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ScienceDirect
Chemie der Erde 69 (2009) 247–277
CHEMIE der ERDE GEOCHEMISTRY
www.elsevier.de/chemer

Mineralogy, whole-rock and Sr–Nd isotope geochemistry of mafic microgranular enclaves in Cretaceous Dagbasi granitoids, Eastern Pontides, NE Turkey: Evidence of magma mixing, mingling and chemical equilibration

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Received 12 March 2008; accepted 4 August 2008

Abstract

Rocks of the Late Cretaceous Dagbasi Pluton (88–83 Ma), located in the eastern Pontides, include mafic microgranular enclaves (MMEs) ranging from a few centimetres to metres in size, and from ellipsoidal to ovoid in shape. The MMEs are composed of gabbroic diorite, diorite and tonalite, whereas the felsic host rocks comprise mainly tonalite, granodiorite and monzogranite based on both mineralogical and chemical compositions. MMEs are characterized by a fine-grained, equigranular and hypidiomorphic texture. The common texture of felsic host rocks is equigranular and also reveals some special types of microscopic textures, e.g., oscillatory-zoned plagioclase, poikilitic K-feldspar, small lath-shaped plagioclase in large plagioclase, blade-shaped biotite, acicular apatite, spike zones in plagioclase and spongy-cellular plagioclase textures and rounded plagioclase megacrysts in MMEs. Compositions of plagioclases (An_{33}–An_{60}), hornblendes (Mg# = 0.77–1.0) and biotites (Mg# = 0.61–0.63) of MMEs are slightly distinct or similar to those of host rocks (An_{12-57}; hbl Mg# = 0.63–1.0; Bi Mg# = 0.50–0.69), which suggest partial to complete equilibration during mafic–felsic magma interactions.

The felsic host rocks have SiO_2 between 60 and 76 wt% and display low to slightly medium-K tholeiitic to calc-alkaline and peraluminous to slightly metaluminous characteristics. Chondrite-normalized rare-earth element (REE) patterns are fractionated (La_{cn}/Lu_{cn} = 1.5–7.3) with pronounced negative Eu anomalies (Eu/Eu* = 0.46–1.1). Initial $\varepsilon_{Nd(i)}$ values vary between −3.1 and 1.6, initial $^{87}Sr/^{86}Sr$ values between 0.7056 and 0.7067.

Compared with the host rocks, the MMEs are characterized by relatively high Mg-number of 22–52, low contents of SiO_2 (53–63 wt%), low ASI (0.7–1.1) and low to medium-K tholeiitic to calc-alkaline, metaluminous to peraluminous composition. Chondrite-normalized REE patterns are relatively flat [$(La/Yb)_{cn}$ = 1.4–3.9; $(Tb/Yb)_{cn}$ = 0.9–1.5] and show small negative Eu anomalies (Eu/Eu* = 0.63–1.01). Isotope signatures of these rocks ($^{87}Sr/^{86}Sr_{(i)}$ = 0.7054–0.7055; $\varepsilon_{Nd(i)}$ = –1.0 to 1.9) are largely similar to the host rocks. Gabbroic diorite enclaves have relatively low contents of SiO_2, ASI; high Mg#, CaO, Al_2O_3, TiO_2, P_2O_5, Sr and Nb concentrations compared to dioritic and tonalitic enclaves.

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 suggest that a basic magma derived from an enriched subcontinental lithospheric mantle, interacted with a crustal melt that originated from dehydration melting of the mafic lower crust at deep crustal levels.

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0009-2819/$ - see front matter
doi:10.1016/j.chemer.2008.08.002

The existence of compositional and textural disequilibrium and the nature of chemical and isotopic variation in these rock types indicate that magma mixing/mingling between an evolved mafic and a granitic magma was involved in their genesis. Microgranular enclaves are thus interpreted to be globules of a more mafic magma probably from an enriched lithospheric mantle source. Al-in-amphibole estimates the pluton emplacement at ca. 0.3–3.8 kbar, and therefore, magma mixing and mingling must have occurred at 3.8 kbar or below this level.

