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Geochemistry of post-collisional mafic lavas from the North Anatolian Fault zone, Northwestern Turkey

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Abstract

Extensive magmatic activity developed at the northwestern part of the Anatolian block and produced basaltic lavas that are situated along and between the two segments of the North Anatolian Fault zone. This region is a composite tectonic unit formed by collision of continental fragments after consumption of Neotethyan ocean floor during the late Cretaceous. Northwestern Anatolian basalts and evolved lavas exhibit both tholeiitic and calc-alkaline characteristics. Mafic lavas are moderately enriched in LILE (except depleted part of Yuvacık and İznik samples) and depleted in HFSE (but not Zr, Hf) relative to primitive mantle values, suggesting derivation from a MORB-like mantle source that is unexpected in this subduction environment. Sr and Nd isotopes are close to the mantle array and vary beyond analytical error ($^{87}Sr/^{86}Sr$ 0.70404–0.70546, $^{143}Nd/^{144}Nd$ 0.51270–0.51289). These geochemical features may result from two possible processes: (1) melting of a MORB-like mantle source that was modified by subduction-released fluids and melts or (2) modification of mafic liquids derived from a dominantly MORB-like source by crustal or lithospheric mantle material. Geochemical characteristics of the lavas (e.g., Ba/Rb, Rb/Sr, Ba/Zr, $^{87}Sr/^{86}Sr$, Sr/P) vary systematically along the fault zone from east to west, consistent with a decrease in the degree of melting from east to west or a change in the nature of the source composition itself. Thus, the difference in incompatible elements and Sr–Nd isotopic ratios seems to result from small-scale mantle heterogeneity in a post-collisional tectonic environment.

Keywords: Basalt Geochemistry; Northwestern Anatolia; Geochemical melting model; Mafic lavas; Northern Anatolian Fault (NAF)

1. Introduction

Extensive magmatic activity that developed at northwestern part of Anatolian block produced basaltic lavas presently situated along and between the two segments of North Anatolian Fault (NAF) zone from Gölcük in the east to Armutlu in the west (Fig. 1). The Armutlu peninsula is a composite tectonic unit formed by the collision of the Sakarya and Rhodope-Pontide continental fragments, after the total consumption of Neotethyan ocean floor during the late Cretaceous (Genç and Yılmaz, 1997). The northern margin of Sakarya underwent progressively increasing deformation prior to and during the advancing collision, reflecting continued convergence between the two continents (Yılmaz et al., 1995). Following the collision,

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the Armutlu–Ovacık zone underwent extensional tectonism between the late Cretaceous and early Eocene. During this phase, strike-slip tectonics also affected the region (Yiğitbaş et al., 1995). The collision-related geological events persisted until the end of the early Eocene. Middle Eocene ophiolites, metamorphics and sandsones formed under a new tectonic regime and now blanket these earlier units (Yiğitbaş et al., 1999).

Tectonically active regions can produce mafic lavas that reflect several geochemical processes. Magmatic compositions can indicate the nature of the source region(s), but can also be affected by processes associated with melt segregation, ascent and emplacement. The volcanic products of Northwestern Anatolia are dominantly basalts and basaltic andesites with minor basaltic trachyandesites and andesites; they exhibit both calc-alkaline and tholeiitic characteristics. These products have complex geochemical features that likely result from the changing tectonic environment in which they were derived and emplaced.

A recent study by Genç and Yılmaz (1997) proposed that these rocks were derived from a LIL-enriched mantle source as a consequence of convergence-related magmatism but the limited number of trace elements, the lack of isotopic data and radiometric age determinations make it impossible to rule out alternative interpretations for the genesis of the basaltic products. We present new trace and rare earth element (REE) data, Sr–Nd isotopic ratios and $^{40}Ar/^{39}Ar$ age determinations on a suite of Northwestern Anatolian lavas which, together with geochemical modeling, provide further insight into the origin of the basaltic products and the nature and structure of the mantle source(s). We also model changes in the source composition or the rates of geochemical processes that may be responsible for the magmatic development during the complex tectonic history of this region. In particular, we explore the possible roles of lithospheric foundering and slab melting in contributing to the geochemical character of the erupted lavas.

2. Geological background

The geology of the study region is detailed by Yılmaz et al. (1995) and is only summarized here. The study region contains three main tectonic units: the Rhodope-Pontide and Sakarya continental fragments, and the intervening Intra-Pontide suture (Fig. 1). The Armutlu peninsula is a narrow, linear east–west trending mountain range extending between the two fault-controlled gulfs and two lakes formed along North Anatolian Fault zone (Yılmaz et al., 1995). The region lying south of the Sea of Marmara is generally referred to in the geological literature as Sakarya continent (Fig. 1) (Şengör and Yılmaz, 1981).

The Rhodope-Pontide fragment comprises metamorphic assemblages consisting of amphibolite, hornblende

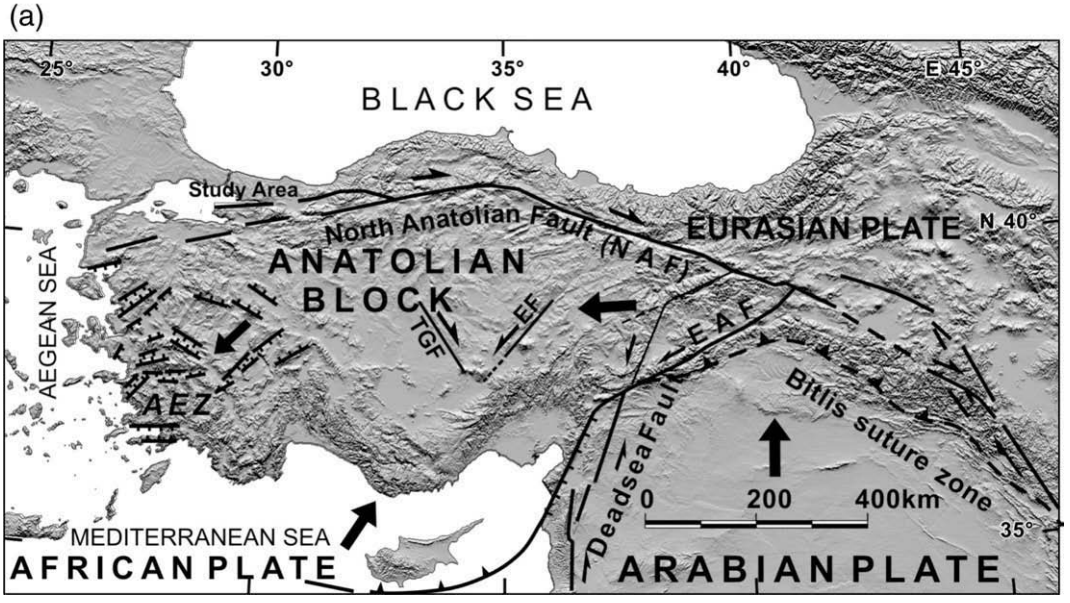

Fig. 1. Tectonic and geological setting of the study area. (a) Neotectonic map of the Anatolian block. Major faults and the study area are placed on a digital elevation model of Anatolia, adapted from Köse (2000). AEZ: Aegean Extension Zone; NAF: North Anatolian Fault; EAF: East Anatolian Fault; EF: Ecemiş Fault; TGF: Tuz Gölü Fault. Black arrows indicate the direction of plate motion; black half arrows show the relative direction of motion on the faults. (b) Geological and main structural map of the study region, simplified from Genç and Yılmaz (1997).