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***Research Article***

# Geochemistry of the Volcanic Rocks of the Yüksekova Complex near Güneyköy (SE of Elazığ, E Turkey)

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**Abstract**

Some of the volcanic products of the Yüksekova Complex crop out in the Güneyköy (SE Elazığ, E Turkey) area in the Southeast Anatolian Suture Belt. This study reports the whole rock geochemical data of the volcanics of the Upper Cretaceous Yüksekova Complex around Güneyköy. The volcanic rocks are burgundy and greenish in color. The rocks are massive or have distinct pillow structure. The volcanic rocks occasionally showing spilitization have basaltic composition and tholeiitic character. The rocks are mainly composed of plagioclases and to a lesser extent clinopyroxene and pseudomorphic olivine minerals. In thin-sections microlytic and hyalomicrolytic porphyritic textures, as well as spherulitic and amygdaloidal textures are common. The secondary minerals are calcite and epidote. In binary diagrams, the Zr, is considered as immobile and index element; show positive correlation with $Al_2O_3$, $TiO_2$, Nb, Y, Hf, whereas show negative correlation with CaO showing plagioclase, clinopyroxene, olivine and Fe-Ti oxide fractionation during the evolution of the volcanics. N-type mid-ocean ridge basalt-normalized trace element distributions of the rock samples indicate enrichment in large-ion lithophile elements (LILE) and Th, and negative anomalies in Ta, Nb, Ti and P elements. The chondrite normalized diagrams of the samples show an approximately parallel and straight trend ($La_N/Sm_N$: 0.93-2.13; $La_N/Lu_N$: 0.23-0.89), suggesting a similar source for the volcanic rocks. The geochemical implications such as negative Nb anomaly, depleted HFS element abundances and enriched LIL element pattern indicate the contribution of a subducting plate. As a result, the volcanites in the near of Güneyköy (Elazığ) are members of the Yüksekova Complex and were formed in an intra-oceanic arc environment within the Southern Branch of Neotethys.

**Keywords:** Güneyköy (SE Elazığ), Yüksekova Complex, Volcanic Rock, Geochemistry, Intra-Oceanic arc

# Güneyköy civarındaki (GD Elazığ, D Türkiye) Volkanik kayaçların (Yüksekova Karmaşığı) Jeokimyası

**Öz**

Güneydoğu Anadolu Sütur Kuşağında, Yüksekova Karmaşığı birimine ait volkanik ürünlerin bir kısmı Güneyköy çevresinde yüzeylenmiştir. Bu çalışma, bu alandaki Üst Kretase yaşlı volkanik kayaçların tüm kayaç jeokimyasını ele alır. Bu volkanik kayaçlar bordo ve yeşilimsi renk tonlarındadır. Kayaçlar masif görünümlü ve yer yer de belirgin yastık yapısındadır. Yer yer spilitleşmeler gösteren volkanitler bazaltik bileşimli ve toleyitik karakterlidir. Bazik kayaçlar genel olarak, plajiyoklas, daha az oranda klinopiroksen ve psödömorf olivin minerallerinden oluşmaktadırlar. Kayaçlarda, mikrolitik, hiyalomikrolitik porfirik dokular yanında, amigdaloidal ve sferulitik dokular da yaygın olarak gözlenir. Kalsit ve epidot ikincil minerallerdir. İkili değişim diyagramlarında Zr elementi $Al_2O_3$, $TiO_2$, Nb, Y, Hf ile pozitif, CaO ile ise negatif korelasyon göstermektedir ki, bu ilişkiler incelenen volkanik kayaçların evriminde plajiyoklas, klinopiroksen, olivin ve Fe-Ti oksit fraksiyonlanmasına işaret etmektedir. Kayaç örneklerinin N-tipi Okyanus Ortası Sırtı Bazaltına (N-MORB) normalize edilmiş iz element dağılımları; örneklerin LIL Elementler ve Th bakımından MORB a göre zenginleştiğini, Ta, Nb, Ti, P gibi elementler bakımından ise nisbeten fakirleştiğine işaret etmektedir. Örneklerin kondrite normalize

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edilmiş diyagramları ise kondrite göre paralel ve yaklaşık düz bir trend sergilemektedir ($La_N/Sm_N$: 0.93-2.13; $La_N/Lu_N$: 0.23-0.89) ki bu durum benzer kaynaktan türediklerine işaret eder. Negatif Nb anomalisiyle birlikte, tüketilmiş HFSE ve zenginleşmiş LIL element desenleri yitim katkısına işaret etmektedir. Sonuç olarak, Güneyköy (Elazığ) çevresindeki volkanik kayaç örnekleri bir okyanus içi yay ortamında oluşmuşlardır.

**Anahtar Kelimeler:** Güneyköy (GD Elazığ), Yüksekova Kompleksi, Volkanik Kayaç, Jeokimya, Okyanus içi yay

# 1. Introduction

The study area is approximately 25 km. southeast of the Elazığ city. In this area, volcanic rocks of the Yüksekova Complex, Hazar Group and Maden Complex are exposed (Figure 1a, 1b).

