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Petrochemistry and Parent Rock Characteristics of the Anıphibolites in the Gümüşler Formation of the Niğde Metamorplıics, Central Turkey

Gümüşler Formasyonundaki amfibolitlerin petrokimyast ve köken kaya özellikleri, Niğde Metamorfitleri, Orta Anadolu

Koçak, K.[1], Arşları, M[2]., Kurt, H. \ Baş, H.,' Döyen, A, '

1: Selçuk Üniversitesi, MMF, Jeoloji Mühendisliği Bölümü, 42040 Konya
e-ıııail: kkocak@selcuk.edu.tr
2: Karadeniz Teknik Üniversitesi, MMF, Jeoloji Mühendisliği Bölümü,61080 Trabzon

Abstract

in this study, it was attempted to determine the petrochcmistry and parent rock characteristics ofthe Gümüşler amphibolites, associatcd with marble and quartzite, from the Niğde metamorplıics by using tlıcir whole-rock chemical analyses. Amphibolites are associated with a seri es of Pre-Cretaceous supracmstal metasediınents ofthe Gümüşler Formation. Massive and variably foliated amphîbolites are made up mainly by plagioclase, hornblende, quartz, diopsite witlı accessory sphene and apatite. Based on trace element characteristics, the amphibolites are suggested to be metaigneous roeks; tuffor less likely basaltic-andesitic lava/sili, which were emplaced between metasediınents. Their parent roeks are subalkalinc basalt and andesite in cnmposition, and are characterisedby high K_2O, Rb, Sr, Ba, K/Rb (-270-550) ratin, and lowMgO, Ti,Y, Zr, CaO/Al_2O_3 ratio. Pctrochenıical dataalso suggcstthat the parent roeks oftheseorthoaınphibolites were possiblyfonuedbyfraetionalcrystallization ofolivine, clinopyroxene and hornblende

Key Words: Amphibolite, Gümüşler Formation, Metamorphism, Niğde Massif, Petrochemistry

Öz

Bu çalışmada, tüm kayaç kimyasal analizleri kullanılarak Niğde metamorfitlerine ait mermer ve kuvarsitlerle ilişkili Gümüşler amfibolitierinin petrokimyası ve köken kayaç özellikleri ortaya konulmuştur. Amfıholitler, Kretase öncesi yaşlı Gümüşler Formasyonunun metasedimentleri ile birlikte bulunmaktadır. Masif ve oldukça yapraklanmış amfibolitler plajiyoklas, hornbiend, kuvars, diyopsü ile tali olarak sfen ve apaiitten oluşmaktadır. Niggli eğilimleri ve iz element karakteristiklerine dayanarak amfibolitlerin metasedimefitlerin arasında yer alan mctanıagmatik kayaçlar (tüf veya daha az ihtimalle buzalük undezitik sil/lav) olduğu söylenebilir. Amfibolitlerin köken kayaçlarının bileşimi suhalkali bazalt ve andezit olup, yüksek K_2O, Rb, Sr, Ba, K/Rb (-270-550) oranı, ve düşük MgO, Ti, Y, Zr, CaO/Al_2O_3 oram ile karakterize olmaktadır. Petrokimyasal veriler ayrıca, bu ortoamfibolitlerin köken kayaçlarının muhtemelen olivin, klinopiroksen ve hornbiend kristal ayrımlaşması ile oluştuğunu ortaya koymaktadır.

***Anahtar** Kelimeler: Amfibolü, Gümüşler Formasyonu, Metamorfizmce, Niğde Masifi, Petrokimya*

1NTRODUCT1ON

in common usage, tlıe terin amphibolite is appliced to inetamoıphosed basit; rocks and other hornblende-andesine rocks in the amphibolite facies (Bowes. 1989). The amphiboliles studied are found E-SE ofGümüşler town in the Niğde Massif, southern edge of Central Anatolian Crystailine Complex (CACC; Göncüoğluetal.,1991).

The "Niğde Massif was subjected to various studies: Blumenthal (1941, 1956) suggested that the Niğde Complex was made up of metamorphised Paleozoic units. The petrology and stratigraphy of tlıe Niğde Massif have been described by Göncüoğlu (1977, 1981a, 1981b, 1982, 1986). who classified metamoıphic units as Niğde Group. Akiman et at. (1993) studied. geochenııstry of the Üç kapılı granite, which is peraluminous and ranges from monzonite to syenitic granite in composition. Demir and İşler (1993) studied the origin and the geochemistry of the amphıbolites at southwestern part of the Niğde Massif, and interpreted them mostly as igneous in origin. Whitney and Dilek (1997, 1998) investigated petrology and mineral chemistry of the gneisses. They point out that the NİĞdc metasedi.mentary protoliths were buried to 16-20 km (5-6 kb) depth at >700 °C temperafure in relation with elosure ofTethyan seaways in EarlyCenozoic.F1oydetal,(2000) suggcst that the concordant amphiboliles of the Kaleboynu formatjon reflect an early ensialic stage ofthe Tauridc-AnatolideCarbonate Platform.

in western part of the CACC (Kırşehir), geochemistry and origin ofthe amphibolites \vere studied by Erkan (1980). He suggested a sedimenlary origin considering field obscrvations, though geochemical data indicates an igneous one. Bascd on geochemical data and preserved volcanic (flow) textures, an igneous origin for amphibolites is suggested by Koçak (1993, 2002) and Koçak and Leake (1994) at southwestern part of CACC (Ortaköy, Aksaray).

