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Palaeomagnetic study of the Karacadağ Volcanic Complex, SE Turkey: Monitoring Neogene anticlockwise rotation of the Arabian Plate

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ABSTRACT

The Karacadağ Volcanic Centre in south east Turkey is a major basaltic complex sited at the northern margin of the Arabian Plate and emplaced in several pulses between ~11 Ma and Late Quaternary times. We have sampled 71 sites in lavas of this complex to constrain the palaeomagnetic record and hence the chronology of magmatic activity and regional rotation. Palaeomagnetic study at sixty two sites yields significant component definition with mixed normal and reversed polarities. From age dating and morphologic criteria we identify three major episodes of lava emplacement and site mean directions of magnetisation for these divisions resolve migration of the palaeofield direction for the northern sector of the Arabian Plate since mid-Miocene times. Successive (reversed polarity) group mean directions are: D/I = 175°/−50.5° (N = 37, R = 33.13, α_{95} = 4.1°) for the oldest (Siverek) division (mean age estimate 11.1–6.7 Ma), D/I = 173.4°/−46.0° (N = 16, R = 15.67, α_{95} = 5.5°) for the middle (Karacadağ) division (mean age 3.3 Ma) and D/I = 167.7°/−47.6° (N = 6, R = 5.93, α_{95} = 7.9°) for the youngest (Ovabağ) division (~1.9 Ma — present). The first two results merit a tectonic interpretation and consistent anticlockwise rotation of ~9° is recognised in the Karacadağ Volcanic Centre between ~11 and 3.3 Ma. The mean directions conform to palaeomagnetic results from other undeformed Neogene igneous complexes of comparable age range further to the west along the northern perimeter of the Arabian Plate. The amount of tectonic rotation observed in Late Pliocene and older volcanic units from this plate is found to be statistically-constant. Tectonism responsible for rotation therefore appears to have been temporally-confined to the last ~2 Myr which is long after collision with the Anatolides and closure of the Bitlis suture. This conclusion conforms to the young distributed block rotations recognised in the Anatolides and Aegean and correlates with the regime of tectonic escape of terranes to the west.

1. Introduction

Closure of the Neotethys Ocean resulted in ophiolite obduction at the northern margin of the Arabian Plate during Late Cretaceous times followed by successive accretion of terranes to the southern margin of Eurasia with the latter now comprising the Anatolides (Şengör and Yılmaz, 1981). Terminal collision between Arabia and the Anatolides in the Cenozoic produced a complex curved suture zone extending as a ~2500 km-long south-vergent (Bitlis–Zagros) fold belt (Fig. 1). A consequence of this collision was the formation of an extensive (~150,000 km^2) eastern Anatolian–Iranian plateau uplifted in Serravalian times at ~13–11 Ma and now with an average elevation of 2 km above sea level (Gelati, 1975; Şengör and Kidd, 1979). Continuing indentation of Arabia into the Anatolian accretionary collage and northward subduction of Tethys oceanic lithosphere has resulted in westward extrusion of terranes within the relatively-weak sector of crust between the two major transform fault zones comprising the North Anatolian Fault Zone (NAFZ) and the East Anatolian Fault Zone (EAFZ, Şengör and Yılmaz, 1981; Bozkurt, 2001; Gürsoy et al., 2009 and Fig. 1). Uplift of the Eastern Anatolian–Iranian high plateau has occurred in parallel with formation of N–S fault sets defining rifts ('impactogens') on the Arabian Platform; these are interpreted and appeared to be the signature of E–W extension related to N–S shortening during ongoing compression (Şengör and Yılmaz, 1981).

