



**The new findings on the Late Devonian volcanism in the Eastern Taurides  
(Develi, Kayseri): Preliminary data**

*Doğu Torid’lerdeki (Develi-Kayseri) Geç Devoniyen volkanizması üzerine yeni bulgular: İlk veriler*

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**Abstract:** The Tauride-Anatolide Platform includes of widespread Paleozoic (Cambrian to Permian) units, which rarely consist magmatic rocks that were identified in two areas: Eastern Taurides (SW of Tufanbeyli and Yahyalı) and Central Taurides (Northern Konya). There are problematic views related to the magmatic evolution of these rocks. The available geochemical database is mostly concentrated on the magmatics from the Central Taurides (Konya Region).

In this study, the mafic volcanic rocks were recently found in the Eastern Taurides (Develi-Kayseri). These mafic volcanics are intercalated with the Late Devonian limestones and covered by the Early Carboniferous sandstones. The geochemical characteristics of the volcanic rocks exhibit back arc basin (BAB) features with slightly negative Nb anomalies, normal-MORB (NMORB)-like high field strength element (HFSE) patterns and flat REE profile.

The newly found basic volcanic rocks in the Eastern Taurides geochemically resemble the meta-dykes in the Konya and Yahyalı regions, which were assigned to a subduction related event. The new data reported in this study will benefit to better understand the mid-Paleozoic evolution of the Taurides.

**Keywords:** BAB, Develi-Kayseri, Eastern Taurides, Late Devonian, volcanism

**Öz:** *Torid-Anatolide Platformu Doğu Torid’ler (Tufanbeyli ve Yahyalı’nın GB’sı) ve Orta Torid’ler (Kuzey Konya) bölgelerinde nadiren tanımlanmış olan magmatik kayalar barındıran yaygın Paleozoik birimleri içermektedir. Bu kayaların magmatik evrimi ile alakalı tartışılabilir görüşler bulunmaktadır. Ulaşılabilir jeokimyasal veriler Orta Torid’lerdeki (Konya Bölgesi) magmatik kayalar üzerine yoğunlaşmıştır.*

*Bu çalışmada, Doğu Torid’lerde (Develi-Kayseri) mafik volkanik kayalar bulunmuştur. Bu mafik kayalar Geç Devoniyen yaşlı kireçtaşları ile ardalanmış ve Erken Karbonifer yaşlı kumtaşları tarafından örtülmüştür. Volkanik kayaların jeokimyasal karakteristikleri hafif negative Nb anomalileri, normal-MORB (N-MORB) benzeri yüksek alan dayanım element paternleri (HFSE) ve düz NTE profili ile yay-ardı havza özellikleri sunmaktadır.*

*Doğu Torid’lerde yeni bulunan mafik volkanik kayalar jeokimyasal olarak dalma-batma olayları ile ilişkilendirilmiş olan Konya ve Yahyalı bölgelerindeki metadiyabaz dayklarına benzemektedir. Bu çalışmada sunulan yeni veriler Torid’lerin Orta Paleozoik evrimini daha iyi anlamaya fayda sağlayacaktır.*

**Anahtar Kelimeler:** *BAB, Develi-Kayseri, Doğu Toridler, Geç Devoniyen, volkanizma*

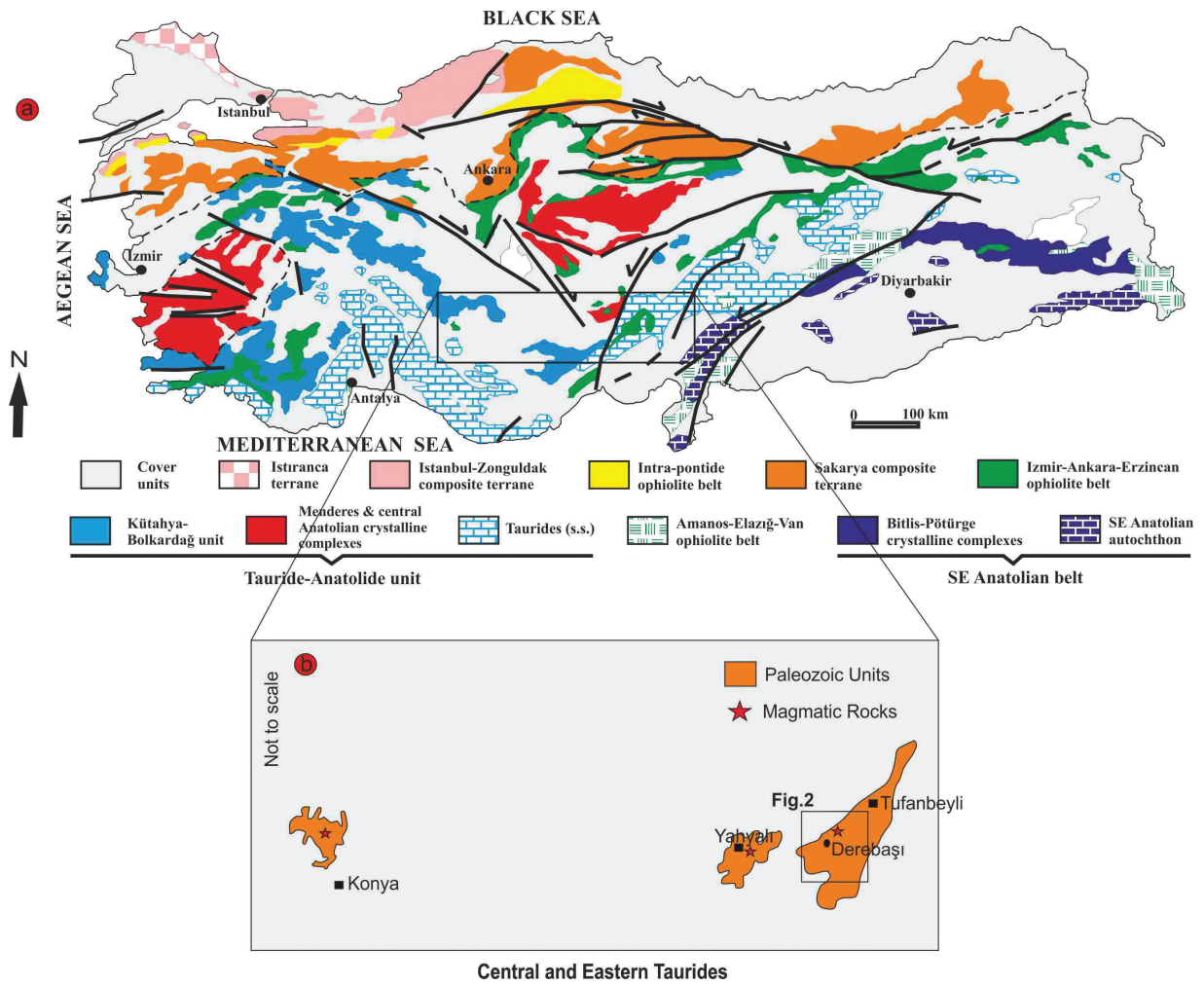
## INTRODUCTION

Turkey has been formed by accretion of a number of oceanic and continental micro-plates (e.g. Şengör and Yılmaz, 1981) or terranes (e.g. Okay and Tüysüz, 1999; Göncüoğlu, 2010). In the north, the Istanbul-Zonduldak Terrane (IZT) has separated from the Sakarya Composite Terrane (SCT) by the Intra-Pontide Suture Belt (Figure 1a; Göncüoğlu et al., 1997; Çimen et al., 2016a). The southern microcontinent, that is Tauride-Anatolide Platform (TAP), separated from the SCT by the Izmir-Ankara-Erzincan Suture Belt (IAESB; Figure 1a; Şengör and Yılmaz, 1981; Göncüoğlu et al., 2000a; Parlak et al., 2012; Robertson et al., 2014; Çimen et al., 2016b).

