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Petrogenesis and $^{40}Ar/^{39}Ar$ geochronology of the volcanic rocks of the Uşak-Güre basin, western Türkiye

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ABSTRACT

In spite of much research over the past 30 years, the dynamic evolution, origin of the volcanism and geometrical–stratigraphical relations of the NE–SW-trending basins in western Anatolia are poorly understood. The Uşak-Güre basin is one of the prominent NE–SW-trending basins developed on the northern part of the Menderes Massif core complex. Three distinct volcanic successions are found in the Uşak-Güre basin: (1) the Beydağı volcanic unit composed of shoshonite, latites and rhyolitic lavas followed by dacitic and andesitic pyroclastic deposits; (2) the Payamtepe volcanic unit composed of potassic intermediate composition lavas (latites and trachytes); and (3) the Karaağaç dikes composed of andesite and latite. The Beydağı volcanic unit occurs in three different NE–SW-trending volcanic centers—Beydağı, İtecektepe and Elmadağ calderas from southwest to northeast, respectively. The oldest radiometric ages for the Beydağı volcanic unit are from the Elmadağ volcanic center in the north and range from 17 to 16 Ma. The data indicate that volcanism was active during the latest early Miocene. The youngest radiometric age for the Beydağı volcanic unit is obtained from the Beydağı caldera located (12 Ma) in the south. The data indicate that Beydağı volcanism was active in the late middle Miocene and migrated from north to south with time. $^{40}Ar/^{39}Ar$ ages of the Payamtepe volcanic unit are restricted to a short period between 16.0 and 15.9 Ma. Volcanic rocks of the Uşak-Güre basin are characterized by strong enrichment in LILE and LREE and depletions of Nb-Ta and Ti on MORB-normalized multi-element diagrams. Geochemical features of the volcanic rocks suggest that they experienced mixing processes between mafic and felsic end-members and also fractional crystallization of dominantly plagioclase and pyroxenes from mixed magma compositions. Crustal contributions to the magma sources may also have occurred during magmatic evolution. These processes have resulted in scattered major and trace element variations with respect to increasing silica contents. Geochemical features of the most mafic samples agree with the results of previous studies from other volcanic areas in western Anatolia, suggesting that the volcanic rocks in the region were derived from a mainly lithospheric mantle source that had been heterogeneously metasomatized by previous subduction events during convergence between the African and Eurasia plates. The volcanic activity in the region, which developed synchronously with the formation of the Menderes Massif core complex, is best explained by delamination of lithospheric mantle slices that were heterogeneously enriched by previous subduction-related processes.

1. Introduction

Following the Eocene collision between the Anatolide-Tauride block to the south and the Sakarya Zone to the north, the Neogene geodynamic evolution of the Anatolian-Aegean area was mainly controlled by (1) continental collision between Arabia and Eurasia to the east since the middle Miocene (ca. 13 Ma; McKenzie, 1978; Dewey et al., 1986; Jackson and McKenzie, 1988; Ring and Layer, 2003); (2) retreating subduction of the African plate under the Aegean-Anatolian plates along the Hellenic and Cyprean trenches (LePichon and Angelier, 1979; Jackson and McKenzie, 1988; Kreemer et al., 2003; Ring et al., 2010) followed by back-arc spreading (e.g. Boccaletti et al., 1974; LePichon and Angelier, 1979). According to van Hinsbergen et al. (2005), from the Early Cretaceous to the present, Africa–Eurasia convergence produced the continuous subduction of short alternating segments of continental and oceanic lithosphere; (3) post-collisional extensional processes as a consequence of the complex kinematic microplate interactions that developed after the latest Oligocene (Seyitoğlu and Scott, 1991, 1992).

