PETROLOGY AND GEOTECTONIC SIGNIFICANCE OF PLAGIOGRANITE FROM THE SARIKARAMAN OPHIOLITE (CENTRAL ANATOLIA, TURKEY)

M. Kenan Yaliniz*, Peter A. Floyd and M. Cemal Göncüoğlu*****

* *Department of Civil Engineering, Celal Bayar University, Manisa, Turkey*
** *Department of Earth Sciences,University of Keele,Staffordshire, ST5 5BG, UK*
*** *Department of Geological Engineering,Middle East Technical University, 06531, Ankara, Turkey*

Keywords: *plagiogranite, low-K ophiolite. Central Anatolia, Turkey.*

ABSTRACT

Plagiogranites within the supra-subduction zone (SSZ) type Sarikaraman Ophiolite (SO), Central Anatolia, are very fine to coarse grained leucocratic rocks with a range of occurrences as simple narrow fracture infilling to wide complex zones of net-veining or agmatites with numerous, partly assimilated enclaves of gabbro and dolerite. Petrographically, they are characterized by the textures ranging from hypidiomorphic granular to granophyric intergrowths of quartz and plagioclase. Geochemically, major and trace elements data revealed that the plagiogranites belong to the typically low-potassium series of ophiolitic complexes and show similar geochemical characteristics with the Ocean-Ridge Granites. They are characterized by 10-20 times enriched flat chondrite REE patterns with a negative Eu anomalies relative to mafic component in the SO. This confirms the cogenetic nature of the plagiogranites and indicates progressive fractionation in the Sarikaraman mafic magma.

Field observations coupled with major-element and trace element chemistry support to a model by which the plagiogranites of SO could be formed as a fractional crystallization of Sarikaraman basaltic magma in SSZ setting, like the other eastern Mediterranean ophiolitic plagiogranites such as Troodos, Pindos, and Oman.

INTRODUCTION

Leucocratic rocks associated with ophiolitic complexes have compositions ranging from albite-granite through trondhjemite and tonalite to granodiorite, and are collectively called oceanic plagiogranites by Coleman and Peterman (1975).

These rocks are characterized by typical interstitial vermicular and/or micrographic intergrowths of quartz and plagioclase, and have very low K_2O contents. Plagiogranites generally occur as intrusive masses of varying size. They form in the upper portions of the plutonic ophiolite sequence and are commonly associated with layered or massive gabbro. Petrogenetically, they are interpreted as representing the late differentiates of tholeiitic basaltic magmas (Coleman and Peterman, 1975; Coleman and Donato, 1979). Plagiogranites, although more abundant at the upper crustal level, are not restricted to this level and a number of processes have been suggested to account for their origin and development in the oceanic environment (e.g Barbieri et al., 1994; Briqueu et al., 1991; Amri et al., 1996). However, as in many other ophiolites, plagiogranites in the SO are primarily restricted to the upper portion of the ophiolite sequence.

Plagiogranitic rocks are significant for understanding the tectonic setting of ophiolitic rocks where the only exposed products of magmatic events are plutonic rocks. After the work of Pearce et al. (1984), attempts have been made to reconstruct the geodynamic environment of ophiolite formation based on the trace element content of the associated plagiogranites. Rocks similar in petrography and chemistry to these plagiogranites have been found in modern oceanic settings such as the mid-oceanic ridges (e.g. Engel and Fisher 1975; Moores and Vine 1971; Cannat et al., 1997; Cannat and Casey, 1995), island arcs (Alabaster et al., 1982; Gerlach et al., 1981; Miyashiro, 1973), marginal or back-arc basin ridges (e.g. Malpas, 1979; Saunders et al., 1979; Vernikovskiy et al., 1993), and SSZ (fore-arc basin) ridges (e.g. Alabaster et al., 1982; Pearce et al., 1984; Jenner et al., 1991; Jafri et al., 1993). SSZ type Mesozoic Neotethyan ophiolites are characterized by a significant proportion of plagiogranites in their pseudomagmatic stratigraphy in the Eastern Mediterranean region (e.g. Troodos, Hatay, Antalya, Vourinos, Oman) (Pearce et al., 1984), including the SO studied here.

In terms of pseudostratigraphic relationships of magmatic units and chemical designation, the Late Cretaceous SO exhibits a SSZ (fore-arc basin) setting and is characterized by a significant proportions of oceanic plagiogranites (Yaliniz et al., 1995; 1996; Yaliniz, 1996; Floyd et al., 1998). These features are mirrored apparently by the ophiolites derived from the southern branch of Neotethys, such as Troodos, Antalya, Hatay, Mersin, Oman (Yaliniz et al., 1996). However, the oceanic plagiogranites of SSZ type SO have not been studied in detail before and invite comparison with the plagiogranites of the same ophiolites of southern branch of Neotethys in the Eastern Mediterranean area. Can the plagiogranites (as well as the ophiolites) be correlated between the different region of Neotethys and thus help with the regional tectonic interpretations?

This paper reports the detailed results of petrological-geochemical studies of plagiogranites from the SO, as well as comparison of different plagiogranites of the ophiolites within the Neotethyan ocean.

