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Petrogenesis of mafic–silicic lavas at Mt. Erciyes, central Anatolia, Turkey

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ABSTRACT

New compositional data are presented for a suite of basaltic andesite to rhyolite flows from the flanks of the Pliocene–Quaternary Mt. Erciyes stratovolcano in Central Anatolia, Turkey. The samples are all part of the most recent (<0.9 Ma) New Erciyes eruptive phase. Temperatures estimated from FeTi-oxides vary from ~1000 °C in the andesites to ~820 °C in the rhyolites, while the dacites preserve a very broad temperature range (~620 °C–1020 °C), consistent with textural and mineral chemistry evidence for their hybrid nature. Oxygen fugacity is about NNO +1 for most samples. The whole rock compositional data, in conjunction with published data, reveal two distinct trends, one formed by the mafic samples (basalts to basaltic andesites) and one by the silicic samples (andesites–dacites–rhyolites). All Erciyes samples plot above the MORB-OIB array on a Nb/Yb–Th/Yb plot, consistent with involvement of subduction-modified mantle, and their low MREE/HREE ratios imply melting of garnet-free mantle. Ratios of incompatible trace elements demonstrate that the basaltic andesite flows are not related to the basalt flows by closed-system fractional crystallization, but instead are derived from a more enriched mantle source, given their higher La/Sm and lower Zr/Nb. The silicic lavas all have higher Th/Nb than the mafic samples, indicating more extensive crustal assimilation. The silicic lavas show linear compositional trends for major elements and most trace elements for SiO_2 contents between 56 wt.% and 72 wt.% that are attributed to mixing processes, consistent with textural observations and mineral data particularly in the intermediate dacite flows (two distinct plagioclase phenocryst populations — clear $An_{33–53}$ cores vs. sieve-textured cores of $An_{59–80}$; wide compositional range for orthopyroxene phenocrysts — Mg# from 63 to 90). We infer that basaltic melts of a heterogeneous, shallow mantle source ponded in the mid- to lower-crust and underwent variable differentiation accompanied by crustal assimilation to form more evolved melt compositions with SiO_2>~55 wt.%. These melts ascended to shallower crustal levels (4–10 km based on amphibole geobarometry) where mixing of diverse melts and entrained crystals gives rise to the linear mixing trends shown by the erupted andesite–dacite–rhyolite lavas.

1. Introduction

Pliocene–Quaternary magmatism in the Central Anatolian volcanic province in Turkey is dominated by two stratovolcanoes (Erciyes and Hasandag: Fig. 1) plus numerous monogenetic centers (e.g. Innocenti et al., 1982). Geodynamic models for the origin of magmatism in Central Anatolia are not well-established, although it is clearly related to the tectonic consequences of the ongoing collision between the Arabian and Eurasian Plates (e.g. Pasquare et al., 1988). Magma compositions show a clear trace element signature of subduction processes (Pearce and Peate, 1995), but this is probably inherited from earlier episodes of subduction and lithospheric assimilation rather than from any active subduction (e.g. Notsu et al., 1995; Deniel et al., 1998; Kürkçüoglu et al., 1998). The locations of the main stratovolcanoes are associated with major fault systems (e.g. Toprak, 1998; Dilek and Sandvol, 2009), and the driving force behind the volcanism appears to be the extensional tectonics that results from westward movement of the Anatolian Plate bounded by two major strike-slip faults (North Anatolian Fault and East Anatolian Fault: Fig. 1; e.g. Sen et al., 2004).

In this study, we present new compositional analyses (whole rock and mineral analyses) on a suite of basaltic andesite to rhyolite samples from Mt. Erciyes. Intensive parameters (temperature, pressure, oxygen fugacity) are estimated from mineral compositional data on selected eruptive units. These data on pre-eruptive conditions are used together with whole rock compositional variations to evaluate models for the generation of these more evolved rock types within the CAV, and to determine

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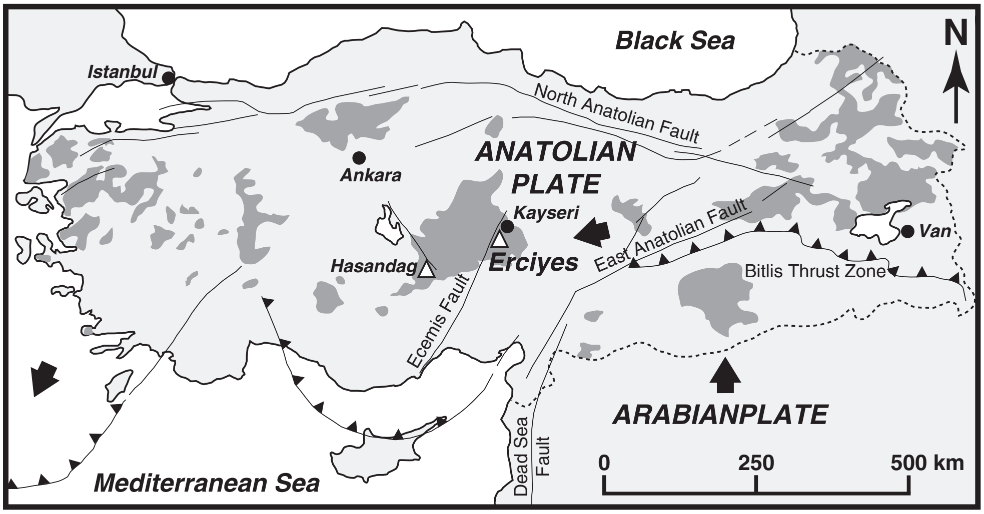

Fig. 1. Location map showing the regional tectonic setting of Mt. Erciyes in the central Anatolian region of Turkey (from Temel et al., 1998). Gray shaded areas = Neogene–Quaternary volcanism; thin black lines = regional faults.

their petrogenetic relationship to the mafic magmatism in the area. Previous studies (e.g. Notsu et al., 1995; Kürkçüoglu et al., 1998, 2001; Sen et al., 2002; Kürkçüoglu et al., 2004; Dogan et al., 2011) have suggested that the evolved andesite–dacite–rhyolite flows formed predominantly by fractional crystallization from basaltic magmas, accompanied by minor crustal assimilation, while textural and mineral compositional data for dacitic lavas from the summit region indicate an important role for magma mixing processes (Dogan et al., 2011).