An overview of the published data reveals significant contradictions and problems for the geodynamic evolution of the northern margin of Gondwana during the Late Paleozoic time. In particular, the subduction polarity of the Paleotethyan Ocean during the Mid to Late Paleozoic is hotly debated for a long time. There are several models which have been proposed for the subduction polarity of this ocean. Briefly, the first hypothesis suggests the northward subduction model beneath the Eurasia during the Late Paleozoic (Robertson and Dixon, 1984; Ustaömer and Robertson, 1994, 1999; Stampfli, 2000;

Eren et al., 2004). Conversely, the second view advocates the opening of a continental rift zone (back arc basin) by southward subduction under the northern active margin of Gondwana during the Early Carboniferous (Göncüoğlu et al., 2000a, 2007). Recently, the last comment proposes the either northward or southward subduction somewhere further west, followed by eastward terrane migration (Robertson and Ustaömer, 2009).

The TAP is a continental microplate that consists of widespread Paleozoic (Cambrian to Permian) units (Göncüoğlu, 1997), which rarely include magmatic rocks (Figure 1b) that were mainly described in two areas: Eastern Taurides (Yahyalı) and Central Taurides (Northern Konya). The evolution of these magmatic rocks are hotly debated in the literature as well (Kurt and Aslan, 1999; Eren and Kurt, 2000; Göncüoğlu et al., 2007; Robertson and Ustaömer, 2009; Akal et al., 2012). Particularly, the available geochemical database is concentrated on the magmatics of the Central Taurides (Konya Region). In addition to these, the presence of Mid-Late Paleozoic magmatics are known in the Afyon zone (Akal et al., 2011; Candan et al., 2016), the Tavas nappes (Göncüoğlu, 2011), the Antalya nappes (Şahin et al., 2014) and Karaburun peninsula (Kozur and Göncüoğlu, 1998) along the TAP.



**Figure 1. a)** Distribution of the main alpine terranes in central North Anatolia (taken from Göncüoğlu, 2010). **b)** Paleozoic units in the Central and Eastern Taurides.

**Şekil 1. a)** Ana Alpin tektonik birliklerinin orta kuzey Anadolu'da dağılımları (Göncüoğlu, 2010'dan alınmıştır). **b)** Orta ve Doğu Torid'lerde Paleozoyik birimleri.

Further east in Iran, similar Late Devonian magmatic rocks have been reported (Ruttner, 1991, Alavi, 1996; Wendt et al., 2002). For instance, a basalt layer (thickness ~1 m) outcrops in the Late Devonian carbonates from the Karmen area (Wendt et al., 2002). Also, the Famennian volcanic horizons are also known in the Dalmeh region (Central Iranian Block; Gharaie et al., 2004). However, there are limited geochemical data from these magmatic rocks since they are mostly related to the paleontology and stratigraphic studies. The

available data indicate that they could have been formed in an intra-plate setting during the Late Devonian (Gharaie et al., 2004).

In this paper, the first geochemical data is reported from the mafic volcanic rocks which have been recently found in the Eastern Taurides (Figure 1b; Derebaşı-Develi-Kayseri). This new data will certainly provide useful insights for the geodynamic evolution of the Taurides, ongoing discussions and further studies.

## GEOLOGICAL FRAMEWORK

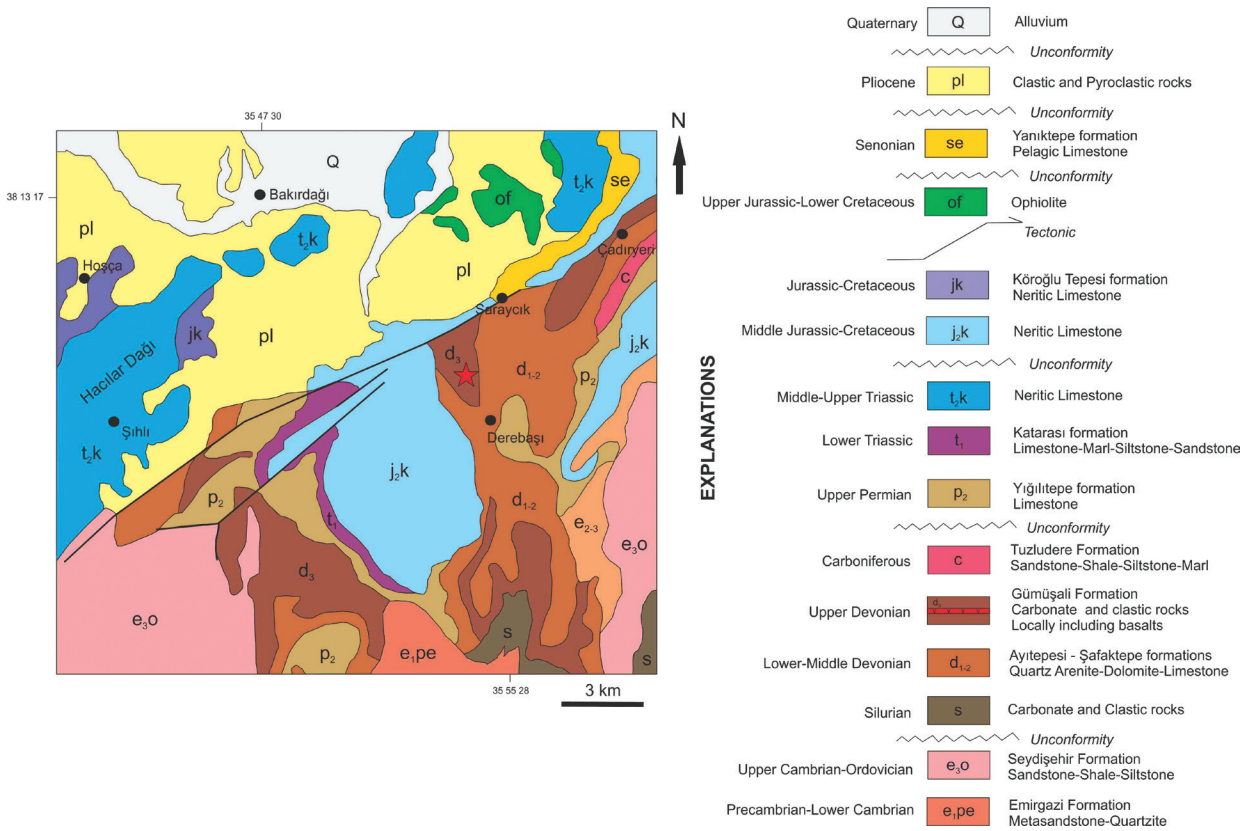
The Anatolides, that represents metamorphic northern margin of the TAP, separated from the SCT by the IAESB (Figure 1a). It has extensively been affected by the Alpine orogeny and mostly metamorphosed and deformed during the Late Cretaceous to Early Cenozoic (Candan et al., 2005). There are three important tectonic zones; Tavşanlı zone, Afyon zone and Menderes Massif, which were distinguished based upon the different ages and types of Alpine metamorphism (Bozkurt and Oberhansli, 2001; Whitney and Bozkurt, 2002; Candan et al., 2016).

On the other hand, the Taurides represent the southern part of the TAP and is composed of a Cambrian basement overlain by the Paleozoic to Early Tertiary thrust sheets (Özgül, 1984; Okay, 2008; Candan et al., 2016). A double-verging napped structure including several distinctive tectonostratigraphic units has been formed by closure of the northern and southern branches of the Neotethyan Ocean (Göncüoğlu, 2010).