The metamorphic sequence in the Niğde Massif starts with sillimanite-biotite-muscovite gneiss, biotite-gneiss with interkıyered calc-silicate, anıphibolite, quartzite and marble (Gümüşler Formation); continues with thinly bedded metaelastic, metabasic and nıetacarbonate schisL (Kaleboynu Formation); and ends with monomineralic calcite marble with interlayered quartzite aııd amphibolite (Aşıgediği Formation; Göncüoğlu, 1981a, 1982, 19.86). Tlıey are cut by Sineksi?.yayla ınetagabbro and aplitic, mieropcgmatitic and pegmatitle dykes of Üçkapıh granadiorite, whiclı are associaıed genetically to Sb-ITg-W deposits (Akçay et al., 1995). Ali these rocks are overlain unconformably by Pliocene aged tuffs (îşler and Büyükgedik, 1994).

The amphibolites studied are of Gümüşler Formation, which eropped out in E-SE of Gümüşler town, Niğde (Figüre]). This study aims to outline petrochemistry and parent rock characteristics of amphibolites from Gümüşler formation within the Niğde Massif

FIELD AND PETROGPHICALFEATURKS OFAMPHIBOLITES Amphibolitesstudiedareobservedassmall lenses or thin layers with thickness up to 30 cm between gneisses and marble, or as discontinous pods aligned paralel to the NE-SW regional strike of the host rocks. The amphiboliles have generally a sharp contact with their wall rocks. The gross fabric displayed by the amphibolites governed mainly by the degree of deformation superimposed on bodies of variable size, and shows gradation from highly foliated and banded to massive, together wıtlı a correspondıng varıation in grain size. They often show migmatitisation with hornblende rich selvages, and quartz and feldspars rich ncosome.

Pctrographically, amphibolites are fine to mediumgrained and made up of plagioclase, hornblende, quartz, diopside and accessory sphene and apatite in a nematoblastic texture. The plagioclase (0.3-0.6 mm) forms up to 70 % by volume of the rocks. it contains abundant epidote and quartz inclusjons, and displays common albite twınning and. rare zoning. Hipidioblastic hornblende {0.04-1,3 mm) is 20 to 25 volume percent in the rocks. İl has inelusions of epidote and quartz. and rimmed by actinolite. Diopside (0.08 mm) also occurs in the hornblende, possibly as a relict igneous mineral. The hornblende sho\vs strong pleochroism in shades ofbrown colour. The grains often show crystallographic prefen'ed orientation, and altered to chlorite along thcir cleavage planes. Quartz (up to 20 volume percent) has undulating extinetion on and some deformation lamellea. Sphenes vary in length 0.05-0.09 mm, and are characterised by rhombic shapc. Retrograde metamorphism is marked by development of small equant grained aetinolite crystalls around large porphyroblastic or poikiloblastic hornblende, and of chlorite after homblendes.

