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Mantle source characteristics and melting models for the early-middle Miocene mafic volcanism in Western Anatolia: Implications for enrichment processes of mantle lithosphere and origin of K-rich volcanism in post-collisional settings

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ABSTRACT

In Western Anatolia, early-middle Miocene post-collisional volcanism is represented by K-rich volcanic rocks; including calc-alkaline, high-K calc-alkaline, shoshonitic and ultrapotassic products. Low-SiO_2 and relatively high-MgO mafic volcanic rocks in the region are represented by high-K volcanic rocks (HKVR) in the west, where strike–slip tectonics related to the İzmir–Balıkesir Transfer Zone dominates, while shoshonitic and ultrapotassic volcanic rocks (SHVR and UKVR) occur in the eastern part of the region, where mid-crustal units were exhumed along detachment faults during orogenic collapse. All three rock groups have nearly identical Sr–Nd isotope ratios, but the SHVR and UKVR are more enriched in incompatible trace elements relative to the HKVR. Comparison of the geochemical characteristics of the most primitive lavas (SiO_2<55 wt.%, Mg#>65 and MgO>6 wt.%) provides an important tool in discussing the origin and evolution of the K-rich magmatic activity in this post-orogenic setting.

Geochemical features of the three rock groups require they were all derived from a primitive mantle-like source that, on the basis of Sr–Nd isotope mixing models, was supplemented by addition of 7–15% sediment components, including both sediment fluid and sediment melt. Low-degree partial melting (~5–10%) of this modified mantle source can account for the incompatible trace element budgets of the HKVR, but an additional trace element enrichment process is required to explain the compositions of the SHVR and UKVR. Numerical modeling suggests that this enrichment developed by multi-stage melting and melt percolation processes in a thicker metasomatized mantle lithosphere than that which produced the HKVR. This petrogenetic model accords with tectonic observations of lithospheric thickening from west to east in the area (where strike–slip deformation occurred to the west and regional uplift and exhumation occurred to the east). Hence, the first enrichment stage of the mantle source (HKVR plus SHVR and UKVR) is interpreted to be the result of subduction-related processes during southward retreat of the Aegean subduction system, with the second-stage of enrichment (SHVR and UKVR) developing in the mantle lithosphere during lithospheric extension.

1. Introduction

Igneous activity along converging plate margins is typically characterized by K-rich magmas with calc-alkaline, high-K calc-alkaline, shoshonitic and ultrapotassic affinities. Geochemical features of the igneous rocks in such geodynamic settings suggest that their origin involves a series of geochemical processes; including metasomatism of the mantle source by melts, and/or fluid fluxes from the descending slab (e.g., Pearce, 1982, 1983; Hawkesworth et al., 1991, 1995; Saunders et al., 1991; Elliott et al., 1997; Turner et al., 1997, 1999; Kelemen et al., 2004), variable degrees of melting of the metasomatized mantle (e.g., Pearce and Parkinson, 1993) and subsequent differentiation processes at shallower depths, such as magma mixing, assimilation and fractional crystallization (DePaolo, 1981).

In the eastern Mediterranean, Tertiary volcanic activity related to subduction or to post-collisional extension is commonly represented by K-rich, high-MgO orogenic magmatic rocks derived from heterogeneously enriched mantle lithosphere (e.g., Cvetković et al., 2004; Prelević et al., 2004, 2005, 2008; Prelević and Foley, 2007; Conticelli et al., 2009). It has been suggested that partial melting of clinopyroxene–amphibole–phlogopite veins in metasomatized mantle produces high-Mg, K-rich magmas with different degrees of silica saturation/under-saturation (e.g., Conticelli et al., 2009, and references therein).

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Western Anatolia (the easternmost part of the Mediterranean) is one of the best regions in the world in which to examine the origin and petrologic evolution of the post-collisional volcanic activity. In this region, the Sakarya Continent to the north collided with the Anatolide–Tauride continental fragment to the south along the İzmir–Ankara Suture Zone after the final consumption of the northern

