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Migrating magmatism in a continental arc: Geodynamics of the Eastern Mediterranean revisited

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ABSTRACT

The eastern Pontide orogenic belt in Turkey offers a critical region to evaluate the geodynamic evolution of the eastern Mediterranean region during the late Mesozoic–Cenozoic. Here we synthesize results from our exhaustive database on the geochemical characteristics of adakitic magmatism from 137 bodies covering 7 domains in the southern zone of eastern Pontides. Together with new Pb–Sr–Nd results, we show that the adakitic magmatism in the eastern Pontide belt is clearly linked to slab window processes during ridge subduction, as against the earlier models that assumed partial melting of a delaminated or thickened lower continental crust following collision. The isotopic compositions display a complex pattern and suggest mixing of multiple source materials such as depleted mantle, enriched lithospheric mantle, and upper crust. We also confirm a southward polarity of subduction as against the previous models that assumed a northward subduction. We supplement our model with evidence for a northward propagation of the adakitic magmatism, spatial and temporal variations in arc magmatism, presence of south-dipping reverse faults and a synthesis of the available paleomagnetic data. Our studies also suggest that the Black-Sea is a remnant of the Tethyan ocean that was situated to the north of the arc during the late Mesozoic–Cenozoic as against the correlation to a late Mesozoic–Cenozoic back-arc basin related to a northward subduction of the Paleo- or Neo-tethyan oceanic lithosphere in alternate models.

1. Introduction

The eastern Pontide orogenic belt geographically corresponds to the Eastern Black Sea Region of Turkey and is one of the most critical segments in evaluating the late Mesozoic–Cenozoic geodynamic evolution of the eastern Mediterranean region (e.g., Dewey et al., 1973; Adamia et al., 1977; Şengör and Yılmaz, 1981; Bektaş et al., 1984; Bektaş, 1987; Dilek et al., 2010; Eyuboglu, 2010). The southern zone of the eastern Pontide orogenic belt is characterized by three main magmatic cycles during late Cretaceous–early Eocene. The first cycle is represented by Campanian shoshonitic trachyandesites and associated pyroclastic rocks. The second cycle includes Maastrichtian–early Paleocene (?) analcimized leucite-rich ultrapotassic rocks. This high-K magmatism is followed by a late Paleocene–early Eocene adakitic magmatism (third cycle). Among these, the Campanian shoshonitic and Maastrichtian–early Paleocene (?) ultrapotassic rocks have been widely studied (e.g., Bektaş and Gedik, 1988; Bektaş et al., 1999; Altherr et al., 2008; Eyuboglu, 2010; Eyuboglu et al., in press-b). However, petrologic characteristics, geochemical affinities and geotectonic setting of the late Paleocene–early Eocene adakitic rocks exposed in the southern part of the Eastern Pontide orogenic belt have not been investigated in detail. Although some previous studies (e.g., Topuz et al., 2005; Karslı et al., 2010; Dilek et al., 2010) suggested that the adakitic rocks were formed by partial melting of a thickened or delaminated lower crust during the final collision following the northward subduction and closure of the Neotethys ocean between the Pontides and Taurides, the tectonic model has not been validated through detailed studies. Conversely, Eyuboglu et al. (in press-a, in press-b) suggested that the late Paleocene–early Eocene adakitic magmas in the eastern Pontide were formed by slab window processes in a southward subduction zone. According to these studies, the magmas also preserve evidence for fractional crystallization, assimilation and mixing processes during storage in the magma chambers in the crust–mantle transition zone and transfer into the overlying continental lithosphere.

The petrology, classification and geotectonic setting of adakites and associated rocks have received considerable attention in recent years as they provide important constraints on convergent margin

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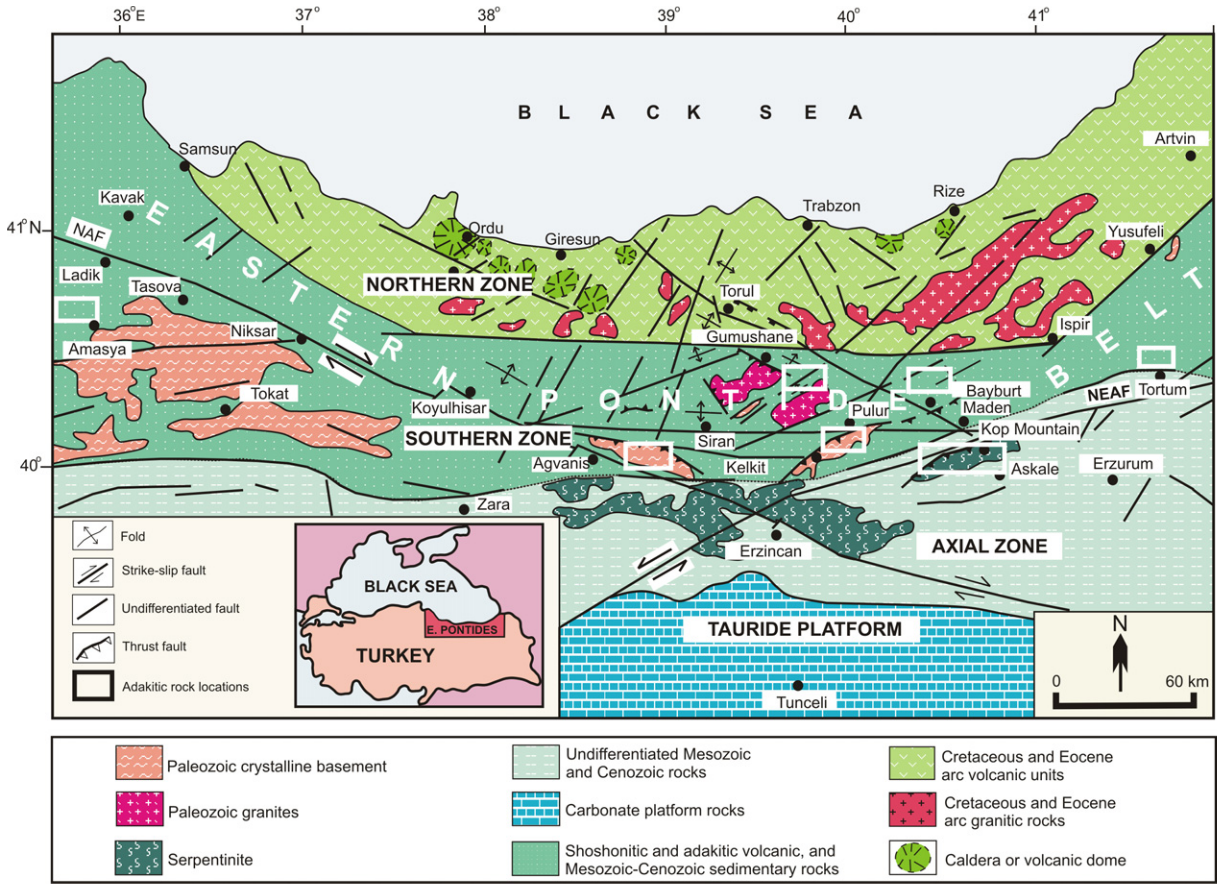