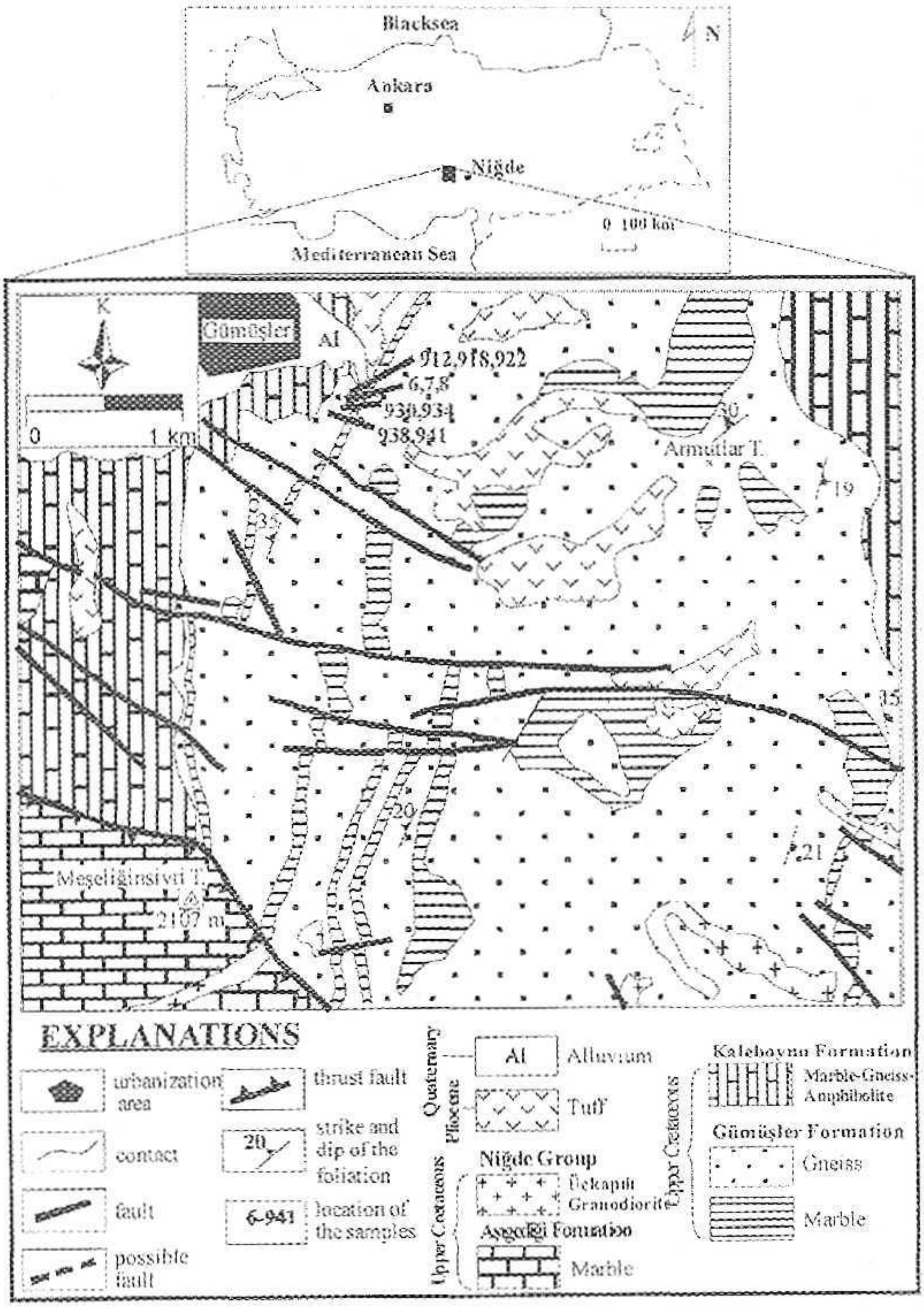

Figure I: Locationand geologicalmap of the investigation area (modified after Göncüoglu, 1982).
§eldl 1: tnceleme alaiinim yer bulduiu vejeolojiharilasi (Göncüoğlu, 19X2'den).

PETROCHEMISTRY OF AMPHIBOLITES

Major and trace element analysis of tine studied amphibolites was carried out at ACME Laboratories (Canada) by ICP-MS method, and **the** results of the analysis with calculated Niggli parameters are presented in Table 1.

An igneous origin is favoured for the amphibolites as they were clearly plotted in ortho-amphibolite field in discrimination diagrams of TiO_2 versus Ni (Figure 2a) andNi aganist Zr/TiO_2 (Figure 2b; Winchester ctal., 1980; Winchester and Max,1982).

Some degree of selective element mobility is to be expected especially for K, Na and the large-ion litophile elements (LTLE; Cs, Rb, Ba) (e.g. Humphris and Thompson, 1978; Thompson. 1991) under medium-high grade metamorphism involving hydrous fluids. Thus, only immobile elemejits such as the high-field-strength elements (HFSE: Ti, Zr, Y), Th and REE were used in the following discussions to identify themagmatic affinity of the basaltic-andesitic protoliths. Good linear coherence between pairs of immobile incompatible elements and smooth normalized patterns of a sequence of incompatible elements have suggested that these elements indicate pre-metamovphic igneous compositional variations. Relative to Zr the data scatter produced by Ba (Fig. 3a) reflects the general mobility of the latter during metamorphism, whereas La (Fig. 3b) is immobile and produces a reasonable linear relationship expected for an igneous evolution.

The amphibolite samples arc characterised by high K_2O. Rb, Sr and Ba contents and K/Rb (-270-550) ratio, and low MgO, Ti, Y and Zr contents and CaO/AkOj ratio. They are ali quartz normative and plot mostly in the fields of sub-alkaline basalt and andesite, while a few sample in the field of rhyodacite/dacite in a classification scheme of Winchester and Floyd (1977; Figure 4).