The magmatism propagated from north to south with time and there were two major episodes (Yılmaz, 1989; Yılmaz et al., 2001; Aldanmaz, 2002). The first episode during the Eocene to Oligocene–Miocene times produced medium to high-K calk-alkaline granitoids and widespread volcanic rocks. The volcanic products of this phase

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have high $^{87}Sr/^{86}Sr$ and low $^{143}Nd/^{144}Nd$ ratios, characteristic of a subduction metasomatized lithospheric mantle source (Aldanmaz et al., 2000, 2009; Innocenti et al., 2005). The second episode is mildly alkaline in nature, displaying gradually decreasing amount of crustal contamination and was active during the Middle Miocene (16–14 Ma) (Aldanmaz et al., 2000; Altunkaynak, 2007; Dilek and Altunkaynak, 2007). During the late Miocene to Pleistocene, an OIB-type volcanism yielded mafic alkaline and finally sodic products (Güleç, 1991; Alıcı et al., 2002; Aldanmaz et al., 2009) that accompanied the most recent extensional phase in the Anatolian-Aegean region. The Late Miocene to Quaternary lavas have low $^{87}Sr/^{86}Sr$ and high $^{143}Nd/^{144}Nd$, indicating a sub-lithospheric mantle origin.

Innocenti et al. (2010) grouped the late Eocene–Holocene volcanic products in the Aegean region into three categories according to their geochemical–isotopic features and age distribution: group A, Late Miocene–Pleistocene alkali basalts which were generated in the sub-slab asthenosphere; group B, calc-alkaline rocks of the Pliocene–Holocene active arc (south Aegean active volcanic arc) which were generated in an asthenospheric supra-slab mantle wedge (e.g. Francalanci et al., 2005); and group C, high-K calcalkaline to shoshonitic rocks belonging to the Late Eocene–Middle Miocene belt.

Different hypotheses have been developed to describe the Cenozoic volcanism across the Aegean region-western Anatolia. One hypothesis postulates that the magmatism is directly related to subduction events (Fytikas et al., 1984; Okay and Satır, 2000; Agostini et al., 2007; Doglioni et al., 2009; Innocenti et al, 2010; Ring et al., 2010). The second hypothesis suggests that the magmatic events developed in response to a post collisional extensional tectonic regime with respect to the Eocene collision between the Anatolide-Tauride block and the Sakarya Zone (Yılmaz, 1989; Aldanmaz et al., 2000; Aldanmaz, 2002; Altunkaynak, 2007; Dilek and Altunkaynak, 2007).

According to the first view, Eocene to Quaternary volcanic rocks in the Aegean are the products of a single subduction system that migrated to the south over time (Fytikas et al., 1984; Okay and Satır, 2000; Agostini et al., 2007; Doglioni et al., 2009; Innocenti et al, 2010; Ring et al., 2010). Innocenti et al. (2010) claim that the geochemical differences among the Aegean volcanic rocks are not only closely related to different subduction enrichments but are also linked to different pre-subduction mantle features north and south. According to these authors, Eocene to Miocene volcanic rocks are the products of melting of a heterogeneously enriched lithospheric mantle on flatly subducted African oceanic lithosphere. The formation of the OIB-type volcanic rocks (such as Quaternary Kula volcanic rocks) is explained by slab tearing that allowed the rise of asthenospheric mantle.

The Neogene post-collisional extensional tectonic regime and related Cenozoic volcanism in western Anatolia has been described by three different models: (1) westward extrusion of the wedge-shaped Anatolian which is accommodated by two major faults: the right-lateral strike-slip North Anatolian Fault (NAF) and the left-lateral strike-slip East Anatolian Fault (EAF) (Şengör et al., 1985; Koçyiğit et al., 1999); (2) the difference between the velocity of the Greek microplate and that of the Anatolian microplate in overriding the African plate (Doglioni et al., 2002; Agostini et al., 2010); (3) postorogenic collapse, in which the Aegean–western Anatolian extension results primarily from 'gravitational collapse', following orogenic crustal shortening and overthickening within the Western Anatolian crust. During this postorogenic collapse, throughout the late Cenozoic, mid-crustal units of several metamorphic massifs were exhumed along low-angle detachment faults (Seyitoğlu and Scott, 1996; Gautier et al., 1999; Gessner et al., 2001; Işık and Tekeli, 2001; Jolivet, 2001; Lips et al., 2001; Sözbilir, 2001). Neogene exhumation of the metamorphic massifs formed the Menderes Massif Core Complex, on which several NE–SW-trending volcano-sedimentary basins were developed synchronously with the exhumation. One of the NE–SW-trending basins in the region is the Uşak-Güre basin, which is the major topic of this paper, located on the eastern side of western Anatolia (Fig. 1). The Uşak-Güre basin contains well-preserved Neogene volcanic units, whose geochemical characteristics have not yet been well documented.