Keywords: Dagbasi Pluton; Mafic microgranular enclaves; Magma mixing/mingling; Geochemistry; Isotope systematic; Eastern Pontides

1. Introduction

Mafic microgranular enclaves (MMEs), occurring in most calc-alkaline granitoids, can provide significant information on the nature of the source rocks, the mechanism of production of granitic melt, as well as evidence of interaction between continental crust and mantle, and have been studied by many authors (e.g., Didier, 1973; Chappell et al., 1987; Chen et al., 1989; Dodge and Kistler, 1990; Didier and Barbarin, 1991; Barbarin and Didier, 1992; Kumar, 1995; Elburg, 1996; Maas et al., 1997; Silva et al., 2000; Waight et al., 2000, 2001; Perugini et al., 2003; Kumar and Rino, 2006). However, there are considerable discrepancies between the models proposed to explain the origin of MMEs. There are three main petrogenetic hypotheses of mafic microgranular enclaves interpreted as: (1) restite, corresponding to source residual material left unmelted during crustal anatexis responsible for the generation of granitoid magmas (Chappell et al., 1987); (2) cumulate, representing preferential accumulation of mafic minerals in enclaves (Clemens and Wall, 1988); and (3) mafic liquids, corresponding to globules of mafic magmas, generally hybrid magma intruded within evolved felsic liquids while it was stil partially liquid (Didier and Barbarin, 1991; Gerdes et al., 2000; Perugini et al., 2003).

Several granitoid outcrops are widely exposed in eastern Pontides (Fig. 1A) and many of them contain enclaves. Although numerous granitoid plutons have been extensively studied in terms of geochemistry and petrology, not much work was done for geochemical and petrological features of mafic microgranular enclaves in eastern Pontides. The Dagbasi Pluton is one of them that are containing the mafic microgranular enclaves.

This paper presents new petrographical, geochemical and Sr–Nd isotopic evidences as well as field observations and mineral chemistry of mafic microgranular enclaves and host granites from the Dagbasi Pluton in the eastern Pontide magmatic arc.

2. Geological setting

Turkey is an essential component of the Alpine–Himalayan orogenic system. It includes a number of tectonic blocks separated by suture zones, formed by the closure of the different branches of the Neo-Tethyan ocean during the Late Cretaceous–Eocene (Şengör and Yılmaz, 1981) (Fig. 1B). The Eastern Pontides are commonly subdivided into a northern zone and a southern zone based on the differences between structural and lithological differences (Fig. 1C) (Özsayar et al., 1981; Okay and Şahintürk, 1997). Late Cretaceous and Middle Eocene volcanic and volcaniclastic rocks dominate the northern zone, whereas pre-Late Cretaceous rocks are widely exposed in the southern zone. The volcanic rocks of the Eastern Pontides lie unconformably on a Palaeozoic heterogeneous crystalline basement that consists of metamorphic sequences of varying metamorphic grades, and is crosscut by granitoids of Permian age (Yılmaz, 1972; Çoğulu, 1975; Okay and Şahintürk, 1997; Topuz et al., 2004). Volcanic and volcano-sedimentary rocks of Liassic–Dogger age lie unconformably on the basement. They are overlain conformably by Dogger–Malm–Cretaceous carbonates. Sediments and volcanic rocks in the southern and northern parts of the Eastern Pontides dominate the Upper Cretaceous series, respectively, and are unconformably overlying the carbonate rocks. Some plutonic rocks (Fig. 1A) were emplaced between Jurassic and Palaeocene time (Okay and Şahintürk, 1997; Yılmaz et al., 1997). Subduction-related arc magmatism is recorded by Senonian submarine volcano-sedimentary units and associated plutonic rocks. The Eocene rocks, mainly volcanics and rarely volcanoclastics and sediments, unconformably overlie the Upper Cretaceous series, indicating that the Eastern Pontides were above sea level during the Palaeocene–Early Eocene, presumably due to collision between the Eastern Pontides and the Anatolide–Tauride basement along the İzmir-Ankara-Erzincan Suture Zone (Okay and Şahintürk, 1997). The Eocene–Neogene volcanic rocks are calc-alkaline to alkaline in composition, although there are lithological and chemical variations between the rocks exposed in the Northern Zone relative to those exposed in the Southern Zone (Arslan et al., 1997; Şen et al., 1998; Arslan et al., 2000). Several granitoids (Fig. 1A) belonging to this magmatic episode intrude the Eocene volcanic and volcaniclastic rocks. Post-Eocene uplift and subsequent erosion have maintained the clastic