Zr is immobile in most metamorphic conditions and assumed a good indicator of fractionation degree in basaltic rocks (e.g. Floyd and Winchester, 1975; Pearce and Cann, 1973; Weaver and Tamcy 1981). Crystal fractionation for the parent rock of amphibolites is therefore suggested by existence of a positive correlation of Zr with SiO_2, Al_2O_3, Na_2O, K_2O, Th, Ba, Rb, La; and a negative correlation with Fe_2O_3t,, CaO, MgO, P2O5, Ni, Co (Figure 5),

N-type MORB normalized trace element patterns for the Giimüşler amphibolite samples are shown in Figure 6, together with Kaleboynu metabasilc sample of Floyd ct al. (2000). The amphibolite samples show coiicraiioy with each other, eon Tinning crystal-fractionation process. They show substantial enrichment of **L1LE,** as much as 100 times to N-type MORB, and depletion of Zr, Y, and Ti. The samples are slightly enriched in REE (La and Ce). They have almost similar REE (La, Ce) contents to N-type MORB. in comparison with K_aieboynu metabasite sample of Floyd et al. (2000), the amphibolite samples studied display a slight to moderate enrichment in LILB and depletion in HFSE, respectively.

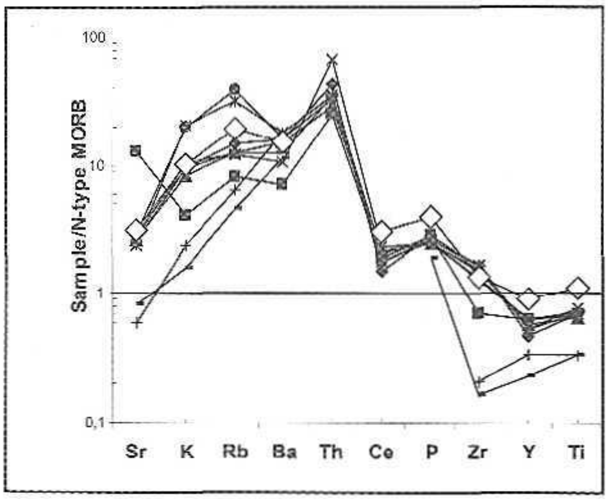

Figure 6. Mid-ocean ridge basalt normalized spider diagram for the Gwirüijler amphibolite samples. Normalizing values are from Sun and McDonough (1989). Diamond represents Kaleboynu metabasite of Floyd et al. (2000).

$ekil 6. Giimiişler amfibolit örneklerinm okyanus ortasi sirti bazaltina oranlanmiş iz element değiijim diyagrami. Normalize ctcğerler Sun ve McDongh (I989)'dan almmi^ur. HI mas, Floyd vc dig. (2000)' in Kaleboynu metabazilim temsil ctmcktedir.

Table 1: *Major (wt. %) and trace element (ppm) analysis and Niggli parameters of the Gümüşler amphibolite samples (Samples 6-8 from Kurt et al., 1999).*

Çizelge 1: Gümüşler amfibolit örneklerinin ana (% ağırlık) ve iz element (ppm) analizleri ve Niggli parametreleri (Örnekler 6-8 Kurt ve diğ., 1999'dan alınmıştır).