SARIKARAMAN OPHIOLITE

The SO is representative of a partially somewhat dismembered ophiolite body that retains still a recognizable pseudostratigraphy (Fig.1). Whereas, voluminous ultramafics are not exposed in direct contact with the rest of the ophiolitic slap, the lowest section is composed of isotropic gabbros, which are faulted against a sheeted dyke complex

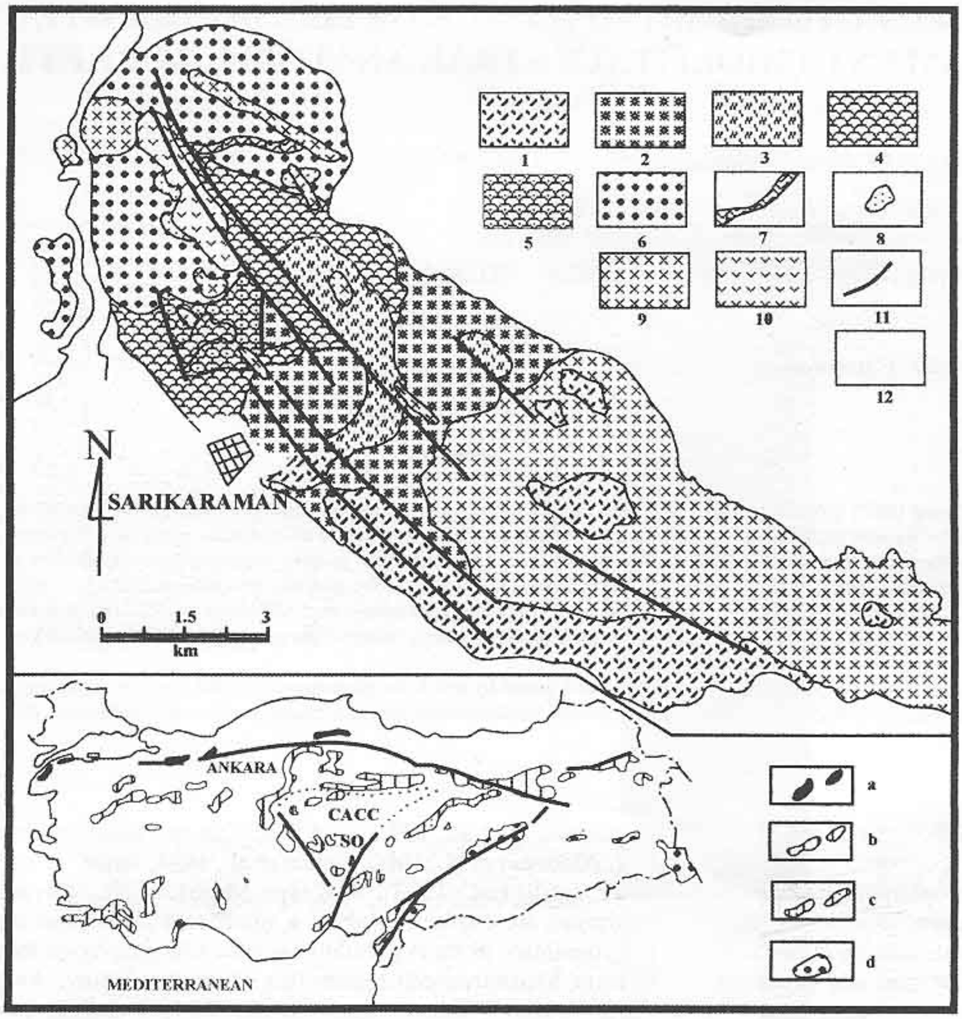

Fig. 1 - Geological map of the Sarikaraman ophiolite, Central Anatolia: 1- Isotropic gabbro, 2- Plagiogranite (trondhjemite), 3- Dolerite dyke complex, 4- Basalt pillow lava, 5- Basalt pillow breccia, 6- Lower Turonian - early Santonian sediments, 7- Early Santonian limestone units, 8- Felsic volcanic block units, 9- Campanian-Maastrichtian Terlemez quartz-monzonite, 10- Paleocene volcaniclastic units, 11- Fault, 12- Neogene cover units. Inset shows the ophiolitic belts of Turkey (Juteau, 1980) and the location of the Sarikaraman ophiolite (SO) within the Central Anatolian Crystalline Complex (CACC): a- Intra Pontide Suture, b- Vardar, Izmir-Ankara-Erzincan Suture, c- Inner Tauride Belt, d- Peri-Arabic Belt.

that merges up section into basalt lavas and breccias. The gabbros are cut by intrusive trondhjemitic plagiogranites which appear to be genetically related to various high-level rhyolitic dykes and sills that traverse the upper volcanic section of the ophiolite. All units are cut by a late set of isolated dolerite dykes. The ophiolite is overlain by a sequence of middle Turonian - lower Santonian pelagic sediments intercalated with a volcanogenic olistrostromal sedimentary cover and uppermost pillow lavas. Both the ophiolite and cover sediments are intruded by a Campanian-Maastrichtian Terlemez quartz-monzonite. These late granites have their counterpart in other areas of the Central Anatolian Crystalline Complex (CACC). They are not related to the plagiogranites of the SO, and are the post-collisional products of the melting of thickened crust (Yaliniz 1996; Göncüoglu and Türeli, 1994; Yaliniz et al. 1998). Finally, the ophiolite and late granites are unconformably overlain by Paleocene volcaniclastites. The field relationships and faunal age of the ophiolite-related sediments indicates that the SO is middle Turonian - early Santonian in age (Yaliniz 1996; Yaliniz et al.,1998).