The Taurides consists of widespread Paleozoic (Cambrian to Permian) units and some of which include various magmatic rocks (Figure 1b). These magmatic rocks have been rarely reported in the Eastern Taurides (Yahyalı) and the Central Taurides (Northern Konya). In addition to these regions, the new volcanic rocks have been found around the Derebaşı village (Figure 1b, 2) where is located on the southeast of Develi towns (south of Kayseri Province). The region consists the Precambrian to Eocene sedimentary units (Dalkılıç, 2009). The Precambrian-Lower Cambrian Emirgazi formation represents the basement unit in the study area which is mostly composed of metasandstone and quartzite (Figure 2). It is conformably overlain by the Seydişehir formation that includes sandstone, shale and siltstone. The Silurian clastic rocks unconformably

overlie the Seydişehir formation and conformably covered by the Lower-Middle Devonian Ayıtepesi and Şafaktepe formations which consist quartz arenite, dolomite and limestone. The Late Devonian Gümüşali formation that conformably overlies the Şafaktepe formation is mostly composed of carbonate and clastic rocks (Figure 2). It is conformably overlain by the Tuzludere formation that contains sandstone, siltstone, shale and marl. The Tuzludere formation is unconformably overlain by the Permian Yığıltepe formation, Lower Triassic Katarası formation and the Triassic to Cretaceous neritic limestones. Lastly, in the northern part, the Senonian, Pliocene and Quaternary cover units unconformably overlie the older units (Dalkılıç, 2009; Metin, 1983; Figure 2).

In the region, the Late Devonian limestones (Gümüşali formation) are locally are intercalated with mafic volcanic rocks and include their fragments (Figure 3). The Gümüşali formation has been firstly named by Demirtaşlı (1967) and its age has been given (Dalkılıç, 2009) using several fossil corals (e.g. *Dishylum minus*, *D. goldfussi*, *Alveolites suborbicularis*) and conodonts (e.g. *Polygnathus* sp., *Peleksygnathus* sp.) and brachiopods (*Composita* sp., *Spinocyrtia* sp.) The thicknesses of the basaltic layers are changing between 30-50 cms. Their lateral distributions are restricted within a small area (about 30-40 meters). Of note, the presence of brecciated basaltic fragments in the limestone (Figure 3) may indicate the interection between magmatism and carbonate deposition (e.g. peperites; Skilling et al., 2002). The basalts have mostly aphanitic/microphaneritic and porphyritic texture. The definable phenocrysts which are mostly plagioclase and pyroxenes minerals commonly altered to chlorite and serizite minerals due to the post magmatic alteration effects.



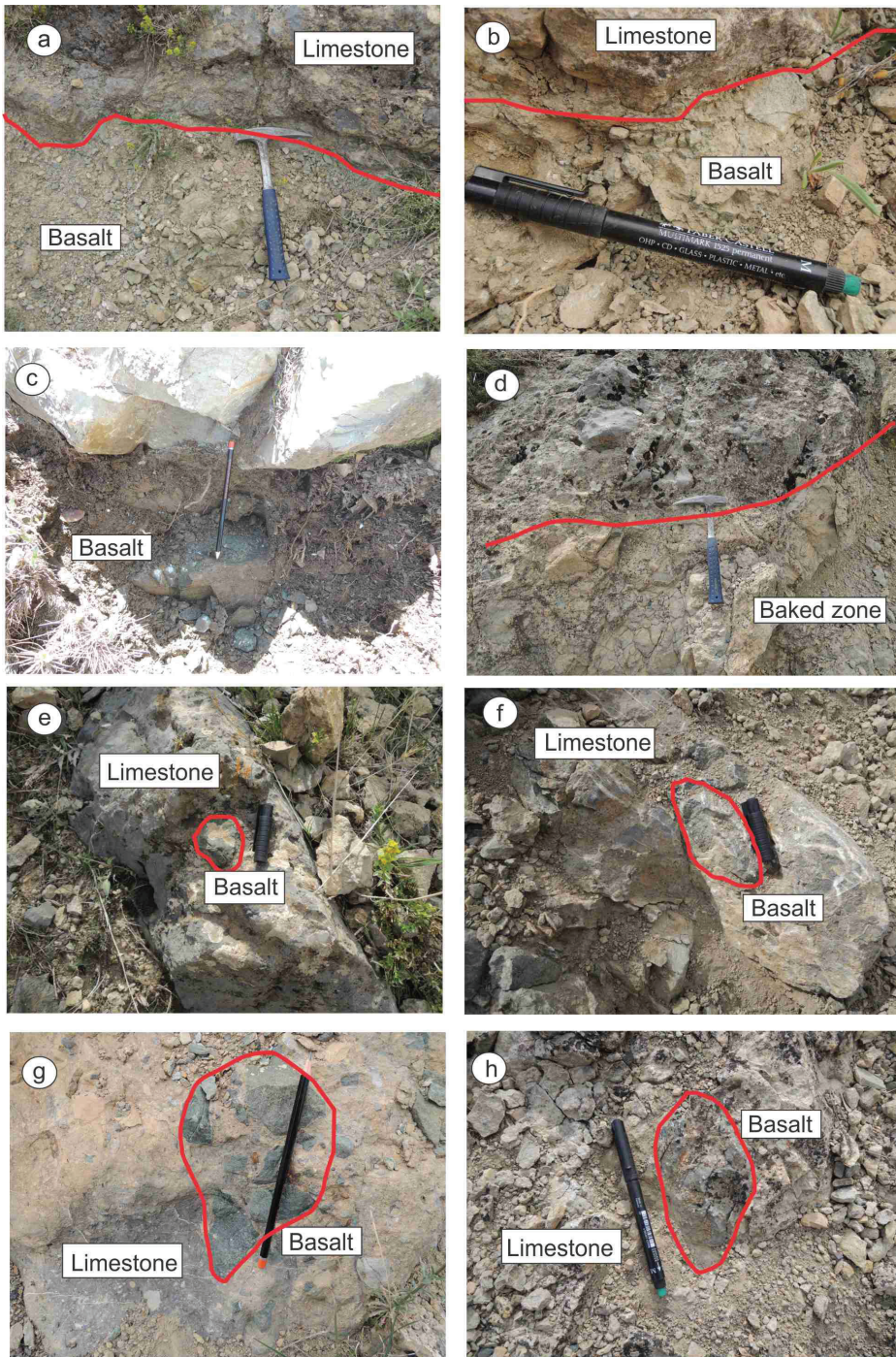
**Figure 2.** Geological map of the study area (modified from MTA, 2003 and Dalkılıç, 2009).

**Şekil 2.** Çalışma alanının jeolojik haritası (MTA, 2003 ve Dalkılıç, 2009'dan değiştirilmiştir).

## ANALYTICAL METHODS

A total of five representative/fresher rock samples were selected for geochemical analyses subsequent the petrographical observations. Major oxides and trace-rare earth elements were analyzed by using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) methods, respectively, at Acme Analytical Laboratories (Canada), and following a lithium metaborate/tetraborate fusion and dilute nitric digestion.

Loss on ignition (LOI) was determined based on weight difference after ignition at 1000°C. In addition, several duplicate analyses of samples were performed during the analyses in order to ensure a measure of background noise, accuracy, and precision. The geochemical classification diagrams were prepared using Geochemical Data Toolkit (GCDkit) software (Janoušek et al., 2006).



**Figure 3.** Field images of the magmatic rocks from the Derebaşı village **a-b-c)** The field relation between the basalts and Late Devonian Limestones **d)** Baked zone in the limestone **e-f-g-h)** Basalt fragments in the Late Devonian Limestones. Coordinates: 341004N, 355615E.

Şekil 3. Derebaşı köyü'nde bulunan magmatik kayaların arazi görüntüleri **a-b-c)** Geç Devoniyen kireçtaşları ile bazaltik birimlerin arazi ilişkisi **d)** Kireçtaşındaki pişme zonu **e-f-g-h)** Geç Devoniyen kireçtaşları içerisindeki bazalt parçaları. Koordinatlar: 341004K, 355615D.