Sample No	938	912	930	934	918	941	922	6	7	8
SiO_2	63.39	51.99	57.35	58.01	58.86	59.14	58.01	49.82	47.23	48.81
TiO_2	0.63	0.63	0.59	0.69	0.62	0.65	0.64	0.37	0.33	0.32
Al_2O_3	18.21	15.63	16.65	17.93	18.12	18.44	17.54	11.51	16.31	15.24
Fe_2O_3t	3.88	6.73	6.31	6.74	5.93	6.21	5.16	7.72	10.24	10.43
MnO	0.06	0.19	0.14	0.10	0.09	0.19	0.14	0.23	0.22	0.20
MgO	1.19	3.52	3.97	2.17	2.24	0.73	2.47	11.31	9.15	9.42
CaO	6.41	18.41	9.42	7.33	7.27	7.05	10.6	14.14	12.92	13.51
Na_2O	3.74	1.11	3.01	3.55	3.65	4.26	2.83	0.62	1.34	0.84
K_2O	1.17	0.52	1.05	1.33	2.54	2.53	1.26	0.35	0.25	0.25
P_2O_5	0.15	0.15	0.13	0.13	0.14	0.14	0.13	0.14	0.14	0.12
LOI	1.12	1.65	1.85	2.34	0.97	0.96	1.73	2.89	1.94	1.42
Total	99.95	100.53	100.47	100.32	100.43	100.30	100.51	99.10	100.07	100.56
Zr	148	63	135	142	153	117	120	19	15	10
Y	14	19	17	16	16	19	19	10	7	24
Sr	315	1527	318	329	294	353	350	72	99	26
U	1	-	8	9	-	1	-	1	5	7
Rb	30	16	25	24	64	79	25	13	9	6
Th	9	5	6	13	7	7	7	-	-	1
Pb	16	6	27	10	16	4	7	5	6	13
Ga	16	24	24	8	20	18	22	8	12	13
Zn	35	54	86	43	50	45	40	44	60	61
Cu	2	20	-	-	-	-	-	19	74	18
Ni	2	9	45	6	6	8	6	111	28	61
Co	9	18	16	16	17	14	17	39	44	50
Cr	56	103	541	105	37	134	220	925	67	129
Ce	15	19	22	23	18	18	21	-	-	-
Ba	321	143	310	209	359	330	250	362	225	289
La	16	8	12	21	14	10	12	-	-	-
Samp. No	**938**	**912**	**930**	**934**	**918**	**941**	**922**	**6**	**7**	**8**
si	237.97	124.16	167.43	186.54	189.69	196.43	176.41	109.55	102.12	105.34
al	40.12	21.99	28.64	33.97	33.94	36.09	31.43	14.91	20.78	19.33
fm	17.83	25.01	31.48	26.98	24.81	19.75	23.36	50.16	46.32	47.50
c	25.68	49.64	29.40	25.25	24.79	25.09	34.53	33.23	29.90	31.22
alk	16.37	3.36	10.47	13.79	16.46	19.08	10.67	1.70	3.00	1.95
k	0.17	0.24	0.18	0.19	0.31	0.28	0.21	0.25	0.09	0.14
mg	0.37	0.50	0.54	0.38	0.42	0.19	0.47	0.73	0.63	0.63
p	1.44	1.98	0.93	0.93	0.99	1.27	1.47	0.66	0.64	0.65
qz	71.55	10.71	25.54	31.36	23.86	20.13	33.73	2.74	9.89	2.46
ti	0.23	0.15	0.16	0.17	0.18	0.19	0.16	0.10	0.09	0.09

Fe_2O_3t is total iron as Fe_2O_3. LOI is loss on ignition.

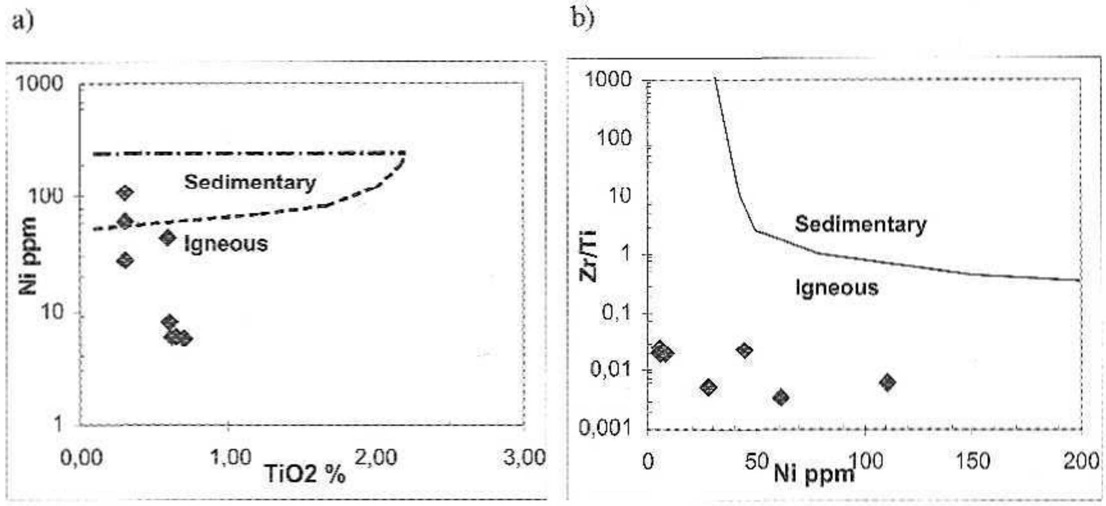

Figure 2: Discrimination diagrams used to denote the parent rocks of the Gümüşler amphibolites. a) TiO2-Ni and b) Ni-Zr/TiO2 plots to distinguish between para- and ortho-amphibolites (Winchester et al., 1980; Winchester and Max, 1982).

Şekil 2: Gümüşler amfibolitlerinin köken kayaçlarını göstermek için kullanılan ayırtman diyagramlar. Para- ve ortoamfibolitleri ayırmak için a) TiO2-Ni ve b) Ni - Zr / TiO2 diyagramları (Winchester ve diğ., 1980; Winchester ve Max, 1982).

