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Geochemical and Sr–Nd–Pb isotopic compositions of the Eocene Dölek and Sariçiçek Plutons, Eastern Turkey: Implications for magma interaction in the genesis of high-K calc-alkaline granitoids in a post-collision extensional setting

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Abstract

The major and trace elements and Sr–Nd–Pb isotopes of the host rocks and the mafic microgranular enclaves (MME) gathered from the Dölek and Sariçiçek plutons, Eastern Turkey, were studied to understand the underlying petrogenesis and geodynamic setting. The plutons were emplaced at ∼43 Ma at shallow depths (∼5 to 9 km) as estimated from Al-in hornblende geobarometry. The host rocks consist of a variety of rock types ranging from diorite to granite (SiO_2 = 56.98–72.67 wt.%; Mg# = 36.8–50.0) populated by MMEs of gabbroic diorite to monzodiorite in composition (SiO_2 = 53.21–60.94 wt.%; Mg# = 44.4–53.5). All the rocks show a high-K calc-alkaline differentiation trend. Chondrite-normalized REE patterns are moderately fractionated and relatively flat [$(La/Yb)_N$ = 5.11 to 8.51]. They display small negative Eu anomalies (Eu/Eu* = 0.62 to 0.88), with enrichment of LILE and depletion of HFSE. Initial Nd–Sr isotopic compositions for the host rocks are ε_{Nd}(43 Ma) = −0.6 to 0.8 and mostly I_{Sr} = 0.70482–0.70548. The Nd model ages (T_{DM}) vary from 0.84 to 0.99 Ga. The Pb isotopic ratios are ($^{206}Pb/^{204}Pb$) = 18.60–18.65, ($^{207}Pb/^{204}Pb$) = 15.61–15.66 and ($^{208}Pb/^{204}Pb$) = 38.69–38.85. Compared with the host rocks, the MMEs are relatively homogeneous in isotopic composition, with I_{Sr} ranging from 0.70485 to 0.70517, ε_{Nd}(43 Ma) −0.1 to 0.8 and with Pb isotopic ratios of ($^{206}Pb/^{204}Pb$) = 18.58–18.64, ($^{207}Pb/^{204}Pb$) = 15.60–15.66 and ($^{208}Pb/^{204}Pb$) = 38.64–38.77. The MMEs have T_{DM} ranging from 0.86 to 1.36 Ga. The geochemical and isotopic similarities between the MMEs and their host rocks indicate that the enclaves are of mixed origin and are most probably formed by the interaction between the lower crust- and mantle-derived magmas. All the geochemical data, in conjunction with the geodynamic evidence, suggest that a basic magma derived from an enriched subcontinental lithospheric mantle, probably triggered by the upwelling of the asthenophere, and interacted with a crustal melt that originated from the dehydration melting of the mafic lower crust at deep crustal levels. Modeling based on the Sr–Nd isotope data indicates that ∼77–83% of the subcontinental lithospheric mantle involved in the genesis. Consequently, the interaction process played an important role in the genesis of the hybrid granitoid bodies, which subsequently underwent a fractional crystallization process along with minor amounts of crustal assimilation, en route to the upper crustal levels generating a wide variety of rock types ranging from diorite to granite in an extensional regime.

Keywords: Eastern Turkey; Granitoid rocks; Magma interaction; Mafic microgranular enclave; Radiogenic isotopes

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1. Introduction

As main components of the continental crust, granitoids are regarded as one of the key elements to understand the tectonics and geological evolution. They are genetically classified as peraluminous granitoids of crustal origin (e.g. Chappell and White, 1992; Chappell, 1999), alkaline granitoids of mantle origin (e.g. Turner et al., 1992; Han et al., 1997; Volkert et al., 2000) and calc-alkaline granitoids of mixed origin having various proportions of crust- and mantle-derived components (e.g. Poli and Tommasini, 1991; Barbarin and Didier, 1992; Wiebe, 1996; Altherr et al., 2000; Chen et al., 2002). It is likely that the latter represents a particular geological setting and provides greater information about the post-collisional magmatic processes in an extensional regime. Furthermore, the mafic–felsic interaction is an important part of the overall processes in calc-alkaline magmatism as revealed by rheological and geochemical data of coeval magmas (e.g. Barbarin and Didier, 1992; Wiebe, 1996) where the mafic components are represented by those MMEs within the host rocks (e.g. Vernon, 1990; Poli and Tommasini, 1991; Barbarin and Didier, 1992; Elburg, 1996). Therefore, they are commonly interpreted as magmatic precursors to interaction process and are regarded as potentially important tracer in understanding the hybrid calc-alkaline granitoid rocks. However, there are still some critical issues concerning the magma interaction that are open to debate: the petrogenetic processes responsible for the generation and chemical variation of the hybrid intermediate rocks, how the obstacles with chemical and physical origin that prevent the interaction of two distinct magmas are overcome at depth and the role and significance of MMEs that are commonly present in the hybrid magmas.