## RESULTS

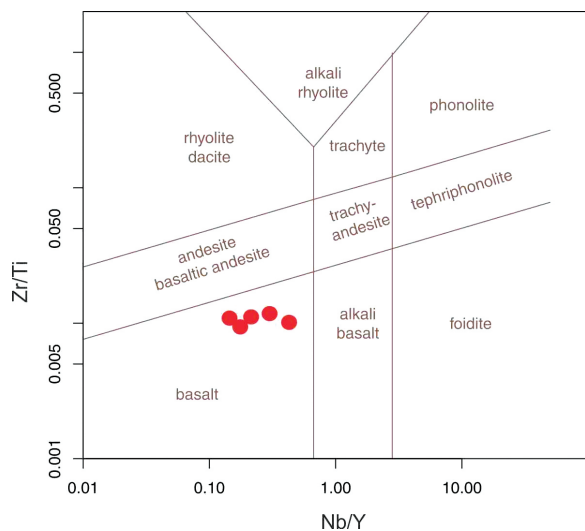
### Whole Rock Geochemistry

#### Post-magmatic processes

The presence of higher loss of ignition (LOI) values (5.70–7.80 wt. %; Table 1) indicate the strong effects of post-magmatic alteration processes (e.g. weathering and hydrothermal alteration). Therefore, the large ion lithophile elements (LILEs; e.g. Sr, Ba, Rb etc.) have not been used due to their mobile characteristics (Wood et al., 1976; Floyd et al., 2000). The immobile trace elements (Ti, Zr, rare earth elements, etc.) which are stable under the alteration conditions (e.g., Pearce and Cann, 1973; Floyd and Winchester, 1978; Çimen et al., 2016a) have been considered for the geochemical evaluation.

#### Geochemical Classification

The mafic volcanic rocks from the Derebaşı village are geochemically plotting in the basalt field (Figure 4) according to the classification diagram of Pearce (1996). The Zr/Ti and Nb/Y values are changing between 0.0009-0.0011 and 0.19-0.45, respectively.



**Figure 4.** Zr–Ti vs. Nb–Y (after Pearce, 1996) diagram for the Derebaşı magmatic rocks.

Şekil 4. Derebaşı magmatik kayalar için Zr-Ti vs. Nb-Y (Pearce, 1996 sonrası) diyagramı.

**Table 1.** Major and trace element concentrations of the volcanic rocks from the Derebaşı region.

**Tablo 1.** Derebaşı bölgesindeki volkanik kayaların ana ve iz element konsantrasyonları.

Sample	Derebaşı				
	DRB1	DRB2	DRB3	DRB4	DRB5
SiO <sub>2</sub> %	46.50	46.61	44.31	49.01	47.22
Al <sub>2</sub> O <sub>3</sub>	17.50	15.22	16.04	15.46	16.12
Fe <sub>2</sub> O <sub>3</sub>	9.66	11.61	13.51	9.51	7.06
MgO	9.02	12.48	9.57	11.19	15.37
CaO	1.22	0.56	1.62	1.41	0.29
Na <sub>2</sub> O	0.10	0.06	0.02	0.07	0.07
K <sub>2</sub> O	8.19	4.13	5.09	6.18	6.26
TiO <sub>2</sub>	1.48	1.20	1.35	1.16	1.16
P <sub>2</sub> O <sub>5</sub>	0.26	0.10	0.13	0.08	0.07
MnO	0.05	0.05	0.15	0.02	0.02
Cr <sub>2</sub> O <sub>3</sub>	0.03	0.05	0.06	0.07	0.08
LOI	5.70	7.60	7.80	5.60	5.90
Ni ppm	81.00	202.00	111.00	152.00	178.00
Sc	22.00	29.00	33.00	37.00	38.00
Mo	0.70	<0.1	0.50	0.80	0.20
Cu	26.00	26.70	117.10	8.00	1.40
Pb	20.10	0.80	7.50	0.10	0.10
Zn	107.00	103.00	118.00	9.00	8.00
Ba	366.00	176.00	946.00	104.00	89.00
Co	39.70	44.10	43.80	37.20	27.00
Cs	0.30	2.10	0.50	0.50	1.10
Hf	2.60	1.80	2.80	2.30	2.00
Nb	5.90	4.30	5.60	4.20	3.90
Rb	43.00	24.20	44.90	23.90	19.80
Sr	254.30	88.40	104.50	121.70	489.70
Ta	0.40	0.30	0.40	0.10	0.20
Th	1.00	0.30	0.90	0.80	0.90
U	2.00	0.60	0.60	0.20	0.30
V	217.00	248.00	240.00	183.00	208.00
Zr	99.90	67.70	92.60	76.80	73.60
Y	24.80	9.50	17.10	22.30	17.20
La	6.70	2.50	7.20	2.80	3.60
Ce	17.90	4.70	15.60	5.30	8.70
Pr	3.36	0.78	2.18	0.80	1.24
Nd	18.00	4.30	9.40	3.90	5.50
Sm	4.62	1.30	2.44	1.65	1.66
Eu	1.09	0.49	0.72	0.72	0.68
Gd	4.88	1.64	2.90	2.59	2.54
Tb	0.78	0.32	0.52	0.52	0.47
Dy	4.76	2.00	3.30	3.50	3.20
Ho	1.05	0.45	0.81	0.88	0.71
Er	3.12	1.28	2.28	2.52	2.28
Tm	0.49	0.20	0.34	0.36	0.33
Yb	2.93	1.23	2.06	2.44	2.20
Lu	0.44	0.19	0.35	0.39	0.34
Nb/Y	0.24	0.45	0.33	0.19	0.23
Zr/Y	4.03	7.13	5.42	3.44	4.28
Zr/Nb	16.93	15.74	16.54	18.29	18.87
Zr(M)	1.35	0.91	1.25	1.04	0.99

In the spider diagrams, they exhibit similar high field strength element (HFSE; Ti=0.69-0.89 ppm, Zr=68-100 ppm) concentrations and show more flat patterns with the N-MORB (Ti = 0.76 ppm, Zr = 74 ppm; Sun and McDonough, 1989). In addition, they are characterized by enrichments in Th/N-MORB-normalized ( $Th_N=2.50-8.33$ ; Figure 5a) and display generally flat REEs/ chondrite-normalized patterns ( $[La/Sm]_N=0.76-2.20$ ; Figure 5b).

#### *Mantle Source and Geotectonic Environment*

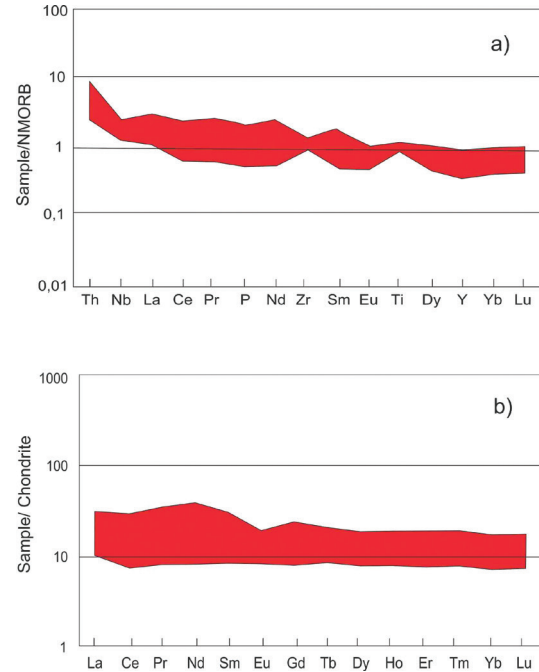
The spider and binary diagrams were used to figure out the mantle source and the geotectonic environment (Figures 5, 6, 7 and 8). The mafic volcanic rocks from the Derebaşı region show the characteristics of the back arc basin basalts (BABB) and display enrichments in Th coupled with slightly negative Nb anomalies (Figure 5a; Pearce and Peate, 1995; Peate et al., 1997). Moreover, they mostly exhibit N-MORB-like HFSEs and REEs patterns (Figure 5b).

These volcanic rocks are plotting in the island arc and N-MORB fields regarding their trace element systematics (Figures 6a, b, c) which support deriving within an arc-back arc setting (Shervais, 1982; Wood, 1980; Meschede, 1986).