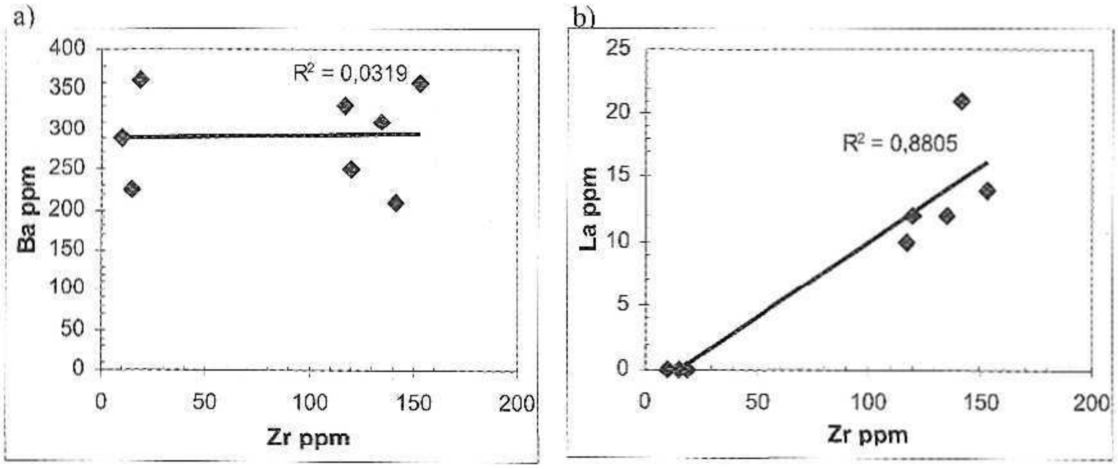

Figure 3: Zr versus Ba (a) and La (b) plots showing LILE mobility and HFSE immobility in the studied amphibolites.

Şekil 3: İncelenen amfibolitlerde büyük iyon yarıçaplı element (LILE) hareketliliğini ve HFSE hareketsizliğini gösteren Zr'a karşı Ba (a) ve La (b) diyagramları.

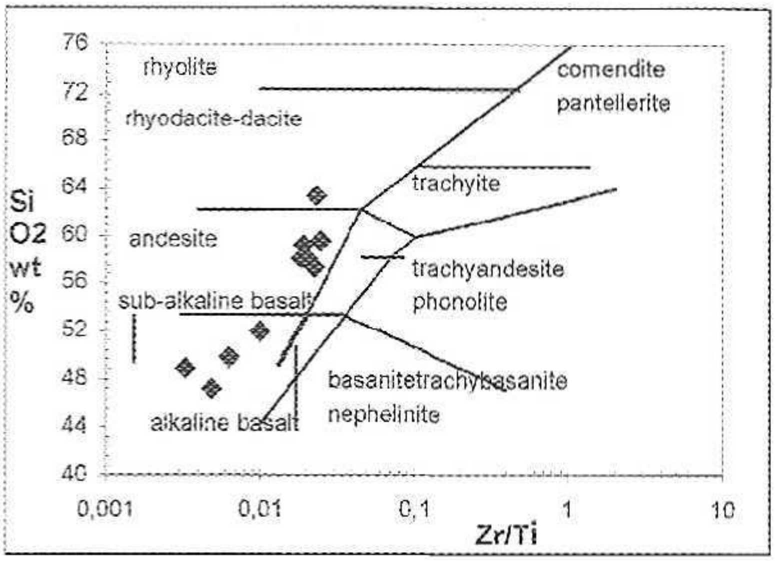

***Figure 4:** Parent rock nomenclature diagram for the Gümüşler amphibolites (Winchester and Floyd, 1977).*

Şekil 4: Gümüşler amfibolitlerinin köken kayaçlarının adlandırma diyagramı (Winchester ve Floyd, 1977).