2. Geological and volcanological settings

Western Anatolia is characterized by wide-spread Neogene continental volcanic activity that was accompanied by fluvio-lacustrine sedimentation in several continental basins. The volcanic rocks and related Neogene sediments rest on continental blocks and suture zone rocks which were amalgamated during Paleogene continental collision events. The continental blocks are the Anatolide-Tauride block to the south and the Sakarya Zone to the north, which were joined along the İzmir-Ankara Suture Zone. The suture zone represents the northern branch of the Neo-Tethys Ocean which was consumed by northward subduction beneath the Sakarya Zone, giving rise to development of the Pontide magmatic arc on the southern margin of Eurasian (e.g., Şengör and Yılmaz, 1981).

The volcanic rocks in western Anatolia are not restricted to the Neogene, as they were preceded by Eocene to Oligocene volcanic activity further north and succeeded by Quaternary intra-plate alkali-basaltic volcanism (Kula volcanic rocks) in the central part of the region. The origin and the evolution of the Eocene volcanism in the north are debated. Some authors claim that these volcanic rocks represent the beginning of the post-collisional volcanic activity in the region with respect to the collision between the Anatolide-Taurides and the Sakarya Zone (e.g., Dilek and Altunkaynak, 2007). On the other hand, it has recently been proposed that the Eocene magmatic activity may represent the end of subduction, as some granites show northward imbrications, which have been dated at 47.6 Ma (Lutetien) by zircon U-Pb ages (Ustaömer et al., 2009).

The Neogene volcanic rocks in the region developed in extensional basins. In western Anatolia, these basins mainly trend in a NE–SW-direction. The NE–SW-trending basins in the region were developed synchronously with exhumation of the mid-crustal units, namely, the metamorphic rocks of the Menderes Massif (Seyitoğlu and Scott, 1991; Helvacı and Yağmurlu, 1995; Yılmaz et al., 2000; Ersoy et al., 2010). Exhumation of the massif occurred initially by north-facing detachment faulting and later by high-angle normal faulting in an approximately N–S-directed extension. Therefore, the Neogene volcanic activity in these basins is post-orogenic extensional in nature. Subsequently, during the Plio-Quaternary, the high-angle normal faulting in the region gave rise to the development of nearly E–W-trending grabens which cut and offset the previously formed Neogene basins. The intra-plate Kula volcanic rocks were emplaced during this later stage. The eastern part of the NE–SW-trending basins, to the east of the exhumed Menderes Massif, is represented by the N–S-trending Kırka-Afyon-Isparta volcanic area (Fig. 1).

The main NE–SW-trending Neogene basins in the region are, from west to the east, the Bigadiç basin (Erkül et al., 2005), the Gördes basin, (Seyitoğlu and Scott, 1994), the Demirci basin (Yılmaz et al., 2000), the Selendi basin (Ersoy et al., 2010) and the Uşak-Güre basin (Ercan et al., 1978; Seyitoğlu, 1997). The volcanic activity in these basins is characterized by (1) early Miocene high-K calc-alkaline dacites and rhyolites and their pyroclastics with small amounts of shoshonitic and ultrapotassic-lamproitic occurrences (e.g., Erkül et al., 2005; Ersoy and Helvacı, 2007), (2) middle Miocene high-K calc-alkaline dacites and andesites with high-Mg shoshonitic to ultra-potassic lavas (Innocenti et al., 2005; Ersoy et al., 2008), (3) late Miocene K-trachybasalts (Innocenti et al., 2005) and (4) Plio-Quaternary strongly sodic-alkaline, OIB-type basic lavas (the Kula volcanic rocks, e.g., Alıcı et al., 2002).

The amount of the more mafic volcanic products in the region increases from early Miocene to Quaternary. This variation is mainly interpreted to result from lithospheric thinning in response to extension (e.g., Yılmaz, 1989, 1990; Seyitoğlu, 1997; Ersoy et al.,