According to the Th/Yb and Ta/Yb diagram of (Pearce, 1983), they show subduction related signatures by higher Th/Yb (0.24-0.44) and similar Ta/Yb (0.04-0.24) values (Figure 7) compared to the N-MORB ( $Th/Yb=0.039$ ;  $Ta/Yb=0.043$ ; Sun and McDonough, 1989).

Also, the Nb/Y ratio (0.19-0.45) vs Zr/Y ratio (3.44-7.13) and Zr (N-MORB-normalized; 0.91-1.35) vs. Zr/Nb ratio (15.74-18.87) exhibit consistent values with two important arc-back arc environments (e.g. Mariana back arc and South Sandwich island arc; Figure 8; Pearce et al., 1995, 2005). Overall trace elements systematics of the volcanic rocks from the Derebaşı region

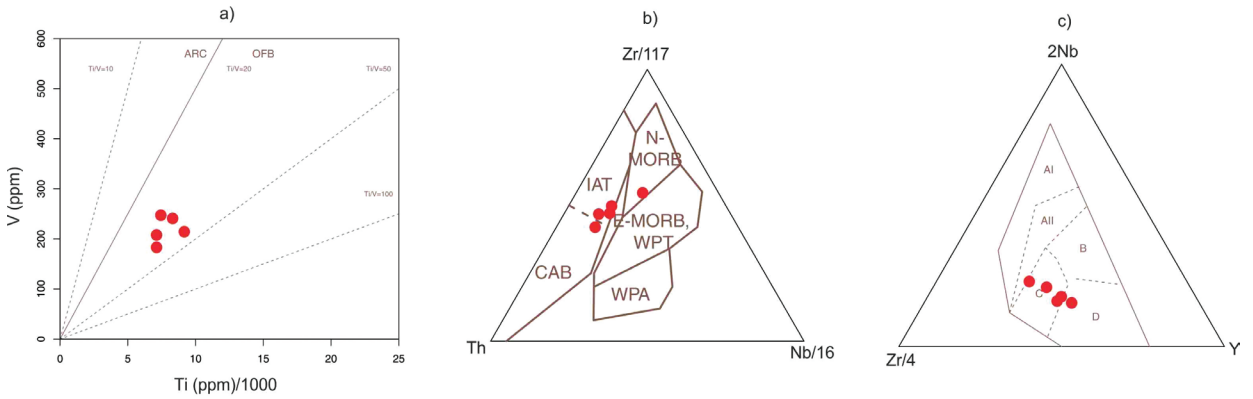
have significant geochemical similarities with a subduction-related arc-back arc basin.



**Figure 5.** N-MORB normalized multi element and Chondrite normalized REE spider diagrams (Sun and McDonough, 1989).

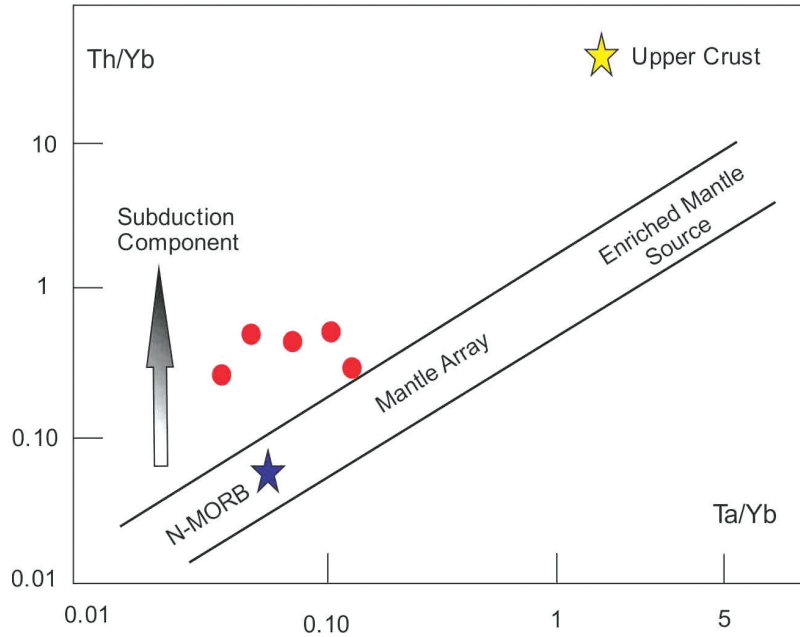
**Şekil 5.** N-MORB'a göre normalize edilmiş çoklu element ve Kondrit'e göre normalize edilmiş NTE örümcek ağı diyagramları (Sun ve McDonough, 1989).





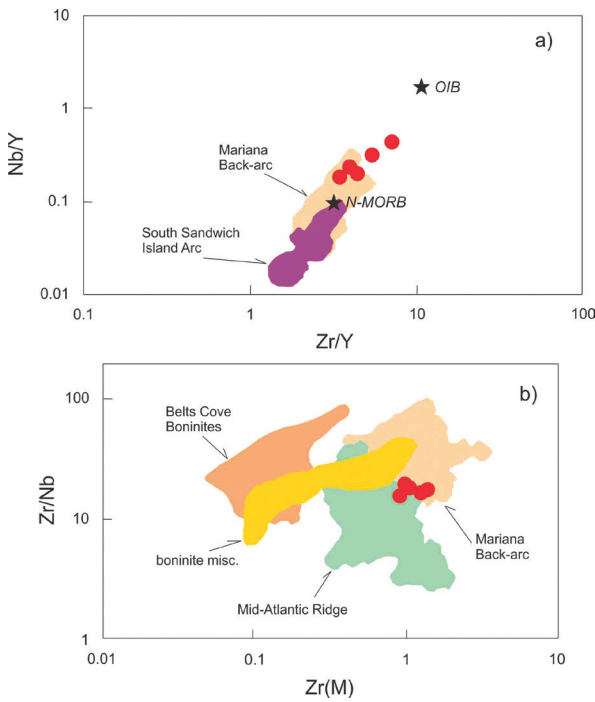
**Figure 6.** Geotectonic discrimination diagrams **a)** after Shervais (1982) **b)** after Wood (1980) **c)** after Meschede (1986). (AI: within-plate alkali basalt; AII: within-plate tholeiite; B: E-MORB; C and D: volcanic arc basalts; D: N-MORB).

**Şekil 6.** Jeotektonik diskriminasyon diyagramları **a)** Shervais (1982) sonrası **b)** Wood (1980) sonrası **c)** Meschede (1986) sonrası. (AI: kıta-içi alkali basalt; AII: kıta-içi toleyit; B: E-MORB; C ve D: volkanik yay bazaltları; D: N-MORB).



**Figure 7.** Th/Yb and Ta/Yb diagram (after Pearce, 1983).

**Şekil 7.** Th/Yb ve Ta/Yb diyagramı (Pearce, 1983 sonrası).



**Figure 8. a)** Zr/Y-Nb/Y and **b)** Zr(M)-Zr/Nb diagrams (Sayıt et al., 2016). Average OIB and N-MORB values taken from Sun and McDonough (1989), Mariana Back-arc data taken from Pearce et al. (2005), South Sandwich Arc data taken from Pearce et al. (1995), Mid-Atlantic Ridge data taken from Niu et al. (2001), Betts Cove boninites taken from Bedard (1999), Miscellaneous boninites data taken from Cameron et al. (1983).

**Şekil 8. a)** Zr/Y-Nb/Y ve **b)** Zr(M)-Zr/Nb diyagramları (Sayıt vd., 2016). Ortalama OIB ve N-MORB değerleri Sun ve McDonough (1989)'dan, Mariana Yay-ardı verileri Pearce vd. (2005)'den, South Sandwich Yaytı verileri Pearce vd. (1995)'den, Orta-Atlantik Sırtı verileri Niu vd. (2001)'den, Betts Cove boninitlerinin verileri Bedard (1999)'dan, Miscellaneous boninitleri verileri Cameron vd. (1983)'den alınmıştır.