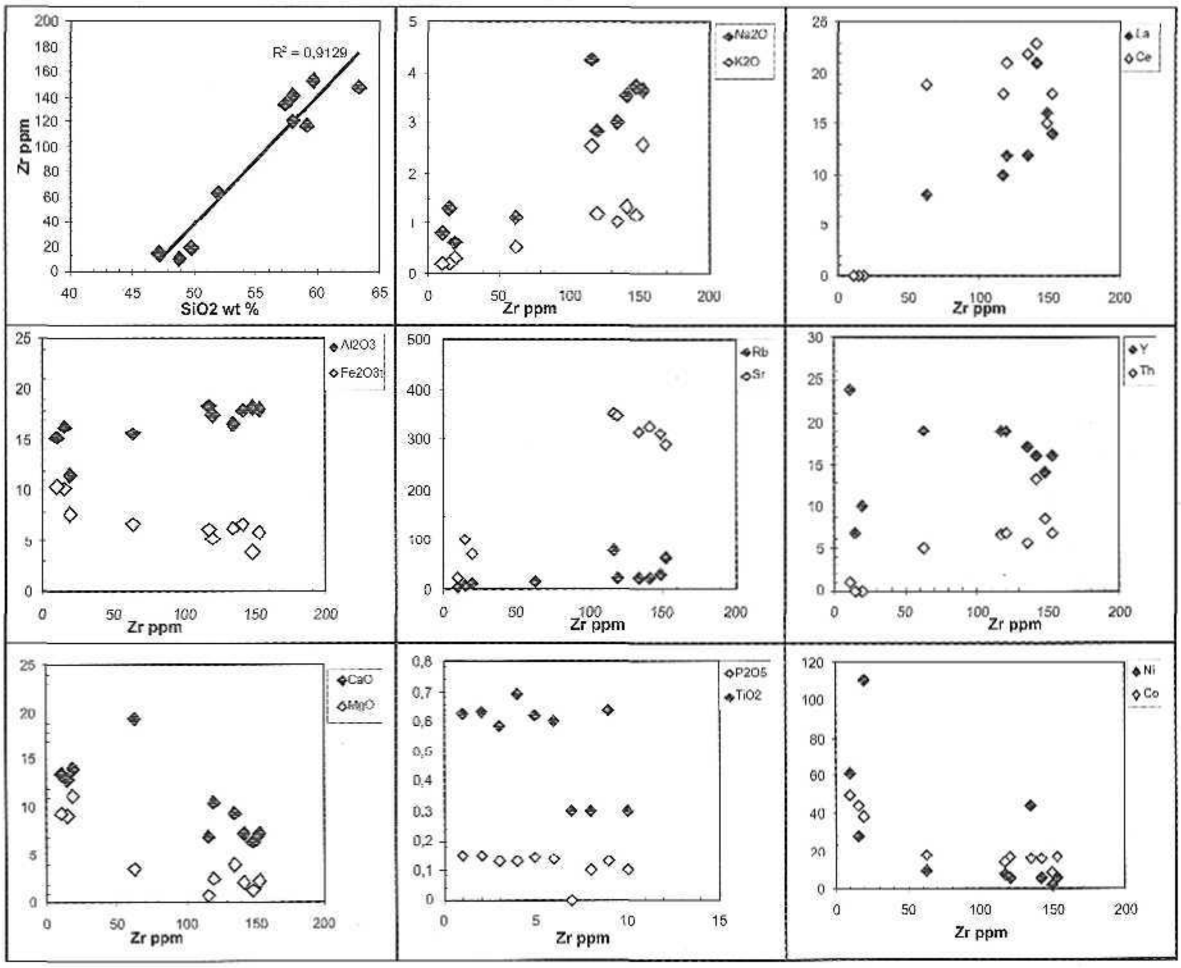

***Figure 5.** Major and trace element variation diagram of the Gümüşler amphibolites.*

Şekil 5. Gümüşler amfibolitlerinin ana ve iz element değişim diyagramları.

DISCUSSION AND CONCLUSIONS

The metaigneous rocks studied were metamorphosed to greenschist Tacies as evidenced by existence of epidotc inclusions in the hornblende before amphibolite facies producing typical assemblage of homblendcH-plagioclase. The rocks were then retrograded to the greenschist facies marked by small equant grains of actinolite crystals around large porphyroblastic or poikiioblastic hornblende, and of chlorite after mafics. Whitney and Mek (1998) suggested that Barrovian metamorphism occurred at mid-crustal pressures of5-6kbarbutathigh temperatures (>700°C), followed by low-P (34 kbar)modcratc-T (550-650 °C) metamorphism associated with magniatism (intrusion of the Uckapih granite). Accordingly, the hornblende+plagioclase paragenesis within the amphibolites studied may represent moderate-temperature metamorphism.

Petrochemical data obtained indicate that amphibolites are of igneous in origin with their parent rock composition ranging from subalkaline basaltic to andesitic. Similarly most amphibolites at southwestern part of the Niğde Massif were suggested to have ignous origin (Demir and İşler, 1993).

Crystal (ractionation for the parent rocks is strongly suggested by binary diagrams of Zr with some major and trace elements, and "N-type MORB normalized trace element diagram. The increase in Zr/Y with increasing SiO2 indicates removal of a mineral phase capable of fractionating Y from Zr. This can be hornblende or garnet, and to a lesser extent clinopyroxene. CaO/A^Og and the trace elements Ni and Cr decrease with increasing degree of differentiation, suggesting that oliv.ine and clinopyroxene were among the fractionating mineral phases. Existence of negative correlation between MgO and Sr (not shown), the only mineral enter into the plagioclases, indicates that the plagioclases are possibly retained in the melt,

Floyd et al. (2000) indicate that Kaleboynu metabasites are mostly alkalic basalts in composition on the basis of stable Nb/Y ratios (Winchester and Hoyd, 1977), and can be directly compared with OIB from the Ankara Melange. However, the amphibolites studied are plotted within fields of sub-alkaline basalt (Figure 4) and fholeiitic on a diagram of Zr-P_2O5 (Floyd and Winchester, 1975, not shown). They also ploimostiy next to within plate basalt field on that of Zr/Y-Zr (Figure 7). Therefore it has been suggested that parent rocks of the amphibolite studied with tholeiitic composition may have been formed in a within plate basalt setting. The conformable relationships of many thin Kaleboynu formation amphibolites with the surrounding marbles also indicate that they were probably intrusive sheets and/or basic lavas and/or volcaniclastic accumulations in shallowriftedbasins (Floyd etal., 2000).