Field relationships and features

Texturally, the plagiogranites vary from very fine to coarse grained. They mainly occur at the boundary between the isotropic gabbro and the dyke complex, occupying a significant volume of the SO (Fig. 1). Plagiogranites are uniform at outcrop level, but overall they are usually compositionally and/or texturally heterogeneous (Plate 1). They are laterally discontinuous and pass gradationally sidewards and downwards into gabbros and sidewards and upwards into dyke complex with sharp to diffused margin, without marginal chilling (Plate 1a,b). The absence of chilled margins and frequently observed variation from quite sharp to rapidly gradational margins suggests that the host rock was sometimes plastic and in other instances was sufficiently cool to be brittle (Plate 1b).

Traversing upwards in the Sarikaraman ophiolitic sequence, the trondhjemites exhibit a number of different emplacement relationships ranging from: simple narrow fracture infillings to wide and complex netveined or agmatitic zones with numerous, partly assimilated and sometimes plastically deformed gabbro and dolerite enclaves in the gabbros (Plate 1d,e). The plagiogranitic segregations frequently pass directly into sharp margined veins, dykes and pods that range in width from a few centimetres to more than a metre. The veins grade rapidly into the gabbro with a diffuse margin often coarse-grained. The field appearance of these veins suggests they are in situ segregations of residual liquid. They are composed of saussuritized plagioclase laths, with interstitial quartz and hornblende and a variety of secondary greenschist facies minerals.

Plagiogranites were also found as dykes and irregular bosses in the dolerite sheeted dyke complex and dykes and rhyolitic lavas in the upper volcanic units (Plate 1c). They are generally linked with both the dyke margins and joints, and are frequently loci for epidotization. Finally, similar felsic lava is also found as blocks in olistostrome units within the sedimentary cover, implying that autobrecciated equivalents of the high-level volcanics were subjected to the secondary redeposition via mass flow mechanism (Yaliniz 1996).

Petrography

As a group, the plagiogranites are equigranular, medium- to fine-grained leucocratic rocks with subhedral plagioclase and quartz. Their texture ranges from hypidiomorphic granular, where quartz forms a granular mosaic partly enclosing