In the Eastern Pontides, several granitoid plutons were examined to identify the geodynamics of the region (e.g. Yilmaz, 1972; Yilmaz and Boztuğ, 1996; Okay and Şahintürk, 1997; Karsli et al., 2004a; Boztuğ et al., 2004; Topuz et al., 2005; Boztuğ et al., 2006; Dokuz et al., 2006), but little effort has been made to combine the tectonics and the petrological data in order to contribute to the understanding of the geodynamic evolution of the Eastern Pontides. The chemical, isotopic and geochronological data in the region are very limited. A wide spectrum of rock types from diorite to granite and MMEs are well exposed in the area that makes the Eocene Dölek and Sariçiçek plutons ideal candidates to evaluate the underlying processes of magma interaction. The current study aims to understand (i) the petrogenetic model responsible for the generation of young granitoid rocks and their source characteristics, (ii) origin of the MMEs, (iii) emplacement age of the plutons, and (iv) geodynamic setting of the plutons by the use of Sr–Nd–Pb isotopes, mineral and whole-rock chemical compositions and geochronological data.

2. Geological setting

Eastern Turkey is divided into five major tectonic blocks based on their geological and tectonic properties (Şengör et al., 2003). Rhodope–Pontide Fragment (RPF) is an EW-trending block (Fig. 1A), which is generally divided into a northern zone and a southern zone based on the differences between the rock associations (Akin, 1979; Okay and Şahintürk, 1997; Okay et al., 1997). The initiation of arc magmatism (Upper Cretaceous–Late Paleocene) is related to a northward subduction of the northern branch of Neotethys in the Eastern Pontides (e.g. Akin, 1979; Şengör and Yilmaz, 1981; Okay and Şahintürk, 1997; Yilmaz et al., 1997; Şengör et al., 2003) and the subsequent collision between the Pontides and the Tauride–Anatolide platforms, although the timing of the collision is still controversial (e.g. Robinson et al., 1995; Okay and Şahintürk, 1997; Şen et al., 1998; Şengör et al., 2003). Okay et al. (1997) suggested that the collision should date back to Late Paleocene to Early Eocene, based on field relationships and ages of granitoids. The basement of RPF consists of Devonian metamorphic rocks, Lower Carboniferous granitic and dacitic rocks, Upper Carboniferous–Lower Permian shallow-marine to terrigeneous sedimentary rocks and Permo-Triassic metabasalt–phyllite–marble (e.g. Yilmaz, 1972; Şengör and Yilmaz, 1981; Okay and Şahintürk, 1997; Yilmaz et al., 1997). The basement is overlain by Lower and Middle Jurassic tuffs, pyroclastic and interbedded clastic sedimentary rocks, and Upper Jurassic–Lower Cretaceous carbonates (Şengör and Yilmaz, 1981; Okay and Şahintürk, 1997). Late Mesozoic and Early Cenozoic times are recorded by ophiolitic melange, volcanic and granitoid plutons (e.g. Tokel, 1977; Yilmaz and Boztuğ, 1996; Boztuğ et al., 2004) and these are covered by Upper Paleocene–Lower Eocene major foreland flysch and Post Eocene terrigeneous units (e.g. Okay and Şahintürk, 1997).

The RPF extends for 450 km along the northeastern coast of Turkey (Fig. 1B) and consists of a series of granitoid bodies, which are parts of the composite Kaçkar Batholith, emplaced during Late Cretaceous to Late Eocene times. The granitoid bodies occurred in various geodynamic settings and have different ages (Taner, 1977; Moore et al., 1980) and compositions (Yilmaz and