## DISCUSSION

The whole rock geochemical data of newly discovered mafic volcanic rocks from the Derebaşı region play a crucial role in order to better understand the geodynamic evolution of the northern margin of the Gondwana during the Late Paleozoic. The available geochemical data

is mostly concentrated on the magmatic rocks from the northern Konya (Ladik) and Yahyalı regions (Eren et al., 2004; Göncüoğlu et al., 2007; Robertson and Ustaömer, 2009; Akal et al., 2012). These magmatic rocks cut the Paleozoic sedimentary units and display subduction related signatures in the both regions.

In detail, the metatrachyandesites from the Kadınhanı region (northern Konya) could have been derived from subcontinental lithosphere involving a small amount of subduction component in an extensional regime (Kurt and Arslan, 1999). Eren et al. (2004) has also geochemically studied the Kadınhanı metamagmatics within the Silurian-Early Permian Sızma Group and suggested that they could have been generated from the sub-continental lithosphere and subduction components. In relation to these magmatics from the Konya region, Göncüoğlu et al. (2007) proposed that an aborted rift basin formed in a back arc setting above the southward subducting Paleozoic oceanic plate along the northern margin of Gondwana. However, an oceanic crust did not develop since the rifting failed and the basin was progressively filled with a regressive sequence (Göncüoğlu et al., 2007). Later on, these subduction related metatrachyandesites have been dated as Early Triassic and attributed to the rifting of Neotethyan ocean (Akal et al., 2012). It must be noted that the region contains several types of magmatics including volcanic and subvolcanic rocks and there is still no consensus yet with regards to their geochemical characteristics and ages.

In addition, some felsic and intermediate volcanics have been found within the Mid-Late Paleozoic units from the Karaburun peninsula (Kozur and Göncüoğlu, 1998; in the western TAP). Moreover, the rift related basaltic rocks have been found in the Permian units from the Antalya nappes (Şahin et al., 2014; southern TAP). However, there is no published geochemical data from both of these volcanics. The Tavas nappes (south of

Denizli) also include volcanics rocks within the Carboniferous units. They display geochemically oceanic island and MORB features and can be evaluated together with the coeval back arc basin units found in the Konya region (Göncüoğlu et al., 2000b; Göncüoğlu, 2011). According to the recent studies, the Devonian and Carboniferous granites have been found in the Afyon Zone (Akal et al., 2011; Candan et al., 2016). Of note, the volcanic equivalents of these Devonian and Carboniferous magmatism in the Afyon Zone should be found in somewhere of the Tauride-Anatolide Platform.

In this study, the volcanic rocks from the Derebaşı region are intercalated with the Late Devonian limestones and exhibit typical characteristics of a back arc basin. The overall geochemical features suggest that all these mafic rocks were predominantly generated in a subduction setting from a subduction-modified mantle source. Also, similar Late Devonian magmatics have been reported in the Central Iran Block which exhibit the geochemical features of an intra-plate setting (e.g. Ruttner, 1991, Wendt et al., 2002; Gharaie, 2004).

In a continental rift zone, the chemical composition of magmas depend on several factors such as chemical and mineralogical heterogeneity of the mantle source, the degree of partial melting, the depth of melting, the rate of magma transfer to the surface (Wilson, 1989). Basaltic lavas, which rise relatively rapidly to the surface without undergoing significant fractional crystallization or crustal contamination, may display geochemical characteristics of the asthenospheric mantle (Wilson, 1989). Thus, the volcanic rocks, which show back arc basin signature in the TAP, can be attributed to fastly rising of magma by rifting during the Late Devonian and the Early Carboniferous time.

In the literature, the northward subduction model beneath the Eurasia during the Late Paleozoic (Robertson and Dixon, 1984; Ustaömer

and Robertson, 1994, 1999; Stampfli, 2000; Eren et al., 2004) and the southward subduction model under the northern active margin of the Gondwana during Early Carboniferous (Göncüoğlu et al., 2000, 2007) have been proposed in several studies. But, there is still no consensus for the subduction polarity of the Paleotethyan Ocean. In any case, all these magmatic products from the Tauride-Anatolide Platform indicate that the northern margin of Gondwana was active during the Late Paleozoic. However, further geochemical and geochronological studies are needed in order to better understand the geodynamic evolution of the TAP.

## **CONCLUSION REMARKS**

The newly found Late Devonian volcanism from the Derebaşı region exhibit geochemical characteristics of a back arc basin environment. It geochemically resembles the magmatic rocks from the Konya and Yahyalı regions, which were assigned to a subduction related event. The presence of Mid-Late Paleozoic magmatism has also been reported in the Karaburun peninsula, Afyon zone, Tavas and Antalya nappes and the Central Iran Block. The available geochemical data suggest that these magmatic rocks were mostly generated in a subduction setting from a subduction-modified mantle source. It may indicate that the Tauride-Anatolide Platform was active continental margin of Gondwana during the Late Paleozoic.

## **GENİŞLETİLMİŞ ÖZET**

*Torid-Anatolide Platformu (TAP) Türkiye'yi oluşturan mikro-kıtalarından biri olup kuzeyinde bulunan Sakarya Tektonik Birliği ile İzmir-Ankara-Erzincan Sütur kuşağı tarafından ayrılmaktadır (Şekil 1a; Şengör ve Yılmaz, 1981; Göncüoğlu, 2010). Bu platform, batıda metamorfik kısmını temsil eden Anatolide'ler ve daha güneyde*

bulunan Torid'ler olarak iki kısma ayrılmıştır. Anatolid'ler; Menderes Masifi, Afyon ve Tavşanlı zonları gibi değişik Alpin metamorfizma dereceleri ve yaşları ile birbirinden ayrılmış tektonik zonlardan oluşmaktadır (Bozkurt ve Oberhansli, 2001; Candan vd., 2016). Torid'ler ise Kambriyen temeli üzerleyen Paleozoyik ve Erken Tersiyer birimlerinden oluşmaktadır (Özgül, 1984; Okay, 2008; Göncüoğlu, 2010; Candan et al., 2016).

TAP boyunca geniş yayılım gösteren Paleozoyik birimleri bulunmakta ve bunların bir kısmı nadiren de olsa magmatik birimler içermektedir (Şekil 1b). Bu magmatik birimler üzerine yapılan jeokimyasal çalışmalar genellikle Kuzey Konya bölgesinde yoğunlaşmıştır (Kurt ve Arslan, 1999; Eren vd., 2004; Göncüoğlu vd., 2007; Akal vd., 2012). Bunlara ilaveten Karaburun yarımadası, Tavas ve Antalya napları, Yahyalı bölgesi ve İran Blok'u üzerinde de Paleozoyik birimlerinin içerisinde bulunan magmatik kayaçlar rapor edilmiştir (Kozur ve Göncüoğlu, 1998, Göncüoğlu vd., 2007; Göncüoğlu, 2011; Şahin vd., 2014; Wendt vd., 2002; Gharaie, 2004).

Paleotetis okyanusu'nun dalma-batma yönü ile alakalı literatürde çeşitli modeller öne sürülmüştür. Genel olarak bir grup araştırmacı Geç Paleozoik süresince Lavrasyanın altına doğru kuzeye dalma-batma modelini savunurken (Robertson ve Dixon, 1984; Ustaömer ve Robertson, 1994, 1999; Stampfli, 2000; Eren vd., 2004), Erken Karbonifer boyunca aktif olan Gondwana'nın kuzey kenarının altına güneye doğru dalma-batma düşüncesi de bulunmaktadır (Göncüoğlu et al., 2000, 2007). Bu modellerin oluşturulmasında en önemli katkı aktif kıta kenarının varlığını temsil eden magmatik birimlerin bulunmasıdır. Ancak halen literatürde bulunan bu magmatik kayaçların jeokimyasal özellikleri ve yaşları ile alakalı tartışmalar bulunmakta ve henüz bir uzlaşma sağlanamamıştır.