The typ locality of the Yüksekova Complex unit firstly studied by Perinçek (1979) is in the area of Yüksekova town, Hakkari city. The outcrops of the unit are widespread in the north of Hazar Lake and in the vicinity of Elazığ province (Akgül 1991, Akgül 1993; 2015; Hempton 1985; Hempton and Savcı 1982; Ural and Kürüm 2009; Kürüm et al. 2011). The unit is represented by oceanic sediments (red-greenish grey-light grey limestone, shale, sandstone) associated with volcanic (basalt, diabase, andesite) and volcanoclastic (tuff, agglomerate) rocks together with their intrusive equivalents (gabbro, diorite, granodiorite and granite,) and minor serpentinized ultramafic rocks (Perinçek 1979). Overall, the Yüksekova Complex is Late Cretaceous in age (Ural 2012; Ural et al. 2014; Tekin et al. 2015; Ural and Sarı 2019; Ural and Kaya 2019) and is covered by the Eocene Simaki Formation of the Maden Complex and Gehroz Formation of the Hazar Group (Çelik 2003, Kaya 2004). The Maden Complex is the common cover of all pre-Eocene tectonic units including the Pütürge Massif and the Guleman Ophiolite in SE Anatolia (Altunbey and Sağıroglu 1995, Ertürk 2016, Ertürk et al. 2018, Şaşmaz et al. 2014, Yılmaz 1993, Yılmaz et al. 1993).

This study is the first detailed geochemical one to determine the petrological features of the mafic volcanic rocks in the Güneyköy area and aims to contribute to the evolution of the Southern Neotethys.

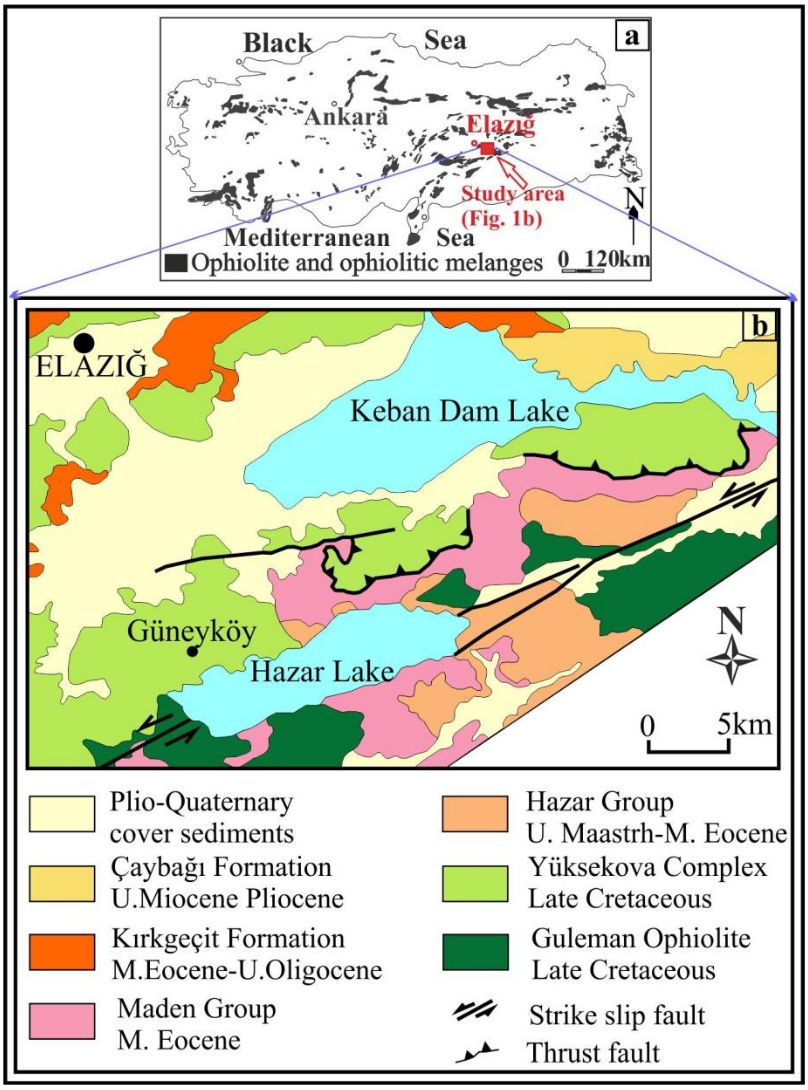


**Figure 1. a)** The distribution of the ophiolitic mélanges of Turkey (modified after [Göncüoğlu 2014]) and the location map of the study area, **b)** The geological map of the study area (after Çelik 2013).

# 2. Material and Method

Twenty samples was collected from the basaltic volcanites of Upper Cretaceous Yüksekova Complex along Güneyköy around east of Elazığ in E Turkey (Figure 1a, 1b). Eight samples were selected considering alteration conditions and analysed for whole-rock major, trace and rare earth elements (REE) at ACME Analytical Laboratory (Canada). Major and trace element datas were determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES), while REE contents were analyzed by inductively coupled plasma mass spectrometry (ICP-MS).

