuşağı'nın Jeolojisi ve volkanik kayaları. Türkiye Jeoloji Kurultayı Bülteni, 25, 49-60.
Floyd, P., A., and Winschester, J. A., 1975. Magma type and tectonic setting discrimination using immobile elements. Earth and Planetary Scientific Letters, 27, 211-218.
Floyd, R, A., Göncüoğlu, M. C., Winchester, J. A. and Yalınız, M. K., 2000. Geochemical character and tectonic environment of Neotethyan ophiolitic fragments and metabasites in the Central Anatolian Crystalline Complex, Turkey. In: Bozkurt., E., Winchester, J. A. (eds). Tectonics and Magmatism in Turkey and the surrounding area, Geological Society of London Special Publications, 173, 182-202.
Gerlach, D. C., Leeman, W.P. and Lallement, A. H. G. 1981. Petrology and geochemistry in the Canyon Mountain ophiolite, Orogens Contribution Minerals Petrology, 77, 82-92.
Göncüoğlu, M. C. and Turhan, N.,1984. Geology of the Bitlis metamophic belt. In: Tekeli, O. and Göncüoğlu, M. C. (eds). International Symposium on the Geology of the Taurus Belt, Proceedings, 237-244.
______, and Türeli, K., 1993. Petrology and geodynamic interpretation of plagiogranites from the Central Anatolian Ophiolites (Aksaray-Turkey). Turkish Journal of Earth Sciences, 2, 195-203.
Hawkesworth, C. J., O'Nions, R. K., Pankhurst, R. J., Hamilton, P. J. and Evensen, N. M. 1977. A geochemical study of island arc and back arc tholeiites from the Scotia Sea. Earth and Planetary Science Letters, 36,2, 253-262.
Hebert, R. and Laurent, R.1990. Mineral chemistry of the plutonic section of the Troodos ophiolite: new constraints for genesis of arc-related ophiolites. In: Malpas, J., Moores, E. M., Panayiotou, A., Xenophontos, C. (eds). Ophiolites: Oceanic crustal analogues. Geological Survey Cyprus, Nicosia, Cyprus, 149-163.
Hempton, M. R., 1984, Results of detailed mapping near Lake Hazar (eastern Taurus Mountains), Geology of the Taurus Belts, 229-235.
______, 1985, Structure and deformation history of the Bitlis suture near Lake Hazar, so-

utheastern Turkey. Geological Society America Bulletin., 96, 233-243.

Hopson, C. A., Mattinson, J. M.,and Pessagno, E. A., 1981, Coast range ophiolite, western California. In: Ernst, W. G. (ed). The geotectonic development of California, Rubey, Vol. I: Englewood Cliffs, Nj, Prentice-Hall, 418-510.

Jenner, G. A., Dunning, G. R., Malpas, J., Brown, M. and Brace, T., 1991, Bay of Island and Little Port complexes, revisited: age, geochemical and isotopic evidence confirm suprasubduction-zone origin. Canadian Journal of Earth Sciences, 28,1635–52.

Kılıç, A. D., 2005. Hazar Gölü (Sivrice-Elazığ) güneyinin petrografik ve petrolojik özellikleri. Fırat Üniversitesi Fen Bilimleri Enstitüsü, Elazığ, Doktora Tezi, 103, (unpublished).

Li, X., Zhou, H., Chung, S., Ding, S., Liu, Y., Lee, C., Ge, W., Zhang, Y. and Zhang, R., 1997. Geochemical and Sm-Nd isotopic characteristics of metabasites from central Hainan Island, South China and their tectonic significance. Island Arc, 11,129-144.

Luchitskaya, M. V., Morozov, O. L. and Palandzhyan, S. A., 2005. Plagiogranite magmatim in the Mesozoic island-arc structure of the Pekulney Ridge, Chukotka Peninsula, NE Russia. Lithos, 79, 1-2, 251-269.

Lytwyn, J. N. and Casey, J. F., 1993. The geochemistry and petrogenesis of volcanics and sheeted dikes from the Hatay (Kızıldağ) ophiolite, southern Turkey: possible formation with the Troodos ophiolite, Cyprus, along fore-arc spreading centers, Tectonophysics, 232, 237-272.

McCullogh, M.T. and Gamble, J. A., 1991, Geochemical and geodynamical constraints on subduction zone magmatism. Earth and Planetary Science Letters, 102, 358-374.

Meschede, M., 1986, A method of discriminating between different types of mid-ocean ridge basalts and continental tholeiites with the Nb-Zr-Y diagram. Chemical Geology, 56, 207-218.

Özkan, Y. Z., 1982. Guleman (Elazığ) ofiyolitinin jeolojisi ve petrolojisi. Yerbilimleri Dergisi, 3-4/6, 33-39.

_______, 1984. Guleman ofiyolitinde metamorfizma etkileri. Maden Teknik Arama Dergisi 101/102, 47-57.

_______, and Öztunalı, Ö., 1984. Petrology of the magmatic rocks of Guleman ophiolite: In: Tekeli, O. and Göncüoğlu, M. C.(eds). Geology of the Taurus Belt, International Symposium Proceedings, Ankara, 285-293.

Pallister, J. S. and Knight, R. J., 1981. Rare-earth element geochemistry of the Samail ophiolite near Ibra, Oman. Journal of Geophysical Research, 86, 2673-2697.

Parlak, O., Rızaoğlu, T., Bağcı, U., Karaoğlan, F. and Höck, V., 2008. Geochemistry of ophiolites in the Southeast Anatolia, Turkey. Tectonophysics, doi:10.1016/j.tecto.2008.08.002.

Pearce, J. A.,1982. Trace element characteristics of lavas from destructive plate boundaries. In: Thorpe, E. S. (ed). Andesites, Wiley, London, 525-548.