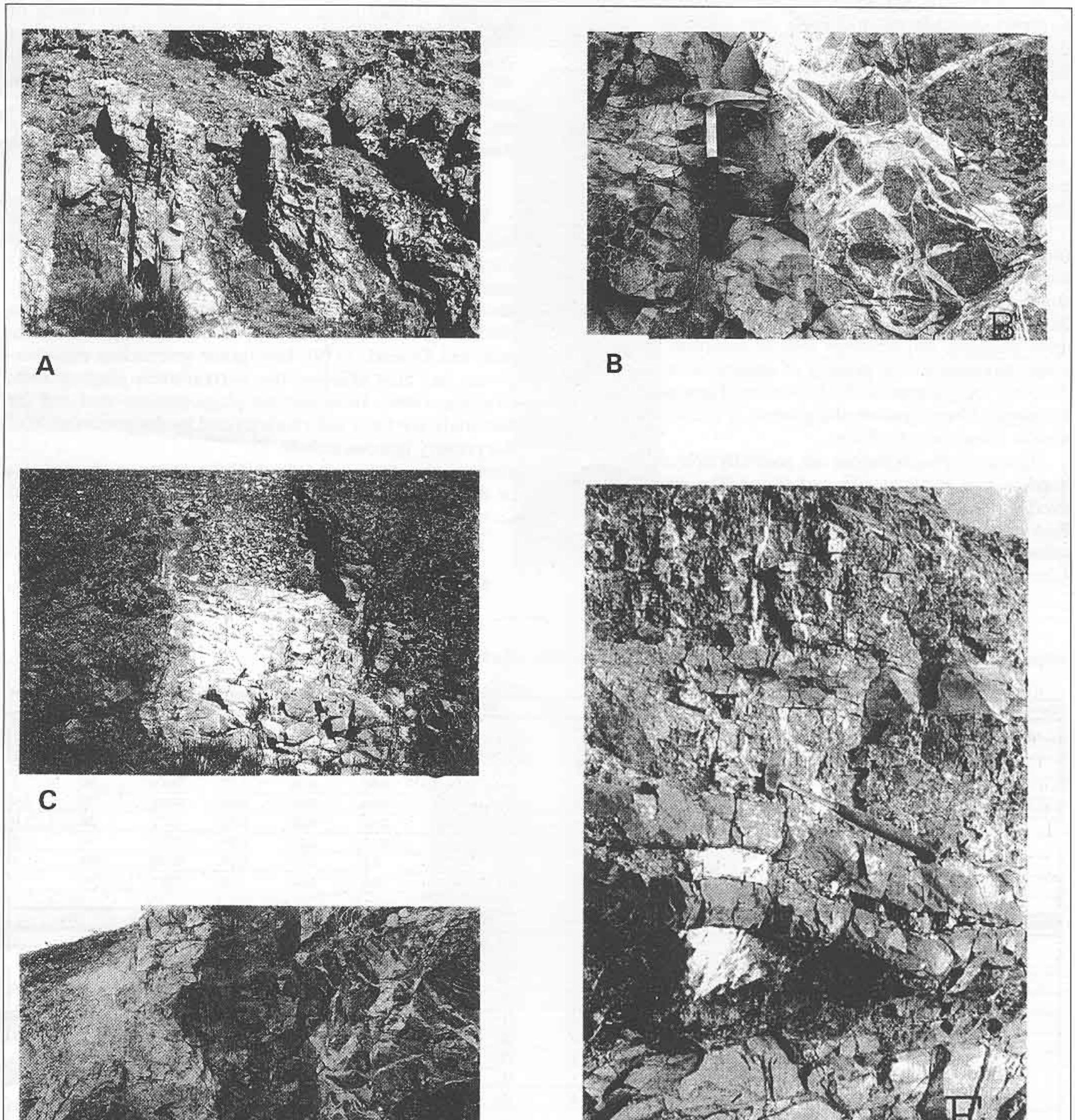

Plate 1 - a) Association of dolerite and plagiogranite dykes (light colored), b) View of plagiogranite veins and pods within the isotropic gabbro, c) plagiogranite dyke intruding into the basaltic volcanics, d) dolerite dykes intruding into the host consist.

earlier formed feldspar, to granophyric, where a graphic intergrowth of secondary plagioclase and quartz predominates. The plagiogranites are variably altered with secondary minerals occurring in interstitial cavities and as veins in a granular mosaic. Secondary mineralization comprises mainly epidote, chlorite and quartz with subordinate calcite and traces of sphene.

Plagioclase is the best indicator of alteration. Zoned feldspar often has an epidotized core and almost kaolinitized. Quartz frequently shows a wide variety of textures. Often, there is no clear distinction between primary and secondary quartz as the partial replacement of plagioclase by quartz is usually in optical continuity with interstitial quartz. Although feldspar is always more abundant than primary quartz, primary and secondary quartz sometimes can comprise up to 75% of the mode. Quartz and feldspar commonly appear in a variety of granophyric textures.

Epidote minerals of a range of compositions occur, almost invariably associated with turbid plagioclase and secondary quartz. The early formed type of epidote is clinozoisite, typically replacing the calcic cores or, exceptionally, individual zones of plagioclase. The later formed epidote is more pistacitic and develops without regard to pre-existing grain boundaries. The process of epidotization is progressive, and it culminates in the formation of epidosite. Epidote frequently forms close or along joints, it is also observed in narrow cross-cutting veinlets.

High-level plagiogranites are generally aphyric with flow banding and occur as sills and flows. The groundmass is everywhere fine grained crystalline due to devitrification. Recrystallized quartz and possibly albite sometimes form spherules with radial structures. The larger spherules exhibit microgranophyric texture.

Geochemistry

Sampling and analytical methods

Representative plagiogranite samples (9 specimens) were collected from the SO and analysed for major and selected trace elements. For two of the samples, rare earth elements (REE) and Hf, Ta, Th, U were also determined. All samples were analysed on an ARL 8420 X-Ray Fluorescence spectrometer (Department of Earth Sciences, University of Keele; analysts: M. Aikin and D. Emley) calibrated against both international and internal Keele standards of appropriate composition (details of methods, accuracy and precision are given in Floyd and Castillo (1992), whereas the REE etc. were determined by Instrumental Neutron Activation Analysis (Activation Laboratories ltd., Canada; Table 1).

Alteration

The application of trace element abundances to petrogenetic interpretation requires that the trace element geochemistry reflects igneous processes and is not controlled by later metasomatism. Plagiogranites in ophiolites suites invariably show the effect of low-grade greenschist metamorphism characterized by the presence of chlorite and epidote (Coleman and Donato, 1979). Low-grade greenschist metamorphism has also affected the Sarikaraman plagiogranite (Yaliniz, 1996). However, the plagiogranites analyzed for this study are fresh and characterized by the preservation of the primary igneous texture. The general uniformity of trace element abundances and the LREE patterns of the samples of Sarikaraman plagiogranite indicate that the chemical effects of alteration are relatively minor.