Fig. 1. Main tectonic features and tectonic zones of the eastern Pontide orogenic belt. NAF: North Anatolian Fault; NEAF: Northeast Anatolian Fault (after Eyuboglu et al., 2006).

processes (e.g., Defant and Drummond, 1990; Castillo et al., 1999; Xu et al., 2002; Chung et al., 2003; Thorkelson and Breitsprecher, 2005; Zhao et al., 2009; Yin et al., 2010). Adakite, named for rocks on the Adak island in the Aleutian island arc, is a term used to describe intermediate and silicic igneous rocks, which are characterized by high SiO_2 (>56 wt.%), Al_2O_3 (>15 wt.%), Na_2O (>3.5 wt.%), high Sr/Y and La/Yb of 40 and 20, respectively, low HFSE, $^{87}Sr/^{86}Sr$ usually <0.7040, and the presence of abundant plagioclase and amphibole phenocrysts. Magma generation is thought to be linked to the partial melting of hot and young (<25 Ma) subducted oceanic crust (Defant and Drummond, 1990). However, numerous documented examples of adakitic magmas in various geodynamic settings indicate that they do not necessarily conform to the thermal requirements associated with the subduction of young oceanic lithosphere (e.g., Castillo, 2006). Alternate models such as partial melting of thickened lower crust (Chung et al., 2003; Wang et al., 2005), partial melting of delaminated lower crust (Xu et al., 2002; Gao et al., 2004), assimilation and fractional crystallization processes involving basaltic magma (Feeley and Hacker, 1995; Castillo et al., 1999) and slab window processes related to ridge subduction (Thorkelson, 1996; Kinoshita, 2002; Thorkelson and Breitsprecher, 2005; Zhang et al., 2010; Eyuboglu et al., in press-a, in press-b), have also been invoked to explain their genesis.

In this paper, we synthesize our recent geochemical data (Eyuboglu, 2010; Eyuboglu et al., in press-a), together with some new geochronological and isotopic data for the late Paleocene–early Eocene adakitic rocks from the southern zone of the eastern Pontides. Our new interpretations from these results challenge some of the earlier models proposed for the origin of these adakites through northward subduction of the eastern Pontides during the late Mesozoic–Cenozoic. Based on the previous data together with our new results, we propose a new geodynamic model for the evolution of the eastern Mediterranean region and the origin of the Black Sea.

2. Geological background

The eastern Pontide orogenic belt is divided into three domains: the northern, southern and axial zones, distinguished from north to south by different lithological units, facies changes and tectonic characteristics (Bektaş et al., 1995; Eyuboglu et al., 2006). Each zone is separated by E-W-, NE-SW- and NW-SE-trending fault zones, which impart to the entire belt a block-faulted structural architecture (Fig. 1). The Northern Zone is characterized by Mesozoic–Cenozoic bimodal volcanic rocks and granitic intrusions. The late Cretaceous volcanism in this zone occurred in two different cycles (Eyuboglu, 2010), and is especially significant because it hosts several volcanogenic massive sulfide deposits such as those of Harkköy, Eseli, Kutlular, Köprübaşı, Murgul, Lahanos and Israildere (Akçay et al., 1998). The first cycle of the late Cretaceous volcanism (Turonian–Coniacian) started with basalt–andesite and grades upward into hematitic dacite–rhyodacite and associated pyroclastics interbedded limestone and marls (Eyuboglu, 2010). The units of the first cycle are covered by the Santonian units consisting of limestone interbedded with volcanoclastic rocks. The second cycle (Campanian–Maastrichtian) began with basaltic–andesitic rocks and continues with biotite-bearing rhyolite–rhyodacite and is overlain by Maastrichtian–Paleocene sandy limestone, biomicrite and marl alternations (Eyuboglu, 2010). The Hercynian basement is exposed in the Southern Zone, consisting of the Pulur–Ağvanis–Tokat metamorphic massif and Gümüşhane–Köse granitoids (Topuz et al., 2010; Dokuz, in press). Phlogopite and