## 3. Results

### 3.1. Geology and Stratigraphy

The Southeast Anatolian Suture Zone in Turkey represents the remnants of a Mesozoic ocean (Southern Branch of Neotethys) between the Arabian and Anatolian plates (Figure 1a) of the Alpine-Himalayan belt (Şengör and Yılmaz 1981; Göncüoğlu et al. 1997). It northerly borders the southeastern Anatolian shelf area (Yılmaz et al. 1993) and connects the Zagros belt of Iran in the east (Moghadam et al. 2009) to the Tauride belt at the west (Parlak et al. 2004; Robertson et al. 2006). Kököm and İnceöz (2018) mentioned the existence of successive deformation phases which were effective in 3 different periods, M. Eocene-M. Miocene, Late Miocene-Early Pliocene, and lastly Late Pliocene, respectively in the studied region.

The Pütürge Metamorphites at the south (Arabian plate margin), Keban-Malatya Metamorphites, Baskil Magmatics at the north (Anatolides) and their cover rocks of Upper Cretaceous-Early Tertiary age (Ural et al. 2014; 2015) are the major tectonic units in the Elazığ region. These pieces of continental crust represented by two crystalline units are separated by various rocks of ophiolitic mélange derived from different members of a Late Cretaceous oceanic lithosphere and a subduction-accretion prism (Tekin et al. 2015). The Maden complex was formed within a volcanosedimentary basin that developed on these units.

The Guleman Ophiolite is thrusted over the Maden Complex, autochthon Arabian platform sediments and the Lice formation (Aktaş and Robertson 1984; Özkan and Öztunalı 1984, Kılıç 2009; Rizeli et al. 2016; Uysal et al. 2018). Sungurlu et al. (1985) grouped the rocks in the Elazığ-Hazar-Palu region as autochthonous, allochtonous, paraallochtonous and neotochthonous units and concluded that most of these rocks are transported to the Arabian plate to the south.

The Yüksekova Complex which is a Late Cretaceous volcanosedimentary unit (Perinçek 1979) overlies the mantle cumulate rocks of the Guleman Ophiolites (e.g. harzburgite, dunite, and lherzolite) with a tectonic contact. The mafic volcanic and subvolcanic rocks are characterized by the oceanic crustal products of the Late Cretaceous Yüksekova Complex (Ural et al. 2015; Ural et al. 2019). The unit is unconformably overlain by the Upper Maastrichtian–Paleocene sediments of the Hazar Group. Middle Eocene volcaniclastic rocks of the Maden Group unconformably set above these units. However, Çelik (2003) stated that the Maden Complex conformably overlies the Hazar Group but overthrusted by the Yüksekova Complex (Figure 1b). In the Güneyköy area the Yüksekova Complex has been divided into three northerly dipping units that are represented by a series of imbricate thrust faults (Hempton and Savcı 1982, Yazgan 1984). The southernmost first unit is composed of basaltic pillow lavas, diabase and metagabbros whilst the second units consists of lava flows, volcanogenic sediments, agglomerates and basaltic-andesitic pillow lavas (Figure 2). The northernmost third unit in the upper part of the complex is represented by basaltic pillow lavas and volcaniclastic sediments.

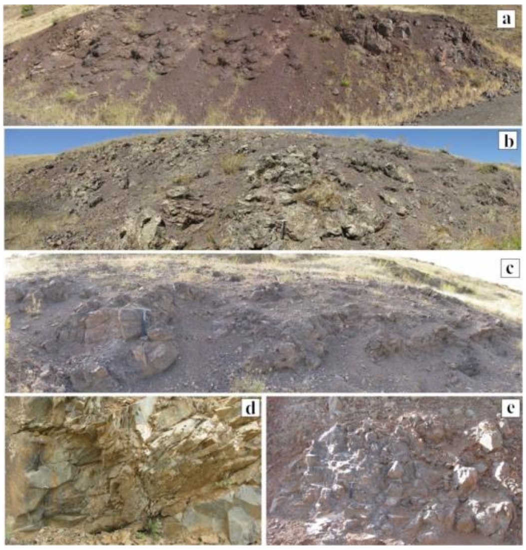


**Figure 2.** Field view of volcanic rocks in the study area, **a)** Bordeaux-colored pillow basalts, **b)** Tabular-shaped volcanic lavas, **c)** Bordeaux-colored volcanics and mudstone alternation, **d)** Green colored massive lavas, **e)** Breccia-like volcanic rocks near Güneyköy.

### 3.2. Petrography and Geochemistry

The volcanites of the Yüksekova Complex in the study area have relatively extensive outcrops. They consists of burgundy, green and gray colored massive lavas and dykes. Greenish gray color is predominant in basalts showing spilitization in places and pillow structures are also evident.

The basaltic rocks are dominant in the study area. The rocks are mainly composed of plagioclases and to a lesser extent clinopyroxene and pseudomorphic olivine minerals (Figure 3). In thin-sections microlytic and hyalomicrolytic porphyritic textures, as well as spherulitic and amygdaloidal textures are common. Alterations of seritization and carbonation type, especially chloritization, are observed in rocks (Figure 3).

