Petrochemical investigation of volcanics in Uşak regions (Western Anatolia), Turkey

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Introduction

In Uşak region in western Turkey (Fig 1), the Late Oligocene - Early-Middle Miocene volcanic rocks show calc-alkaline and shoshonitic characteristics. However, during the Late Miocene-Pliocene and Quaternary era, the rocks exhibit alkaline characteristics. Different tectonic models have been proposed for the origin of both the western Anatolian and Aegean Neogene magmatic rocks. They may classified as follows:

a) In the area, North-South extension began during the latest Oligocene-Early Miocene; therefore even early volcanism may be related to the extensional tectonic activity (Seyitoğlu et al., 1997).

b) Volcanic rocks were formed due to north-dipping subduction of the East Mediterranean ocean floor along the Hellenic trench (Fytikas et al., 1984; Pe-Piper and Piper, 1989).

c) Volcanic rocks were formed under different tectonic settings in different periods of time: Magmatism of Oligocene-Lower Miocene age, under the North-South compression regime, and magmatism formed later under the North-South extensional regime (Yılmaz 1989; Savaşçın and Güleç, 1990).

Uşak volcanic rocks (UV) were distinguished into five different groups from the north to south as follows: Dikendere (DKV), Karaboldere (KBV), Beydağ (BDV), Payamtepe (PYV) and Kula (KLV) volcanics (Fig.1). In Uşak and surrounding areas, the volcanic activity begins in the Early Miocene with the formation of normal fault systems, and continues till Quaternary time. It appears in Emet area, in the southern part of Uşak. The lavas isotopic age, determined

Fig.1. Spreading areas on Uşak Volcanics.
based on the K-Ar method, ranges from 20.3 ± 0.6 Ma to 18.9 ± Ma. Later volcanic activity was continued in the surroundings of Uşak. The K-Ar ages determined for these rocks are: 18.9 ± 0.6 Ma for DKV, 15.9 ± 0.4 Ma for KVB, 15.5 ± 0.4 Ma for BDV, 15.2 Ma for PYV and 7.55 ± 0.11 to 0.0025 Ma for KLV. (Ercan et al., 1985, Seyitoğlu et al., 1997)

**Method of Study**

The aim of this paper is to present detailed chemical data for the Uşak region volcanic rocks. First of all, during this study detailed geological mapping (1:25000 and 1:5000) was made before microscopic and chemical analysis has been performed. The mineralogical compositions of lavas and tuffs were qualitatively determined by both XRD (31 lavas and 12 tuff samples) and electron microprobe (4 samples). The chemical analysis of the lavas (20 samples) was performed by ICP-MS in Acme Analytical Laboratories Ltd., Canada (Table 1). Moreover, mineralogical composition and textural properties of 51 selected lava samples were analyzed by X-ray diffraction. Additionally, chemical analyses were carried out for 20 samples of tuffs by utilizing XRF in the Association of Turkey Cement Producers Laboratories, in Ankara.

**Chemical characteristics of the volcanic rocks**

**Major element characteristics and classification of volcanics**

Chemical analyses for major, trace and rare-earth elements on representative samples of the Uşak lavas were carried out. The results are presented in table 1. On the basis of SiO$_2$ wt. %-

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(Na$_2$O + K$_2$O) wt.% TAS classification diagram (Fig. 2a), Uşak lavas were classified as rhyolite (DKV), dacite, trachydacite and trachyandesite (KBV), dacite, trachyandesite (BDV), trachydacite (PYV) and trachybasalt and basalt (KLV). Uşak volcanic rocks have a significant compositional variation. Fe$_2$O$_3$, MgO, CaO, TiO$_2$ and P$_2$O$_5$ decrease with increasing SiO$_2$ (44.98-69.25 wt.%) but levels of Na$_2$O and K$_2$O increase with increasing SiO$_2$. Al$_2$O$_3$ ranges from 13.62 (wt.%) to 15.57 (wt.%) with increasing SiO$_2$ in the rocks. Comparing the chemical composition of the rocks of the various groups, significant differences have been observed between the Plio-Quaternary Kula lavas and the others.

![Diagram](image)

Fig. 2a. The Na$_2$O+K$_2$O (wt.%) vs. SiO$_2$ (wt.%) diagram b. N-Type MORB normalized multielement pattern for Uşak volcanic rocks.