Bu çalışma kapsamında, Kayseri'nin Develi ilçesine bağlı Derebaşı köyü civarında yüzeylenen

Geç Devoniyen yaşlı Gümüşali formasyonu içerisinde bazaltik kayaçlar bulunmuştur (Şekiller 1b, 2). Bu kayaçlar dar bir alanda yayılım göstermekte ve jeokimyasal olarak tipik bir yay-ardı havza özelliği sunmaktadır. Bu özelliği ile Kuzey Konya ve Yahyalı bölgelerinde tespit edilen magmatik kayaçlara benzemekte ve Orta-Geç Paleozoyik süresince Gondwana'nın kuzey kenarının aktif olabileceği düşüncesini desteklemektedir.

Bu yeni bulunan önemli birime ilaveten, TAP boyunca çeşitli bölgelerde Paleozoyik birimlerin içerisinde varlığı saptanan magmatik kayaçların ayrıntılı jeokimyasal ve jeokronolojik çalışmaları Gondwana'nın Paleozoyik esnasındaki jeodinamik evrimini anlamada önemli katkılar sunacaktır.

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## REFERENCES

- Akal, C., Candan, O., Koralay, O.E., Okay, A.I., Oberhansli, R. Chen, F., 2011. Geochronology, geochemistry and geology of the Devonian granites in Afyon Zone, north of Simav. TÜBİTAK Project, 109Y144, 247 pp. (in Turkish with English Abstract).
- Alavi, M., 1996. Tectonostratigraphic synthesis and structural style of the Alborz Mountain system in northern Iran. Journal of Geodynamics, 21, 1–33.

- Bedard, J.H., 1999. Petrogenesis of Boninites from the Betts Cove Ophiolite, Newfoundland, Canada: identification of subducted source components. *Journal of Petrology*, 40, 1853–1889.
- Bozkurt, E., Oberhänsli, R., 2001. Menderes Massif (Western Turkey): structural, metamorphic and magmatic evolution - a synthesis. *International Journal Earth Sciences*, 89, 679-708.
- Cameron, W.E., Culloch, M.T., Walker, D.A., 1983. Boninite petrogenesis: chemical and Nd-Sr isotopic constraints. *Earth and Planetary Science Letters*, 65,75–89.
- Candan, O., Çetinkaplan, M., Oberhänsli, R., Rimmele, G., Akal, C., 2005. Alpine high-pressure/low temperature metamorphism of Afyon Zone and implication for metamorphic evolution of western Anatolia. *Turkey, Lithos* 84, 102-124.
- Candan, O., Akal, C., Koralay, O.E., Okay, A.I., Oberhänsli, R., Prelevic, D., Mertz-Kraus, R., 2016. Carboniferous granites on the northern margin of Gondwana, Anatolide-Tauride Block, Turkey-Evidence for southward subduction of Paleotethys. *Tectonophysics*, 683, 349-366.
- Çimen, O., Göncüoğlu, M.C., Sayit, K., 2016a. Geochemistry of the meta-volcanic rocks from the Çangaldağ Complex in Central Pontides: Implications for the Middle Jurassic arc - back - arc system in the Neotethyan Intra-Pontide Ocean. *Turkish Journal of Earth Sciences*, 25, 491-512.
- Çimen, O., Toksoy Köksal, F., Öztüfekçi Önal, A., Aktağ, A., 2016b. Depleted to Refertilized Mantle Peridotites Hosting Chromitites within the Tunceli Ophiolite, Eastern Anatolia (Turkey): Insights on the Back Arc Origin. *Ophioliti*, 41, 1-20.
- Dalkılıç, H., 2009. Türkiye Jeoloji Haritaları, 1:100.000 ölçekli. Kayseri-L35 Paftası, No: 124.
- Demirtaşlı, E., 1967. Pınarbaşı-Sarız-Mağara ilçeleri arasındaki sahanın litostratigrafi birimleri ve petrol imkanları. Maden Tetkik ve Arama Enstitüsü Raporu, No: 6305, Ankara (in Turkish, unpublished).
- Eren, Y., Kurt, H., 2000. The stratigraphical, geochemical and geodynamical modelling of the northeast margin of Menderes-Taurus Block. *Mühendislik-Mimarlık Fakültesi Dergisi, Selçuk Üniversitesi*, 15, 25–41.
- Eren, Y., Kurt, H., Rosselet, F., Stampfli, G.M., 2004. Paleozoic deformation and magmatism in the northern area of the Anatolian block (Konya), witness of the Paelotethys active margin. *Eclogae geologicae Helvetiae*, 97, 293-306.
- Floyd, P.A., Winchester, J.A., 1978. Identification and discrimination of altered and metamorphosed volcanic rocks using immobile elements. *Chemical Geology*, 21, 291-306.
- Floyd P.A., Winchester J.A., Seston R., Kryza R., Crowley Q.G., 2000. Review of geochemical variation in Lower Palaeozoic metabasites from the NE Bohemian Massif; intracratonic rifting and plume ridge interaction. In: W. Franke, V. Haak, O. Oncken and D. Tanner (Eds.), *Orogenic processes: Quantifications and modeling in the Variscan Belt*. Geological Society London Special Publications, 179, 155-174.
- Gharaire, M.H.M., Matsumoto, R., Kakuwa, Y., Milroy, P.G., 2004. Late Devonian facies variety in Iran: volcanism as a possible trigger of the environmental perturbation near the Frasnian-Famennian boundary. *Geological Quarterly*, 48, 323-332.
- Göncüoğlu, M.C., 1997. Distribution of Lower Paleozoic units in the Alpine Terranes of Turkey: paleogeographic constraints. In: Göncüoğlu MC, Derman AS, editors. *Lower Paleozoic Evolution in Northwest Gondwana*. Turkish Association of Petroleum Geologist Special Publications, 3, 13–24.
- Göncüoğlu, M.C., Kozlu, H., Dirik, K., 1997. Pre-Alpine and Alpine terranes in Turkey: explanatory notes to the terrane map of Turkey. *Annales Géologiques des Pays Helleniques*, 37, 515-536.
- Göncüoğlu, M. C., Turhan, N., Sentürk, K., Özcan, A., Uysal, S., 2000a. A geotraverse across NW Turkey: tectonic units of the Central Sakarya region and their tectonic evolution. In: Bozkurt, E., Winchester, J. A. & Piper, J. D. (eds) *Tectonics and Magmatism in Turkey and the Surrounding Area*. Geological Society of London Special Publications, 173, 139–162.
- Göncüoğlu, M.C., Yalınız, M.K., Floyd, P.A., 2000b. Petrology of the Carboniferous volcanic rocks in the Lycian Nappes, SW Turkey: implications for the Late Paleozoic evolution of the Tauride-Anatolide Platform. *International Earth Science Congress Aegean Regions, Izmir, Sept.25-29, 2000, Abstracts*, 213.