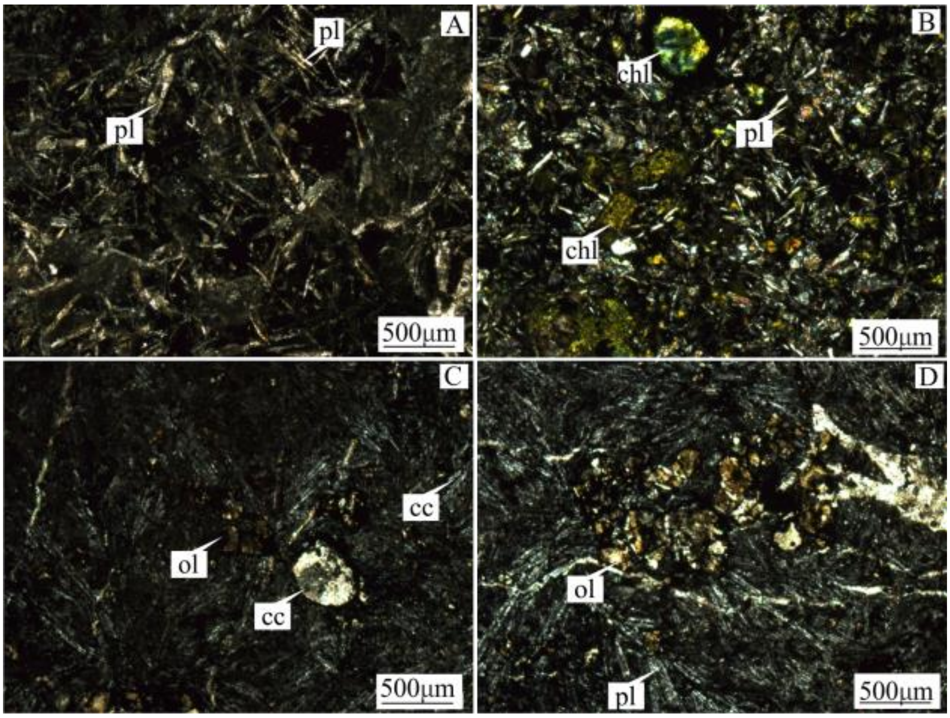


**Figure 3.** The microphotos of the studied rocks in the Güneyköy province (SE Elazığ, eastern Turkey); **a)** Variolitic textured basalt, **b)** The hyalo-microlithic porphyritic basalts; **c)** Amygdaloidal basalt, **d)** Glomeroporphyric basalt. Abb.: pl: plagioclase, ol: olivine, chl: chlorite, cc: calcite.

The whole rock datas of the studied rocks are presented in Table 1. The volcanic rocks have basaltic composition and tholeiitic character (Figure 4a, b). In binary diagrams, the Zr, is considered as immobile and index element; show positive correlation with $Al_2O_3$, $TiO_2$, Nb, Y, Hf, whereas show negative correlation with CaO (Figure 5).

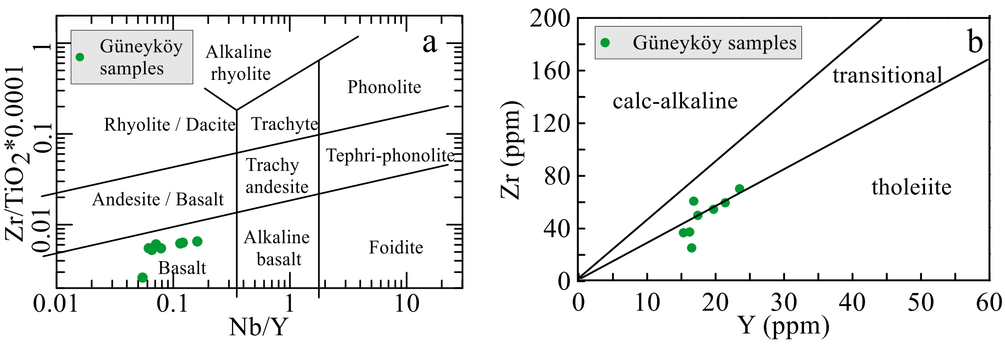


**Figure 4.** The distributions of the rocks in **a)** Nb/Y versus $Zr/TiO_2$ * 0.0001 diagram (Winchester and Floyd 1977), **b)** Zr versus Y diagram (Barrett and MacLean 1997; Ross and Bedard 2009).