Chemical relationship

Major, trace, and rare earth element data are presented in

Table 1 - Analyses of plagiogranites from Sarikaraman ophiolite, Turkey

Sample	SIO2	TIO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	LOI	Total	Ba	Th
1	77.01	0.29	12.06	2.18	0.03	0.5	1.67	5.3	0.41	0.02	0.9	100.4	45	0
2	77.14	0.45	12.89	0.77	0.02	0.28	1.65	4.68	1.31	0.06	0.87	100.3	43	1
3	77.91	0.33	12.21	0.95	0.03	1.08	0.87	5.19	0.42	0.05	1.11	99.97	14	0
4	72.82	0.41	13.44	3.48	0.09	1.24	1.5	4.9	0.92	0.06	1.23	100.1	94	1
5	73.07	0.3	13.07	2.8	0.04	0.48	4.36	5.13	0.03	0.03	0.63	99.94	32	0.5
6	77.15	0.37	12.14	1.59	0.03	0.79	1.14	5.68	0.41	0.03	0.89	100.2	24	0
7	79.38	0.17	12.02	1.03	0.02	0.3	0.13	6.45	0.17	0.01	0.51	100.2	31	0
8	80.42	0.19	10.94	0.79	0.01	0.56	0.99	4.45	0.6	0.02	0.89	99.86	149	1
9	72.63	0.52	13.84	1.64	0.05	1.81	2.27	4.92	0.9	0.09	1.39	100.1	16	0
Sample	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Pb**	**Ga**	**Zn**	**Cu**	**Ni**	**V**	**Cr**	**Hf**	**Sc**
1	15	116	26	170	1	4	11	16	2	4	30	23	*	*
2	35	124	30	179	1	3	11	11	1	3	24	20	*	*
3	15	102	40	115	1	1	10	21	1	3	8	59	*	*
4	30	104	29	136	1	4	12	38	2	3	29	25	*	*
5	4	130	22	164	1	6	11	17	7	9	54	31	4.2	6.3
6	14	66	33	173	1	1	13	18	19	4	26	19	*	*
7	6	31	52	195	1	1	12	13	1	4	2	25	*	*
8	22	70	33	165	1	1	11	15	1	3	10	26	4.6	4.9
9	30	123	26	171	1	3	11	26	2	6	54	29	*	*
Sample	**Ta**	**U**	**La**	**Ce**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Yb**	**Lu**	**Ab**	**Or**	**An**
1	*	*	1	6	10	*	*	*	*	*	*	45.03	2.44	7.93
2	*	*	3	34	19	*	*	*	*	*	*	39.85	7.81	7.9
3	*	*	2	16	12	*	*	*	*	*	*	44.29	2.51	4.06
4	*	*	2	12	21	*	*	*	*	*	*	41.89	5.5	7.18
5	0.26	0.2	3.7	12	7	2.02	0.82	2.8	0.6	2.83	0.45	43.66	0.18	12.62
6	*	*	4	20	25	*	*	*	*	*	*	48.33	2.44	5.52
7	*	*	2	42	30	*	*	*	*	*	*	54.69	1.01	0.59
8	0.19	0.4	4.3	14	9	2.47	0.56	4.1	0.7	3.92	0.57	38	3.59	4.85
9	*	*	1	12	17	*	*	*	*	*	*	42.14	5.4	10.89

Table 1 and show that the plagiogranites are characterized by 72.63-80.42 %SiO_2, 10.94-13.84 %Al_2O_3, 4.45-6.45 % Na_2O, 0.03-1.31 %K_2O, 0.17-0.52 %TiO_2, 1 ppm Th and Nb, 22-52 ppm Y. On the basis of normative feldspar proportions, the analysed oceanic plagiogranites are trondhjemites (Fig. 2).

On the basis of normalized REE content, it is possible to distinguish the ophiolitic plagiogranites from the tonalites-trondhjemites of continental environment. Ophiolitic plagiogranites are characterized by a flat pattern (light REE's depleted relative to heavy REE's), and they are enriched approximately ten times relative to average chondrite with negative Eu anomalies (Coleman and Peterman, 1975). The chondrite-normalized rare earth element abundance in two analysed samples of the Sarikaraman plagiogranite is shown in Fig. 3. Both samples are characterized by a normalized flat pattern enriched > X10 to the average chondrite and exhibiting a slight depleting of the light REE's (La_N/Yb_N<0.79-0.94). The broadly undifferentiated REE patterns of the Sarikaraman plagiogranite are similar to those of other ophiolitic plagiogranites on the basis of flat REE pattern. In addition, the REE patterns of the rock units of Sarikaraman ophiolite in Fig. 3, varied from 2X chondrite in isotropic gabbro to 20X chondrite in felsic volcanics (rhyolite) and show typical higher incompatible element enrichment and increasing Eu anomalies towards felsic component (plagiogranite and rhyolite). This feature is consistent with the fractional crystallization from a mafic Sarikaraman magma and the cogenetic nature of the mafic-felsic components.

Tectonic discrimination

A systematic study of the geochemistry of granites from known tectonic setting was made by Pearce et al. (1984), who classified the granites into ocean-ridge, volcanic-arc, within-plate and collisional types; with each category being further subdivided. They demonstrated that the elements Rb, Y, Yb, Nb and Ta are the most efficient discriminants between granites from a variety of tectonic environment, such as ocean ridge (ORG), within-plate (WPG), volcanic-arc (VAG) and syn-collisional (syn-COLG). The SSZ type ocean ridge granites (ORG, subgroup d) and post collisional granites (post-COLG) cannot be distinguished from the VAG on this basis (Pearce et al., 1984). The SSZ granites can only be identified successfully when there is geological evidence for an oceanic setting. They may then be identified on a Nb-Y diagram on the basis of their lower Nb content (Pearce et al. 1984).

On the basis of Rb versus Y+Nb (Fig. 4), the Sarikaraman plagiogranite shows similarity to volcanic arc granite (VAG) and clearly differentiated from WPG and syn-COLG. However, in case of Y versus SiO_2 and Nb versus SiO_2 diagrams (Fig. 5), the Sarikaraman plagiogranite differentiated from the ORG sub type (a,b,c) and plot ORG sub type (d) which is know as SSZ type ocean ridge granites.