- Göncüoğlu, M.C., Çapkinoğlu, Ş., Gürsu, S., Noble, P., Turhan, N., Tekin, U.K., Okuyucu, C., Göncüoğlu, Y., 2007. The Mississippian in the Central and Eastern Taurides (Turkey): constraints on the tectonic setting of the Tauride-Anatolide Platform. *Geologica Carpathica*, 58, 427-442.
- Göncüoğlu, M.C., 2010. Introduction to the Geology of Turkey: Geodynamic evolution of the pre-Alpine and Alpine Terranes. MTA, 1-69.
- Janoušek, V., Farrow, C. M., Erban, V., 2006. Interpretation of whole-rock geochemical data in igneous geochemistry: introducing Geochemical Data Toolkit (GCDkit). *Journal of Petrology*, 47, 1255-1259.
- Kozur, H., Göncüoğlu, M.C., 1998. Main features of the pre-Variscan development in Turkey. *Acta Universitatis Carolinae-Geologica*, 42, 459-464.
- Kurt, H., Arslan, M., 1999. Geochemistry and petrogenesis of Kadınhanı (Konya) K-rich metatrachyandesite: The evolution of Devonian (?) volcanism. *Geological Bulletin of Turkey*, 42, 57-69.
- Meschede, M., 1986. A method of discriminating between different types of midocean ridge basalts and continental tholeiites with the Nb-Zr-Y diagram. *Chemical Geology*, 56, 207-218.
- Metin, S., 1983. Doğu Toroslar'da Derebaşı (Develi), Armutalan ve Gedikli (Saimbeyli) köyleri arasının jeolojisi (doktora tezi). İstanbul Üniversitesi. (in Turkish)
- Niu, Y., Bideau, D., Hekinian, R., Batiza, R., 2001. Mantle compositional control on the extent of mantle melting, crust production, gravity anomaly, ridge morphology, and ridge segmentation: a case study at the Mid-Atlantic Ridge 33-35°. *Earth and Planetary Science Letters*, 186, 383-399.
- MTA, 2003. 1/500.000 ölçekli Türkiye Jeoloji Haritaları. Kayseri paftası.
- Okay, A.I., Tuysuz, O., 1999. Tethyan sutures of northern Turkey. In: *The Mediterranean Basins: Tertiary Extension within the Alpine Orogen* (eds Durand, B., Jolivet, L., Horvath, F. & Seranne, M.). Geological Society of London Special Publications, 156, 475-515.
- Okay, A.I., 2008. Geology of Turkey: Synopsis. *Anschmitt*, 21, 19-42.
- Özgül, N., 1984. Stratigraphy and tectonic evolution of the Central Taurides. In: Tekeli, O. and Göncüoğlu, M.C.: *Geology of Taurus Belt*. MTA, 77-90.
- Parlak, O., Çolakoğlu, A., Dönmez, C., Sayak, H., Yıldırım, N., Türkel, A., Odabaşı, İ., 2012. Geochemistry and tectonic significance of ophiolites along the Ankara-Erzincan Suture Zone in northeastern Anatolia. In: Robertson, A.H.F., Parlak, O., Ünlügenç, U.C. (Eds.), 2012. *Geological Society of London Special Publications*, 372, 75-105.
- Pearce, J.A., Cann, J.R., 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. *Earth and Planetary Science Letters*, 19, 290-300.
- Pearce, J. A., 1983. Role of the sub-continental lithosphere in magma genesis at active continental margins. In: Hawkesworth, C.J. and Norry, M.J. eds. *Continental basalts and mantle xenoliths*, Nantwich, Cheshire. Shiva Publications, 230-249.
- Pearce, J.A., Peate, D.W., 1995. Tectonic implications of the composition of volcanic arc magmas. *Annual Review of Earth and Planetary Science*, 23, 251-286.
- Pearce, J.A., Ernewein, M., Bloomer, S.H., Parson, L.M., Murton, B.J., Johnson, L.E., 1995. Geochemistry of Lau Basin volcanic rocks: influence of ridge segmentation and arc proximity. In: Smellie JL, editor. *Volcanism Associated with Extension at Consuming Plate Margins*. London, UK: Geological Society of London Special Publications, 81, 53-75.
- Pearce, J.A., 1996. A users guide to basalt discrimination diagrams. In: Wyman DA, editor. *Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration*. Short Course Notes 12. St. John's, Canada: Geological Association of Canada, 79-113.
- Pearce, J.A., Stern, R.J., Bloomer, S.H., Fryer, P., 2005. Geochemical mapping of the Mariana arc basin system: Implications for the nature and distribution of subduction components. *Geochemical Geophysical Geosystems*, 6, 1-27.
- Peate, D.W., Pearce, J.A., Hawkesworth, C.J., Collie, H., Edwards, C.H.M., Hirose, K., 1997. Geochemical variations in Vanuatu arc lavas: the role of subducted material and a variable mantle wedge composition. *Journal of Petrology*, 38, 1331-1358.
- Robertson, A.H.F., Dixon, J.E., 1984. Introduction: aspects of the geological evolution of the Eastern Mediterranean. In: Dixon, J.E., Robertson, A.H.F.

- (Eds.), *The Geological Evolution of the Eastern Mediterranean*. Geological Society of London Special Publication, 17, 1–74.
- Robertson, A.H.F., Ustaömer, T., 2009. Formation of the Late Palaeozoic Konya Complex and comparable units in southern Turkey by subduction–accretion processes: Implications for the tectonic development of Tethys in the Eastern Mediterranean region. *Tectonophysics*, 473, 113–148.
- Robertson, A., Parlak, O., Ustaömer, T., Taşlı, K., İnan, N., Dumitrica, P., Karaoğlu, F., 2014. Subduction, ophiolite genesis and collision history of Tethys adjacent to the Eurasian continental margin: new evidence from the Eastern Pontides, Turkey. *Geodinamica Acta*, 1–64.
- Ruttner, A. W., 1991. Geology of the Aghdarband area (Kopetdagh, NE-Iran) (with contributions of R. Brander and E. Kirchner). *Abhandlungen der Geologischen Bundesanstalt*, 38, 7–79.
- Sayit, K., Marroni, M., Göncüoğlu, M.C., Pandolfi, L., Ellero, A., Ottria, G., Frassi, C., 2016. Geological setting and geochemical signatures of the mafic rocks from the Intra-Pontide Suture Zone: implications for the geodynamic reconstruction of the Mesozoic Neotethys. *International Journal of Earth Science*, 105, 39–64.
- Shervais, J.W., 1982. Ti–V plots and the petrogenesis of modern ophiolitic lavas. *Earth and Planetary Science Letters*, 59, 101–118.
- Skilling, I.P., White, J.D.L., McPhie, J., 2002. Peperite: a review of magma-sediment mingling. *Journal of Volcanology and Geothermal Research*, 114, 1–17.
- Sun, S.S., McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. *Geological Society of London Special Publications*, 42, 313–345.
- Stamfli, G.M., 2000. Tethyan oceans. In: Bozkurt, E., Winchester, J.A., Piper, J.D.A. (Eds.): *Tectonics and magmatism in Turkey and surrounding area*. Geological Society London Special Publications, 173, 1–23.
- Şahin, N., Altıner, D., Ercengiz, M.B., 2014. Discovery of Middle Permian volcanism in the Antalya Nappes, southern Turkey: tectonic significance and global meaning. *Geodinamica Acta*, 25, 286–304.
- Şengör, A.M.C., Yılmaz, Y., 1981. Tethyan evolution of Turkey: A plate tectonic approach. *Tectonophysics*, 75, 181–241.
- Ustaömer, T., Robertson, A.H.F., 1994. Late Palaeozoic marginal basin and subduction-accretion: the Palaeotethyan Küre Complex, Central Pontides, northern Turkey. *Journal of the Geological Society, London*, 151, 291–305.
- Ustaömer, T., Robertson, A.H.F., 1999. Geochemical evidence used to test alternative plate tectonic models for pre-Upper Jurassic (Palaeotethyan) units in the Central Pontides, N Turkey. *Geological Journal*, 34, 25–53.
- Wendt, J., Kaufmann, B., Belka, Z., Farsan, N., Bavandpur, A., 2002. Devonian/Lower Carboniferous stratigraphy, facies patterns and palaeogeography of Iran. Part I. Southeastern Iran. *Acta Geologica Polonica*, 52, 129–168.
- Wilson, B.M., 1989. *Igneous Petrogenesis A Global Tectonic Approach*. London, Boston, Sydney, Wellington: Unwin Hyman. 466 pp.
- Whitney, D.L., Bozkurt, E., 2002. Metamorphic history of the southern Menderes massif, western Turkey. *Geological Society of America Bulletin*, 114, 829–838.
- Wood, D.A., Gibson, I.L., Thompson, R.N., 1976. Elemental mobility during zeolite facies metamorphism of the Tertiary basalts of eastern Iceland. *Contributions to Mineralogy and Petrology*, 55, 241–254.
- Wood, D.A., 1980. The application of a Th–Hf–Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crustal contamination of basaltic lavas on the British Tertiary Volcanic Province. *Earth and Planetary Science Letters*, 50, 11–30.