**Table 1.** The major (%), trace (ppm) and rare earth element (ppm) analysis datas of the studied rocks.

| Sample | G1 | G2 | G3 | G4 | G5 | G6 | G7 | G8 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 44.96 | 45.01 | 45.85 | 44.35 | 45.86 | 46.01 | 48.75 | 45.79 |
| $Al_2O_3$ | 14.53 | 16.24 | 8.25 | 12.16 | 14.47 | 15.77 | 15.43 | 12.81 |
| $Fe_2O_3$ | 8.39 | 9.00 | 9.09 | 9.36 | 9.00 | 13.75 | 8.08 | 7.44 |
| MgO | 5.04 | 7.14 | 5.49 | 5.63 | 6.90 | 5.22 | 6.70 | 5.50 |
| CaO | 12.60 | 11.13 | 24.20 | 18.70 | 14.78 | 11.01 | 8.77 | 12.85 |
| $Na_2O$ | 3.53 | 3.36 | 1.57 | 3.20 | 2.99 | 3.55 | 5.29 | 5.20 |
| $K_2O$ | 1.40 | 0.58 | 0.10 | 0.50 | 0.29 | 1.08 | 0.26 | 0.23 |
| $TiO_2$ | 0.93 | 1.13 | 0.98 | 0.69 | 0.67 | 1.14 | 0.89 | 0.80 |
| $P_2O_5$ | 0.11 | 0.10 | <0.01 | 0.08 | 0.11 | 0.11 | 0.11 | 0.11 |
| MnO | 0.18 | 0.14 | 0.13 | 0.15 | 0.17 | 0.19 | 0.12 | 0.11 |
| $Cr_2O_3$ | 0.08 | 0.05 | 0.06 | 0.21 | 0.06 | 0.12 | 0.03 | 0.04 |
| Total | 99.94 | 99.80 | 99.79 | 99.83 | 99.79 | 99.80 | 99.75 | 99.77 |
| Ba | 69 | 31 | 15 | 109 | 25 | 65 | 47 | 73 |
| Hf | 1.8 | 1.9 | 0.9 | 1.0 | 1.2 | 1.7 | 1.6 | 1.5 |
| Nb | 2.7 | 2.7 | 0.9 | 1.0 | 1.2 | 1.4 | 1.4 | 2.1 |
| Rb | 15.5 | 6.0 | 1.6 | 8.5 | 4.9 | 13.6 | 2.1 | 3.0 |
| Sr | 191.2 | 253.4 | 243.7 | 227.5 | 306.5 | 231.0 | 411.1 | 460.4 |
| Th | 0.3 | 0.2 | 0.3 | 0.1 | 0.4 | 0.1 | 0.3 | 0.3 |
| V | 188 | 219 | 361 | 175 | 253 | 225 | 256 | 207 |
| Zr | 60.8 | 70.2 | 25.3 | 37.4 | 36.8 | 59.6 | 54.6 | 50.0 |
| Y | 16.8 | 23.5 | 16.5 | 16.2 | 15.3 | 21.4 | 19.7 | 17.4 |
| La | 4.0 | 3.4 | 1.8 | 2.1 | 3.0 | 2.2 | 3.1 | 3.9 |
| Ce | 10.6 | 9.4 | 4.9 | 4.8 | 7.7 | 7.1 | 8.3 | 9.4 |
| Pr | 1.61 | 1.53 | 0.70 | 0.86 | 1.15 | 1.30 | 1.35 | 1.50 |
| Nd | 7.7 | 7.8 | 4.8 | 4.7 | 5.2 | 7.0 | 7.2 | 7.9 |
| Sm | 2.16 | 2.54 | 1.61 | 1.57 | 1.64 | 2.36 | 2.19 | 2.05 |
| Eu | 0.86 | 1.03 | 0.67 | 0.64 | 0.63 | 1.01 | 0.87 | 0.80 |
| Gd | 2.53 | 3.28 | 2.26 | 2.00 | 2.19 | 3.01 | 2.92 | 2.64 |
| Tb | 0.52 | 0.64 | 0.45 | 0.42 | 0.40 | 0.59 | 0.54 | 0.53 |
| Dy | 3.16 | 4.32 | 2.66 | 2.70 | 2.63 | 3.70 | 3.19 | 2.82 |
| Ho | 0.66 | 0.87 | 0.63 | 0.56 | 0.55 | 0.81 | 0.70 | 0.64 |
| Er | 1.82 | 2.63 | 1.83 | 1.66 | 1.63 | 2.32 | 1.97 | 1.76 |
| Tm | 0.29 | 0.39 | 0.30 | 0.27 | 0.25 | 0.37 | 0.30 | 0.31 |
| Yb | 1.69 | 2.31 | 1.72 | 1.58 | 1.63 | 2.11 | 1.89 | 1.73 |
| Lu | 0.25 | 0.37 | 0.29 | 0.24 | 0.26 | 0.34 | 0.30 | 0.28 |