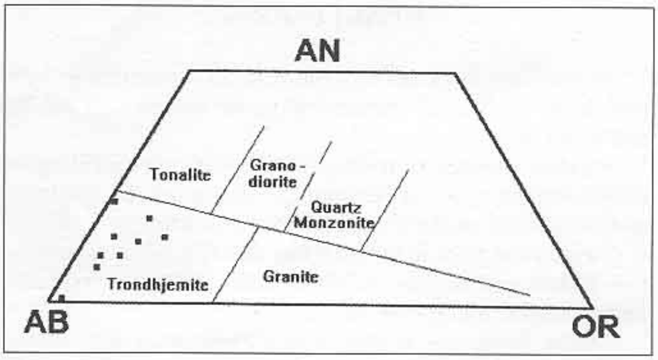

Fig. 2 - Normative Ab, An and Or plot of the Sarikaraman plagiogranite (after Barker, 1979).

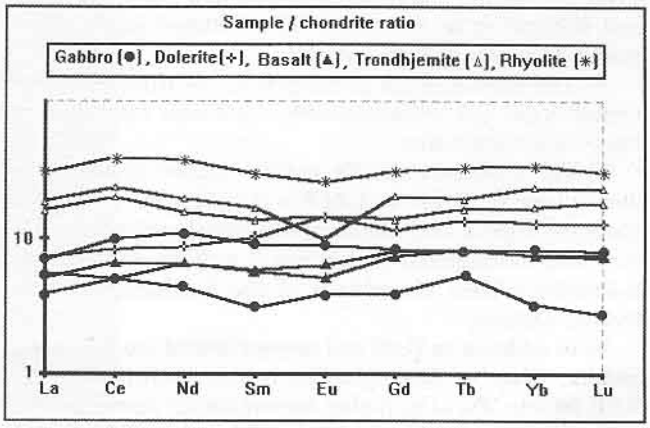

Fig. 3 - Condrite-normalized REE diagram for the Sarikaraman ophiolitic units displaying a progressive enrichment in total REE from gabbro to rhyolite.

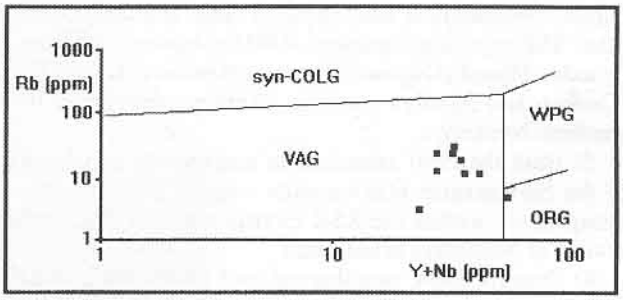

Fig. 4 - Rb versus (Y+Nb) diagram (after Pearce et al., 1984).

Comparison with other Tethyan plagiogranites

The SSZ type ocean ridge granites(ORG, subgroup d) of the island arc tholeiite series from typical Eastern Mediterranean ophiolites are shown in the Nb versus Y diagram (Fig. 6). The Sarikaraman trondhjemites plot almost between VAG- and ORG-type and clearly overlap with the field of the well known SSZ ocean ridge granites from the Troodos Massif of Cyprus (Aldiss, 1978), the Semail Nappe of Oman (Alabaster et al., 1982), and the Antalya complex of Turkey (Cocherie, 1978).

The SSZ type ORG affinity of the Sarikaraman plagiogranite is also substantiated by ORG-normalized multi-element systematics in Fig. 7 which exhibits a low content of HFSE relative to the high abundance of LILE. In particular, the enrichment in Th and Ce relative to Ta and Nb is the most typical and characteristic geochemical feature is on the ORG normalized geochemical pattern of the Sarikaraman trondhjemite samples. Such enrichment is considered typical for many SSZ type granites of the island arc tholeiite series (Pearce et al., 1984) as shown by similar patterns of SSZ type granites from Troodos and Oman. The high values of Ba and Rb, and the low value for K_2O may be attributed to the low-grade of alteration of the Sarikaraman samples.

CONCLUSIONS

1) Plagiogranites occupy the highest stratigraphic horizon in the high-level intrusive plutonic complex of the SO and occur as:

- bodies ranging from simple narrow fracture infillings to wide complex zones of netveining with numerous, partly assimilated mafic enclaves of gabbro and dolerite,
- dykes and pods in gabbros and dolerite dyke complex,
- dykes and bosses intruding into the upper volcanic units, massive and pillow lavas,
- felsic lavas and as blocks in olistostromal units within the epiophiolitic sedimentary cover.

2) Petrographically, typical graphic intergrowths of samples (which are presented in many plagiogranites), provide evidence for the simultaneous late-stage growth of quartz and feldspar in an extremely differentiated liquid derived from an initially tholeiitic magma.

3) The Sarikaraman plagiogranite, is trondhjemitic in composition and volumetrically significant relative to the basic rocks of the area.

4) The enrichment in Th and Ce relative to Ta and Nb, and mildly depletion in LREE's ($La_N/Yb_N<0.79-0.94$) are the most typical and characteristic geochemical feature in the ORG normalized geochemical pattern and chondrite normalized REE abundance of the Sarikaraman trondhjemite samples.

5) In addition to field and petrographical studies, the cogenetic nature of plagiogranites is also confirmed by their REE pattern showing higher incompatible element enrichment with increasing negative Eu anomalies towards evolved felsic components. Such geochemical characteristics considered typical for many SSZ type granites of the island arc tholeiite series (Pearce et al., 1984) as shown by similar patterns of SSZ type granites from Troodos, and Oman. Geochemical data shows a clear similarity with the other SSZ type plagiogranites (ORG subgroup (d)) from the Troodos Massif (Cyprus), Vourinos (Greece), Semail Nappe (Oman), and Antalya complex (Turkey) developed in the southern Neotethys.