2. Samples and analytical techniques

The Pliocene–Quaternary Erciyes stratovolcano developed in two stages: the Kocdag stage (4.4 to 2.6 Ma) and the New Erciyes stage (mainly 0.9 Ma to present) (e.g. Notsu et al., 1995; Kürkçüoglu et al., 1998; Sen et al., 2003). Mt. Erciyes was built from pyroclastic deposits and lava flows, whose compositions are mainly calc-alkaline andesites, dacites, and rhyolites, with minor amounts of basaltic lavas. Samples of lava domes and flows were collected from outcrops related to the recent New Erciyes stage (Unsal, 2005; Yesilyurt, 2006). Three areas were sampled (Fig. 2): #1, the eastern flanks of Mt. Erciyes (within ~4 km of the summit) — these samples are dominated by dacites, plus two andesites; #2, the area to the east of the Perikartin rhyodacite dome (~7 km NNE of the summit) — these samples span the range from andesites to rhyolites; and #3, the Bozdag area (~14 km due east of the summit) — these samples are basaltic andesites and dacites. Development of a detailed eruptive chronology at Erciyes is still in its early stages, and the exact stratigraphic relationships between the three sampled areas are still uncertain.

A suite of 51 samples were analyzed for major and trace elements by ICP-AES and ICP-MS at AcmeLabs, Vancouver, Canada (Table 1). Samples were powdered in a mild-steel ring-and-puck mill at AcmeLabs. A 0.2 g aliquot of powder was mixed with 1.5 g of a mixed lithium metaborate–tetraborate flux and fused in a graphite crucible at 980 °C for 30 min, and the resulting glass bead was dissolved in 5% HNO_3. Estimates of the analytical reproducibility at AcmeLabs can be found in Dogan et al. (2011). Analyses of touching magnetite and ilmenite pairs were measured with a JEOL JXA-8900R Superprobe electron microprobe at the University of Minnesota, using a 15 kV accelerating voltage and a 20 nA beam current (Table A1). Compositions of mafic minerals (orthopyroxene, clinopyroxene, and amphibole) were measured either with a Cameca SX-100 electron microprobe at Oregon State University (15 kV accelerating voltage, 30 nA beam current) or a Cameca SX-50 electron microprobe at the University of Chicago (15 kV accelerating voltage, 50 nA beam current) (Table A2).

3. Results

3.1. Sample classification and petrography

The Erciyes lavas in this study are classified mainly as dacites, with a few basaltic andesites, andesites, and rhyolites, based on the total alkali–silica diagram (Fig. 3A: Le Bas et al., 1986). The SiO_2–K_2O diagram (Fig. 3B: Peccerillo and Taylor, 1976) shows that they are medium-K calc-alkaline lavas, and their calc-alkaline nature is indicated from the AFM ($Na_2O + K_2O$, FeO, MgO) diagram (not shown) of Irvine and

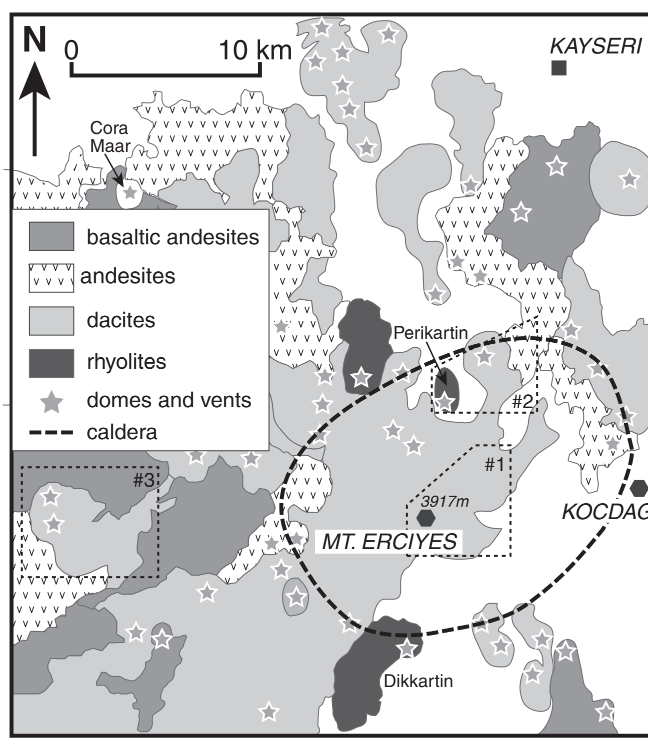

Fig. 2. Simplified geological map of Mt. Erciyes (after Sen et al., 2003), showing the distribution of lava types erupted during the New Erciyes stage. Areas left white are covered by pyroclastic deposits and debris avalanches from the New Erciyes stage, and by magmatic products from the earlier Kocdag stage. Boxes outline the three sampled areas (#1, #2, #3). See Table 1 for sample location grid references.