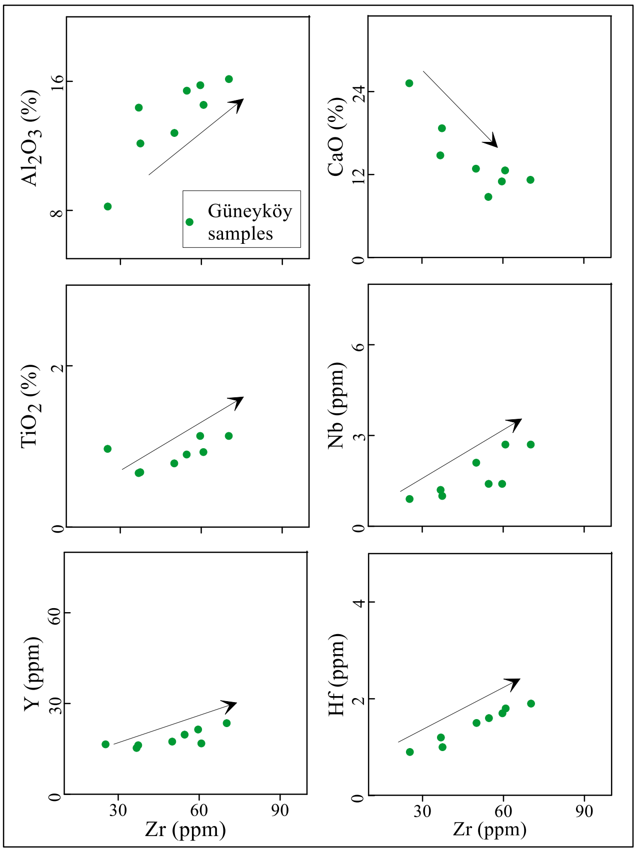


**Figure 5.** Binary variation diagrams of Zr versus selected elements.

According to N-type Mid-Ocean Ridge Basalt (MORB) normalized trace element distributions of rock samples (Figure 6a); 1) LIL elements (Sr, K, Rb, Ba and Th) are enriched according to HFS elements (Ta, Nb, Hf, Zr, Y, Ti), 2) HFS elements are parallel to MORB line but relatively poorer than MORB. Also, the samples were consumed in terms of Nb. The chondrite normalized rare earth element distributions of the rock samples ($La_N$ / $Sm_N$: 0.93-2.13; $La_N$ / $Lu_N$: 0.23-0.89) show that they are parallel to each other (Figure 6b). They have high Th/Yb ratios based on the plot of Nb/Yb vs. Th/Yb diagram (Pearce 2008) (Figure 7). They appear to be enriched a little more than N-MORB.

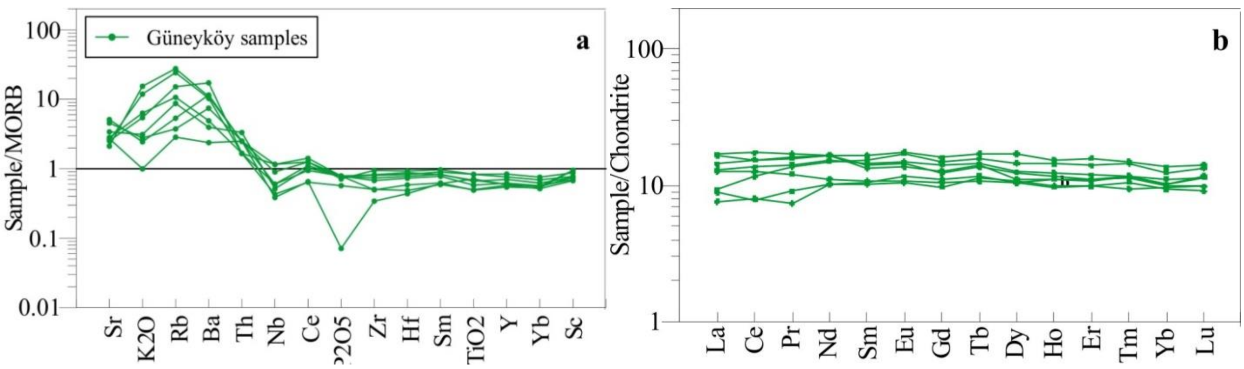


**Figure 6. a)** N-MORB and **b)** Chondrite- normalized spider diagrams for the rocks.
Normalization values for N-MORB and Chondrite are taken from Sun and McDonough (1989).

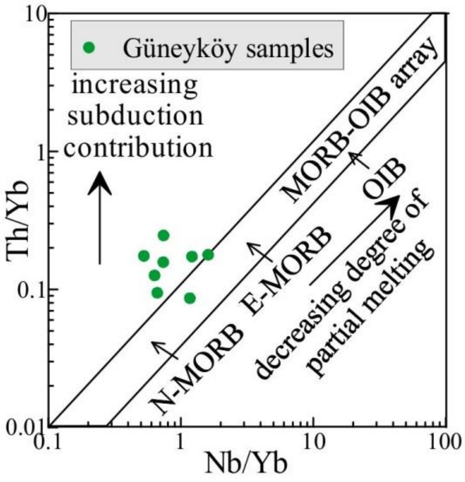


**Figure 7.** Nb/Yb vs. Th/Yb diagram (Pearce 2008) for the rocks.

## 4. Discussion and Conclusion

The volcanic units of the Yüksekova Complex cropping out in the Güneyköy (SE of Elazığ, E Turkey) area in Southeast Anatolia. The Yüksekova Complex is covered by Simaki Formation (Maden Complex) and Gehroz Formation (Hazar Group). This study reports the whole rock geochemical data of the Late Cretaceous basaltic volcanics. The rocks are massive in nature and display distinct pillow structures. The volcanics, which show spilitization in places, are basaltic in composition. The basaltic rocks are generally composed of plagioclase and pseudomorphosed olivine minerals. Hyalomicrolytic porphyritic, amygdaloidal and spherulitic textures are common. Calcite, chlorite and epidote are secondary minerals in the rocks.

The studied volcanic rocks have tholeiitic character. In binary plots, $TiO_2$, $P_2O_5$, Y, Nb, Hf and Th show positive correlation, whereas CaO, MgO, $Cr_2O_3$ and Sc show negative correlation with Zr content of the rocks, suggesting significant plagioclase, clinopyroxene, olivine and Fe-Ti oxide fractionation during the evolution of this volcanics. N-type mid-ocean ridge basalt-normalized trace element distributions of the studied rocks indicate enrichment in large-ion lithophile element (LILE) and Th, and negative anomalies in Ta, Nb, Ti and P elements. This may possibly indicate that the previous subduction event(s) together with the contributions of oceanic crust had played an important role in the magma genesis. The chondrite normalized diagrams of the rock samples show a parallel and approximately straight trend, suggesting a similar source for the volcanics.

The geochemical implications such as negative Nb anomaly, depleted HFS element abundances and enriched LIL element pattern indicate the contribution of subducting plate. As a result, the volcanic rock samples in the vicinity of Güneyköy (Elazığ) were formed in an intra-oceanic arc environment.