5) Both the field associations and overall geochemistry of the Sarikaraman plagiogranite suggest that an ophiolitic paragenesis within the SSZ environment of the northern branch of Neotethys is indicated

6) Overall, field, petrological and geochemical data for the plagiogranites of the SO support the assertion proposed by Yaliniz (1995), Yaliniz et al. (1996), Floyd et al. (1998) that they represent the late-stage differentiates of the Sarikaraman basic magma. This magma was derived by the partial melting of a depleted mantle source in a SSZ (ORG subtype (d);fore-arc basin) setting within the Vardar-Izmir-Ankara-Erzincan ocean of the northern branch of Neotethys.

Acknowledgements

MKY acknowledges a scholarship from the TUBITAK (Turkey) to undertake geochemical work at Keele University, at 1994, and Professor Williams for providing laboratory facilities. Analytical data at Keele University was provided by D. W. Emley and M. Aikin. Funding for the project by the NATO grant, reference: CRG 960549 is gratefully acknowledged. Logistic support in the field was given by TPAO.

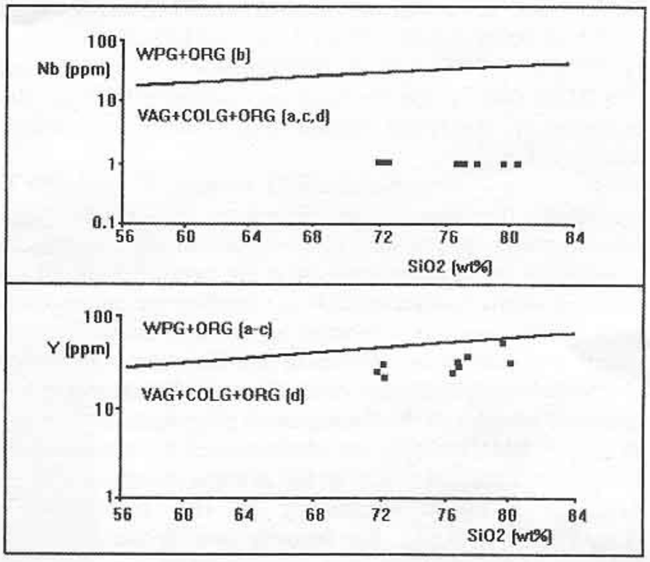

Fig. 5 - Y versus SiO_2 and Nb versus SiO_2 diagrams (after Pearce et al., 1984).

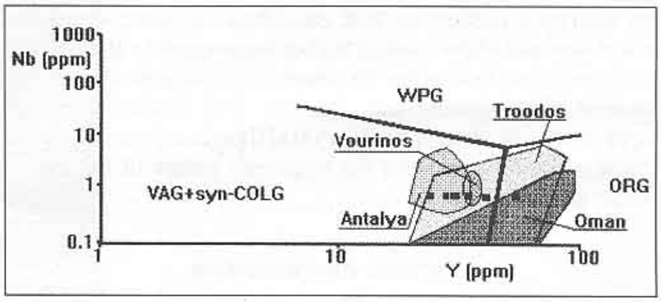

Fig. 6 - Nb versus Y diagram (after Pearce et al., 1984).

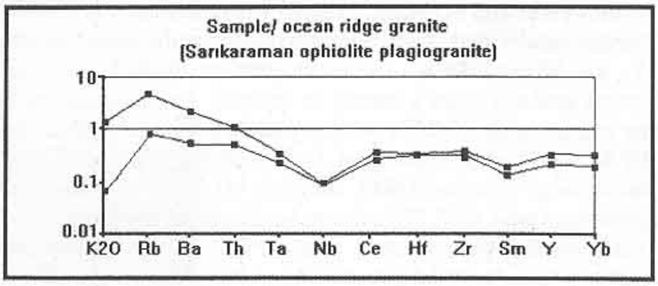

Fig. 7 - ORG-normalized multielement systematics of the trondhjemites (normalizing data taken from Pearce et al., 1984).

REFERENCES

Aldiss D.T., 1978. Granitic rocks of ophiolites. Ph. D. thesis, Open University, UK.

Alabaster T., Pearce J.A. and Malpas J., 1982. The volcanic stratigraphy and petrogenesis of the Oman ophiolite. Contrib. Mineral. Petrol., 81: 168-183.

Amri I., Benoit M. and Ceuleneer G., 1996. Tectonic setting for the genesis of oceanic plagiogranites: evidence from a paleo-spreading structure in the Oman ophiolite. Earth Planet. Sci. Lett., 139:177-194.

Barbieri M., Caggianelli A., Florio M.R. and Lorenzoni S., 1994. Plagiogranites and gabbroic rocks from the Mingora ophiolitic melange, Swat Valley, NW Frontier Province, Pakistan. Mineral. Mag., 58: 553-566.

Barker F., 1979. Trondhjemite: Definition, environment and hypotheses of origin. In: F. Barker (Ed.), Trondhjemites, dacites and related rocks. Elsevier, Amsterdam, p.1-12.