In conclusion, protohths of the Giimiişlcr amphibolites studied are interpreted to be of volcanic in origin with mostly tholeiitic basaltic to andesitic in composition, and their parent rocks have undergone fractional crystallisation oi" olivine, garnet clinopyroxene and hornblende before emplacement between metasediments, and formed possibly in a shallow rifted basin.

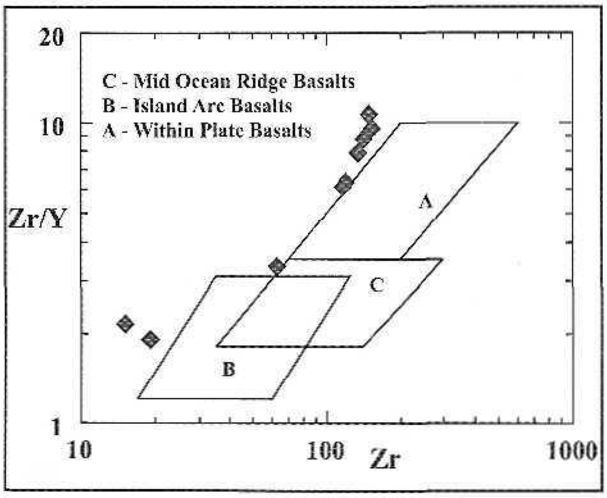

Figure 7: Zr againstZrfYtectonic discrimination plot (Pearce and Worry, 1979) for the parent rock of the Gümihli-r amphibolites.

§eldl 7: Giimü^lcr amflbolitlerinin köken kayaglan için Zr'a kar$i Zr/Y teknotiik orlaro ayjrtmiin diyagrami (Pearce veNory, liffiJ).

GENIŞLETILMI$ÖZET

• Bu çalişma ile Nīgde masifiade yer afan Gümiişler formasyonu amflbolitlerinin pctrokimyasal ve ana kayaç dzclliklerinin ortaya çikanlmasi amaçlanmi§tir.

İneelenen amfibolülcr çalişma alamnda, çevre kayaçlann KD-GB bölgcsel doğmltusuna paralel dizilmis küçük mercek veya 30 cm kalinlığa ulasabilen ince tabakalar geklinde yer almmaktadir. Genellikle cevre kayaclar ile keskin bir dokunağa sahiptir. Migmatitlejme sonucunda honiblendee zengin melanozom, kuvars ve feldispatca zengin neozomlar gelişebilmekledir.

Petrografik olarak nematoblastik dokuya sahip olan amfibolitler, albit ikizlenmenm yaygin olarak izlenebildiği plajiyoklaz (0.3-0.6 mm}, kahverengi renkli hornblend(0.04-1.3 mm), dalgali sönmeli kuvars, diyopsit(0.08 mm) ve tali olarak sfen (0.05-0.09 mm) ve apatitten oluşmaktadir.

Niggli eğilimleri vc iz clement karakteristiklerine dayanarak amfibolitlerin metasedimentlerin arasinda yer alan metamagmatrk kayaçlar (tüf veya daha az ihtimalle bazaltik-andezitik sil/lav) olduğu söyfenebilir. Amfibolitler köken kayaelarinm bilegttni yanalkali bazalt ve andezit olup, yiiksek K_2O, Rb, Sr, Da, K/Rb (-270-550) oram, ve diişük MgO. Ti, Y, Zr, CaO/Ai^O^ oram ile karakterize olmaktadir. Amfibolitlerdeki Zr 'un SiO_2,Al_2O_3, Na_2O, K_2O, Th, Ba, Rb La ile pozitif korelasyonu; ve FeOt, CaO, MgO, P2O5, Ni, Co ile negatif korelasyonu amfibolitlerin köken kayacmin muhtemelen oiivin, klinopiroksen vc bornblend kristal aynrola§masi ile olu^Uïgunu ortaya koymaktadir., Floyd ve diğ.. (2000)'in amfibolit öroegine göre incelenen am fibolitlerbafif nadir toprak elementlerince zayif-orta zcnginlc^me, vc kalicihgi yiiksek elementlerce ise fakirle^me göstermektedirler. Örnekler Zr/Y-Zr (Pearce and Norry, 1979) diyagrammda ise levha ici bazalt alanma yakin olarak yer alniaktadir,

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