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# References

Akgül, M. (1991). Petrographic and Petrological Properties of Baskil Granitoid. *Geosound*, 18, 67 - 78.

Akgül, B. (1993). Petrographical and Petrological Features of Magmatic Rocks in the Vicinity of Piran Village (Keban). *Fırat University, Graduate School of Science and Technology*, Ph.D Thesis, 128p.

Akgül, B. (2015). Geochemical associations between fluorite mineralization and A-type shoshonitic magmatism in the Keban–Elazig area, East Anatolia, Turkey. *Journal of African Earth Sciences*, *111*, 222-230.

Altunbey, M., & Sağıroğlu A. (1995). Properties and origins of Koçkale-Elazığ manganese mineralizations. Bulletin of the Mineral Research and Exploration, 117, 139-148.

Barrett, T.J., & MacLean, W.H. (1999). Volcanic sequences, lithogeochemistry, and hydrothermal alteration in some bimodal volcanic-associated massive sulfide systems. *Reviews in Economic Geology*, 8, 101–113.

Çelik, H. (2003). Stratigraphic and Tectonic Features of Vicinity of Mastar Mountain (SE of Elazığ). Fırat University, Graduate School of Science and Technology, Ph.D Thesis, 95p.

Çelik, H. (2013). The Effects of Linear Coarse-Grained Slope Channel Bodies on the Orientations of Fold Developments: A Case Study from the Middle Eocene-Lower Oligocene Kırkgeçit Formation, Elazığ, eastern Turkey. *Turkish Journal of Earth Sciences*, *22*(2), 320-338.

Ertürk, M.A. (2016). Maden Complex (East Taurus-Turkey) Petrological Features. Fırat University, Graduate School of Science and Technology, Ph.D Thesis,130p.

Ertürk, M.A., Beyarslan, M., Chung, S.L., & Lin, T.H. (2018). Eocene magmatism (Maden Complex) in the Southeast Anatolian orogenic belt: Magma genesis and tectonic implications, *Geoscience Frontiers*, *9*(6), 1829-1847.

Göncüoğlu, M.C. (2014). Comments on a single versus multiarmed Southern Neotethys in SE Turkey and Iran. *3rd Intern. Symp. of IGCP 589 Development of the Asian Tethyan realm. Abstr. and Proceed*., 89-95.

Göncüoglu, M.C., Dirik K.., & Kozlu H. (1997). General characteristics of pre-Alpine and Alpine Terranes in Turkey: Explanatory notes to the terrane map of Turkey. *Ann. Géol. Pays Hellén*., 37, 515-536.

Hempton, M.R. (1985). Structure and deformation history of the Bitlis suture near Lake Hazar, southeastern Turkey. *Geological Society of American Bulletin*, 96, 233-243.

Hempton, M. R., & Savcı, G. (1982). Petrological and Structural Features of Elazığ Volcanic Complex. *Geological Bulletin of Turkey*, *25*(2), 143-151.

Kaya, A. (2004). Geology of Gezin (Maden-Elazığ) and Surrounding Area. Journal of Engineering Sciences, *10*(1) 41-50.

Kılıç, A.D. (2009). Petrographical and geochemical properties of plagiogranites and gabbros in Guleman ophiolite. *Maden Tetkik ve Arama Dergisi*, 139, 33-49.

Köküm, M., & İnceöz, M. (2018). Structural analysis of the northern part of the East Anatolian Fault System. *Journal of Structural Geology*, 114, 55-63.

Kürüm, S., Akgül, B., Önal, A. Ö., Boztuğ, D., Harlavan, Y., & Ural, M. (2011). An Example for Arc-Type Granitoids along Collisional Zones: The Pertek Granitoid, Taurus Orogenic Belt, Turkey. *International Journal of Geosciences*, *2*(03), 214.

Moghadam, H. S. Whitechurch, H., Rahgoshay, M., & Monsef, I. (2009). Significance of Nain-Baft ophiolitic belt (Iran): Short-lived, transtensional Cretaceous back-arc oceanic basins over the Tethyan subduction zone. *Comptes Rendus Geoscience*, *341*(12), 1016-1028.

Özkan, Y.Z., & Öztunalı, O. (1984). Petrology of the magmatic rocks of Guleman ophiolite. Tekeli, O. ve Göncüoğlu, M.C. (eds.), *Geology of theTaurus Belt, Proceedings*, 285-293.

Parlak, O., Höck, V., Kozlu, H., & Delaloye, M. (2004). Oceanic crust generation in an island arc tectonic setting, SE Anatolian orogenic belt. *Geological Magazine*, 141, 583-603.

Pearce, J.A. (2008). Geochemical fingerprinting of oceanic basalts with applications to ophiolite classification and the search for Archean oceanic crust, *Lithos*, 100, 14-48.

Perincek, D. (1979). The geology of Hazro-Korudağ-Çüngüş-Maden-Ergani-Hazar-Elazığ-Malatya Area, Guide Book, *The Geological Society of Turkey*, 33.

Rizeli, M.E., Beyarslan, M., Wang, K.L., & Bingöl, A.F. (2016). Mineral chemistry and petrology of mantle peridotites from the Guleman ophiolite (SE Anatolia, Turkey): Evidence of a forearc setting. *Journal of African Earth Sciences*, 123, 392-402.