Briqueu L., Mevel C. and Boudier F., 1991. Sr, Nd, and Pb isotopic constrains in the genesis of a calcalkaline plutonic suite in Oman ophiolites related to the obduction process. In: T.J. Peters (Ed.), Ophiolite genesis and evolution of oceanic lithosphere, Kluwer Academic Press, p. 517-542.

Cannat M. and Casey J., 1995. An ultramafic lift at the Mid-Atlantic Ridge: successive stage of magmatism in serpentinized peridotites from the 15° N region. In: R.L.M. Vissers and A. Nicolas (Eds.), Mantle and lower crust exposed in oceanic ridges and ophiolites, Kluwer, p. 5-34.

Cannat M., Ceuleneer G. and Fletcher J., 1997. Localization of ductile strain and the magmatic evolution of gabbroic rocks drilled at the Mid-Atlantic Ridge. O. D. P..Sci. Results, 153: 77-98.

Cocherie A., 1978. Geochimie des terres rares dans les granitoids. Ph. D. thesis, Univ. Rennes, France.

Coleman R.G. and Donato M.M., 1979. Oceanic plagiogranite revisited. In: F. Barker (Ed.), Trondhjemites, dacites, and related rocks, Elsevier, Amsterdam, p.149-168.

Coleman R,G. and Peterman Z.E., 1975. Oceanic plagiogranite. J. Geophys. Res., 88: 1099-1108.

Engel C.G. and Fisher R.L., 1975. Granitic to ultramafic rock complexes of the Indian Ocean ridge system, Western Indian Ocean. Geol. Soc. Am. Bull., 86: 1553-1578.

Floyd P.A. and Castillo P.R., 1992. Geochemistry and petrogenesis of Jurassic ocean crust basalts. ODP Leg 129, site 801. In: R. Larson, Y. Lancelot et al. (Eds.), Proc ODP Sci Results, 129: 361-388.

Floyd P.A., Yaliniz M.K. and Göncüoglu M.C., 1998. Geochemistry and petrogenesis of intrusive and extrusive ophiolitic plagiogranites, Central Anatolian Crystalline Complex, Turkey. Lithos, in press.

Gerlach D.C., Leeman W.P. and Lallemant A.H.G., 1981. Petrology and geochemistry in the Canyon Mountain ophiolite, Oregon. Contrib. Mineral. Petrol., 77: 82-92.

Göncüoglu M.C. and Türeli T.K., 1994. Alpine Collision-Type Granitoids from western Central Anatolian Crystalline Complex, Turkey. J. Kocaeli Univ., 1: 39-46.

Jafri S.H., Charan S.N. and Govil P.K., 1993. Plagiogranite from the Andaman ophiolite belt, Bay of Bengal, India. J. Geol. Soc. London, 152: 681-687.

Jenner G.A., Dunning G.R., Malpas J., Brown M. and Brace T., 1991. Bay of Island and Little Port complexes, revised: age, geochemical and isotopic evidence confirm suprasubduction-zone origin. Canad. J. Earth Sci., 28: 1635-1652.

Malpas J., 1979. Two contrasting trondhiemitic associations from transported ophiolites in Western Newfoundland: initial report. In: F. Barker (Ed.), Trondhjemites, dacites and related rocks. Elsevier, Amsterdam, p. 465-487.

Moores E.M. and Vine F.J., 1971. Troodos Massif, Cyprus and other ophiolites as oceanic crust: evaluation and implications. Phil. Trans. Roy. Soc. London, A 268: 443-466.

Miyashiro A., 1973. The Troodos ophiolitic complex was probably formed in an island arc. Earth Planet. Sci. Lett., 19: 128-224.

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

Saunders A.D., Tarney J., Marsh N.G. and Wood D.A., 1979. Ophiolites as ocean crust or marginal basin crust: a geochemical approach. In: A. Panayiotou (Ed.), Proceed. Intern Ophiolite Symp., Cyprus 1979. Geol. Survey Cyprus, Nicosia, p. 193-204.

Vernikovskiy V.A., Neimark L.A., Proskurnin V.F. and Yakovleva S.Z., 1993. On the Late Riphean age of plagiogranites of the Kunar massif (northeastern Taymyr) using U-Pb zircon dating. Dokl. Akad. Nauk., 331: 706-708 (in Russian).

Yaliniz M.K., 1996. Petrology of the Sarikaraman Ophiolite (Aksaray, Turkey). METU PhD Thesis, 270 pp.

Yaliniz M.K., Floyd P.A. and Göncüoglu M.C., 1996. Supra-subduction zone ophiolites of Central Anatolia: geochemical evidence from the Sarikaraman Ophiolite, Aksaray, Turkey., Min. Mag., 60: 697-710.

Yaliniz M.K., Göncüoglu M.C. and Altiner S., 1998. Age and paleotectonic significance of epi-ophiolitic sedimentary cover of Sarikaraman ophiolite (Central Anatolia, Turkey). In prep.

Yaliniz M.K. Göncüoglu M.C. and Floyd P.A., 1995. Petrology of plagiogranites of Sarikaraman Ophiolites (Central Anatolia) and their tectonic significance within the Eastern Mediterranean ophiolites: EUG 8. Biennal Meeting; Strasbourg, 9-14 April 1995, Terra Abstr., 179.

Received, June 18, 1997
Accepted, April 12, 2000