**Trace element characteristics of volcanics**

In the variation diagrams of figure 3, where trace elements are plot against SiO$_2$, it is also shown that the chemistry of Kula lavas is quite different from the other volcanic rocks in the study area. Ba and Rb show positive relation with SiO$_2$ although with some scatter. The relation of Sr, Nb, and Cr with SiO$_2$ for Uşak volcanics is negative with much scatter.

Early Miocene aged Dikendere lavas have low concentration of Cr (95.78 -198.42 ppm) and V (53-62 ppm) while Middle Miocene aged lavas, have more abundances of Cr (maximum 711.57 ppm) and V (78-163 ppm). In the same rocks Nb as well as TiO$_2$ and P$_2$O$_5$ also increase from Early Miocene to Middle Miocene.

On the other hand the ratios of K/Ti and Th/Nb decrease from the Early Miocene to Middle Miocene aged volcanics with decreasing SiO$_2$ while the ratios of Nb/Y and Ti/Y increase. The chemistry of the rare earth elements shows that all light rare earth elements (LREE) are enriched and that patterns are almost flat from Ho to Lu. REE concentrations generally decrease with increasing SiO$_2$ contents. The enrichment of LREE begins with Early Miocene aged DKV and continues with the Middle Miocene volcanics. UV exhibits negative Eu anomaly. However, two samples that belong to Kula volcanics (AB23, 24) have positive Eu anomaly.

N-type MORB-normalized incompatible trace element concentrations for UV rocks have been plotted as multi-element pattern as seen in Figure 2b. The multi-element patterns for UV rocks demonstrates the significant enrichment in all large ion lithophile elements (LILE) Cs, Rb, Ba, Th, U, K and light rare element (LREE) relatively to the high strength element (HFSE), Ta, Nb, P, Zr, Hf, Ti and heavy rare earth elements (HREE). All Uşak volcanic rocks exhibit negative anomalies for Ta, Nb and P elements. However, Plio-Quaternary aged KLV rocks exhibit slightly enrichment in Rb, Th, U and K. In addition, some rock samples such as Early Miocene aged DKV (AB20, 21, 22) and Middle Miocene aged BDV (AB9, 13, 26) exhibit slightly negative anomalies in Ti. Early Miocene and some Middle Miocene aged volcanics (DKV: AB20, 21, 22, KBV: 6, BDV: 9, 13, 26) and Plio-Quaternary aged KLV (AB23, 24, 25) are more enriched in Zr and Hf than the other Middle Miocene aged rock samples such as (KBV: AB16, 17, 18, 19, 28 and PYV: 29, 30, 32).

**Conclusions**

The following major conclusions have been drawn based on petrochemical investigations car-
ried out for volcanic rocks of Üşak regions.

1. In Üşak area, volcanic activity continues from the Early/Mid-Miocene to the Plio-Quaternary. Major volcanic activity, which produced considerable volume of pyroclastic deposits, took place during the Early and the Middle Miocene. Volcanism was calc-alkaline in Early Miocene and became mainly alkaline and more mafic in Middle Miocene. It reached in sodic nature in Plio-Quaternary.

2. Early Miocene aged volcanic rocks have low concentration of MgO, Cr and V while the Middle Miocene aged volcanics have more abundance of MgO, Cr and V. The distinction between Early and Middle Miocene volcanic rocks is also apparent in trace element ratios such as Th/Nb, Nb/Y and Ti/Y. Middle Miocene lavas show considerable variation in Th/Nb (0.31-1.08), Nb/Y (0.5-3.44) and Ti/Y (189-659) ratios.

3. According to Seyitoglu et al., (1997), in the Middle Miocene, enrichment of a range of incompatible elements relative to OIB suggests an enriched lithospheric mantle source. The data of Usak lavas indicate two enrichment processes. The first process is a subduction-related enrichment while the second one is related to lithospheric mantle melts enriched by small degree melts of asthenospheric mantle.

4. Plio-Quaternary aged lavas (KLV) differ from the Middle Miocene aged K-rich lavas in having lower K2O/Na2O ratios and with low Th/Nb (0.18-0.26) but high Nb/Y (1.47-2.09) and Ti/Y (395-430) ratios. Plio-Quaternary aged Kula lavas show OIB-like trace elements patterns characterized by enrichment in LILE, HFSE, LREE and MREE and slight depletion in HREE relative to the N-MORB composition, which may represent asthenospheric melts contaminated on their ascent by previously enriched.

Fig. 3. Trace (ppm) elements vs. silica diagrams for Üşak Volcanics.

References


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