Robertson, A.H., Ustaömer, T., Parlak, O., Ünlügenç, U.C., Taşlı, K., & Inan, N. (2006). The Berit transect of the Tauride thrust belt, S Turkey: Late Cretaceous – Early Cenozoic accretionary/collisional processes related to closure of the Southern Neotethys. *Journal of Asian Earth Sciences*, *27* (1), 108-145.

Ross, P.S., & Bedard, J.H., 2009. Magmatic affinity of modern and ancient subalkaline volcanic rocks determined from trace-element discriminant diagrams. *Canadian Journal of Earth Science,* 46, 823-839.

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

Sungurlu O., Perincek D., Kurt G., Tuna E., Dülger S., Celikdemir E., & Naz H. (1985). Geology of the Elazığ-Hazar-Palu area. *Bull. Turk. Ass. Petrol. Geol*., 29, 83-191.

Şaşmaz, A., Türkyılmaz, B., Öztürk, N., Yavuz, F., & Kumral, M. (2014). Geology and geochemistry of Middle Eocene Maden complex ferromanganese deposits from the Elazığ–Malatya region, eastern Turkey. *Ore Geology Reviews*, *56*, 352-372.

Şengör, A.M.C., & Yılmaz, Y. (1981). Tethyan evolution of Turkey: a plate tectonic approach.. *Tectonophysics*, 75, 181-241.

Tekin, U.K. Ural, M., Göncüoğlu, M. C. Arslan, M., & Kürüm, S. (2015). Upper Cretaceous Radiolarian ages from an arc–back-arc within the Yüksekova Complex in the southern Neotethys mélange, SE Turkey. *Comptes Rendus Palevol*, *14*(2), 73-84.

Ural, M. (2012). Petrochemistry, petrology and age of the basic volcanites of the Yüksekova Complex around Elazığ and Malatya, *Fırat University, Graduate School of Science and Technology*, Ph.D Thesis, 174p.

Ural, M., & Kürüm, S. (2009). Microscopic and Diffractometric Studies Inferred from Skarn Zonations Between the Keban Metamorphites and Elazığ Magmatites, Around Elazığ. *Turkish Journal of Science & Technology*, *4*(2), 87-102.

Ural, M., Göncüoğlu, M.C., Arslan, M., Tekin, U.K., & Kürüm, S. (2014). Petrological and paleontological evidence for generation of an arc-back arc system within the closing southern branch of Neotethys during the Late Cretaceous. *Bull. Shk. Gjeol., Special Issue* 2, 51-54.

Ural, M., Arslan, M., Göncüoğlu, M. C., Tekin, U. K. & Kürüm, S. (2015). Late Cretaceous arc and back-arc formation within the Southern Neotethys: whole-rock, trace element and Sr-Nd-Pb isotopic data from basaltic rocks of the Yüksekova Complex (Malatya-Elazığ, SE Turkey). *Ofioliti, 40* (1).

Ural, M., & Sarı, B. (2019). New Planktonic Foraminifera Data from the Upper Cretaceous Pelagic Limestones of the Yüksekova Complex in the Maden Area (Southeast of Elazığ, Eastern Turkey). In: IOP Conference Series: *Earth and Environmental Science*, *362*(1), p.012121.

Ural, M., & Kaya Sarı, M. (2019). Paleogeographic and Age Findings on Planktonic Foraminiferal Assemblages of Yuksekova Complex in the Northeast of Elazig (Eastern Turkey). In: IOP Conference Series: *Earth and Environmental Science*, *362*(1), p.012146.

Ural, M., Deniz, K., & Sayit, K. (2019). Mafic Volcanic and Subvolcanic Rocks from the Yüksekova Complex in the İçme-Kesikköprü Province (East of Elaziğ, Eastern Turkey): Whole-Rock Geochemistry and Confocal Raman Spectroscopy Characterization. In: IOP Conference Series: *Earth and Environmental Science*, *362*(1), p.012122.

Uysal, I., Kapsiotis A., Akmaz, M., Saka, S., & Seitz, M. (2018). The Guleman ophiolitic chromitites (SE Turkey) and their link to a compositionally evolving mantle source during subduction initiation. *Ore Geology Reviews*, 93, 98-113.

Winchester, J.A., & Floyd, P.A. (1977). Geochemical Discrimination of Different Magma Series and Their Differentiation Product Using Immobile Elements. *Chemical Geology*, 20, 325-343.

Yazgan, E. (1984). Geodynamic evolution of the eastern Taurus Region (Malatya-Elazıg area, Turkey). In: Tekeli, O., Göncüoğlu, M.C. (Eds.): Geology of the Taurus Belt. *Proc. of Int. Sym., Publ. of Min. Res. and Expl*. Inst. of Turkey, Ankara, 199-208.

Yılmaz, Y. (1993). New evidence and model evolution of the southeast anatolian orogen. *Geological Society of America Bulletin*, 105, 251-271.

Yılmaz, Y., Yiğitbaş, E., & Genç, S. (1993). Ophiolitic and metamorphic assemblages of southeast Anatolia and their significance in the geological evolution of the orogenic belt. *Tectonics, 12*(5), 1280-1297.