_______, ve Gale, G. H., 1977. İdentification of ore deposition environment from trace element geochemistry of associated igneous host rocks. Geological Society London Special Publication, 7, 14-24.

_______, and Bender, J.F., de Long, S. E., Kidd, W. S. F.,Low, P. J., Güner, Y., Şaroğlu, F., Yılmaz, Y., Moortbath,S. and Mitchell, J.G., 1990. Genesis of the collision volcanism in Eastern Anatolia. Turkey. Journal of Volcanology Geothermal Research, 44,189-229.

_______, and Parkinson, I. J., 1993. Trace element models for mantle melting: application to volcanic arc petrogenesis. Magmatic Processes and Plate Tectonic. Geological Society, 373-403.

Pedersen, R. B., and Malpas, J.,1984. The origin of oceanic plagiogranites from the

Karmoy ophiolite, western Norway. Contributions to Mineralogy and Petrology, 88, 36-52.

Perinçek, D., 1979*b*. Palu-Karabegan-Elazığ-Sivrice-Malatya alanının jeolojisi ve petrol imkanları. Türkiye Petrolleri Anonim Ortaklığı, Ankara, no: 1361 (unpublished).

______, and Çelikdemir, M. E., 1979. Palu-Karabegan-Elazığ-Sivrice-Malatya alanının jeolojisi ve petrol imkanları. Türkiye Petrolleri Anonim Ortaklığı Raporu (unpublished), 1361.

______, and Özkaya, İ., 1981. Arabistan levhası kuzey kenarının tektonik evrimi. Hacettepe Üniversitesi Yerbilimleri Enstitüsü Bülteni, 8, 91-101.

Phillpotts, A. R., 1976. Silicate liquid immiscibility: Its probable extent and petrogenetic significance. American Journal of Sciences, 276, 1147-1177.

Rao, D., R., Rai, H. and Kumar, J., S., 2004. Origin of oceanic plagiogranite in the Nidar ophiolitic sequence of eastern Ladakh, Indıa, Current Science, 87, 7.

Rheid, I. and Jackson, H.R., 1981. Oceanic spreading rate and crustal thicknesses: Marine Geophysical Research, 5, 165-173.

Robertson, A. H. F., 2002. Overview of the genesis and emplacement of Mesozoic ophiolites in the Eastern Mediterranean Tethyan region. Lithos, 65, 1-67.

Robertson, A. H. F., Parlak, O., Rızaoğlu, T., Ünlügenç, U.C., İnan, N., Taslı,K. and Ustaömer, T., 2007. Tectonic Evolution of the South Tethyan Ocean: Evidence from the Eastern Taurus Mountains (Elazığ region, SE Turkey). In: Rıes, A. C., Butler, R. W. H. and Graham, R. H. (eds). Deformation of the Continental Crust: The Legacy of Mike Coward. Geological Society, London, Special Publications, Vol. 272, 233-272.

Schiling, G., Vollmer, R., Ogden, J., Kingsley, R. H. and Waggoner, D. G., 1984. Nd and Sr isotopes in ultrapotassic volcanic rocks from the Leucite Hills, Wyoming. Contributions to Mineralogy and Petrology, 87, 359-368.

Spulber, S. D. and Rutherford, M. J. 1983. The origin of rhyolite and plagiogranite in oceanic crust: An experimental study. Journal of Petrology,24, 1-25.

Sun, S. S., and McDonough, W. F., 1989. Chemical and isotopic systematics of oceanic basalts; implications for mantle composition and processes. In: Saunders, A. D., and Norry, J. (eds). Magmatism in ocean basins, Geological Society Special Publication, 42, 313-345.

Sungurlu, O., Perinçek, D., Kurt, G., Tuna, E., Dülger, S., Çelikdemir, E. and Naz, H., 1985. Elazığ-Palu-Hazar alanının jeolojisi. Petrol İşleri Genel Müdürlüğü Dergisi, 29, 83-191.

Şengör, A.M.C. and Yılmaz, Y., 1981. Tethyan evolution of Turkey; A plate tectonic approach. Tectonophysics, 75, 181-241.

Turan, M. and Bingöl, A. F., 1991. Kovancılar-Baskil (Elazığ) arası bölgenin tektonostratigrafik özellikleri. Çukurova Üniversitesi Ahmet Acar Sempozyumu Bildiriler Kitabı, Adana, 213-227.

Tüysüz, O., 1993. Karadeniz'den Orta Anadolu'ya bir jeotravers: Kuzey Neotetisin tektonik evrimi. Türkiye Petrolleri Jeoloji Dergisi Bülteni, 5/1, 1-33.

Wilson, M., 1989. Igneous petrogenesis. Unwyn Hyman, London, 466 s.

Wood, D. A., Joron, J. L., and Trevil, M., 1979. A re-appraisal of the use of trace elements to classify and discriminate between magma series erupted in different tectonic settings. Earth Planetary Scientific Letters, Vol. 45, 326-336.

Yazgan, E., 1984. Geodynamic evolution of the eastern Taurus. In: Tekeli, O., Göncüoğlu, M. C.(eds). The Geology of the Taurus Belt, Proceedings of the İnternational Symposium, Ankara, 199-208.

______, and Chessex, R., 1991. Geology and tectonic evolution of the Southeastern Taurides in the region of Malatya. Bulletin of Turkish Association of Petroleum Geologists, 3,1-42.

Yılmaz, Y., Yiğitbaş, E., Yıldırım, M. and Genç, Ş. C., 1992. Güneydoğu Anadolu Metamorfik Masiflerinin kökeni. Türkiye 9. Petrol Kongresi, Bildiriler, 307-318.