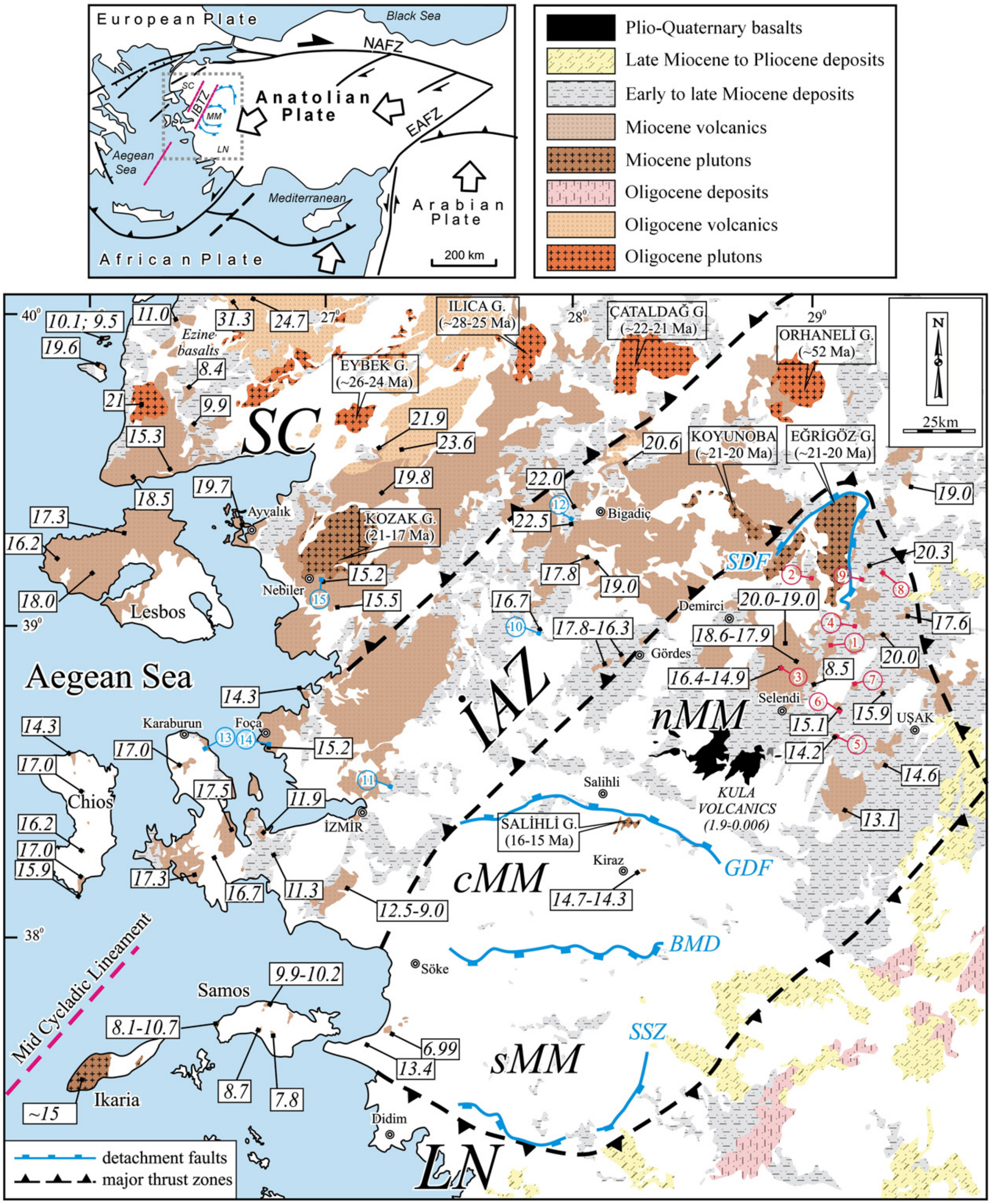

Fig. 1. Geological sketch map of the Neogene magmatic rocks and lacustrine deposits in Western Anatolia (modified from 1:500,000 scale Geological Map of Turkey (1:500000), 2002). The numbers in rectangles indicate the ages of the volcanics in Ma. The age data are from Borsi et al. (1972); Ercan et al. (1986, 1995); Helvacı (1995); Pe-Piper et al. (1995, 2009); Delaloye and Bingöl (2000); Aldanmaz et al. (2000); Emre and Sözbilir (2005); Innocenti et al. (2005); Erkül et al. (2005); Purvis et al. (2005); Pe-Piper and Piper (2007); Altunkaynak and Genç (2008); Ersoy et al. (2008); Boztuğ et al. (2009); Helvacı et al. (2009). The numbers in circles indicate the volcanic units investigated in this study: UKVR and SHVR (red circles): (1) Orhanlar basalt, (2) Naşa basalt, (3) Kuzayır lamproite, (4) Ilıcasu lamproite, (5) Güre lamproite, (6) Kıran basalt; (7) Zahman basalt, (8) Dereköy basalt, (9) Kestel volcanics; HKVR (blue circles): (10) Akhisar basalt, (11) Beşyol basalt, (12) Gölcük basalt, (13) Karaburun volcanics, (14) Foça mafic lavas, (15) Nebiler mafic lavas. The main tectonic units are also indicated with major thrust zones according to Okay and Tüysüz (1999). The tectono-stratigraphic units are: SC: Sakarya Continent; İAZ: İzmir–Ankara Zone; MM: Menderes Massif (separated as northern (n-), central (c-) and southern (s-) MM), LN: Lycian Nappes. Detachment faults are Simav (SDF), Gediz (GDF), Büyük Menderes (BMD) detachment faults and Selimiye shear zone (SSZ), from north to the south. NAFZ: North Anatolian Fault Zone, EAFZ: East Anatolian Fault Zone, İBTZ: İzmir-Balıkesir Trasfer Zone. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)