The magnitudes of regional deformations within the orogen are quantified from palaeomagnetic studies providing a comparison of contemporaneous magnetisation directions between the Arabian Plate, the deformed terranes of Anatolia, and the Eurasian Plate to the north. Extrusive igneous rocks usually provide the most effective palaeomagnetic record and a varied temporal and spatial magmatic response has accompanied the crustal thickening across this region since the Early Miocene (e.g., Ekici et al., 2007; Notsu et al., 1995; Pearce et al., 1990). The post-collision era embracing the Neotectonic history includes the intermittent but widespread volcanism across Eastern Anatolia since Oligo-Miocene times (Yılmaz, 1978, 1990). With the notable exception of the Cappadocian ignimbrite province (Piper et al., 2013), this has been dominated by large stratovolcanoes with eruption of predominantly calc-alkaline products and minor alkaline igneous contributions (e.g.,

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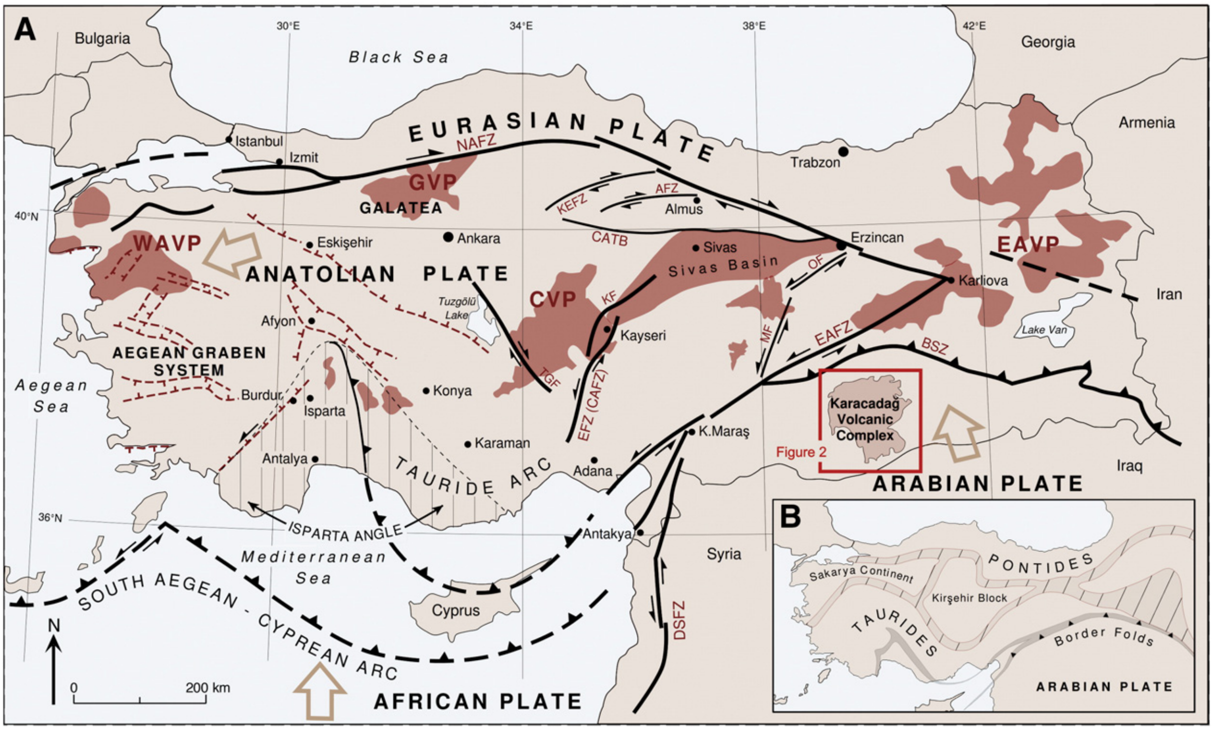

Fig. 1. (A) Tectonic framework and location map of the Turkish sector of the Alpine–Himalayan orogenic belt after Piper et al. (2006). Large brown arrows show directions of current relative plate motions and the smaller half arrows are directions of movement on major strike-slip faults. The volcanic provinces are labelled WAVP, Western Anatolian Volcanic Province; GVP, Galatean Volcanic Province; CVP, Cappadocian Volcanic Province and EAVP, East Anatolian Volcanic Province. Tectonic lineaments are abbreviated: NAFZ, North Anatolian Fault Zone, EAFZ, East Anatolian Fault Zone; BSZ, Bitlis Suture Zone; SLF, Salt Lake Fault Zone; LKF (Laçin–Kızılırmak Fault Zone); KEF (SEFZ), Kırıkkale–Erbaa Fault Zone (becoming Sungurlu–Ezinepazarı Fault Zone, SEFZ to the west); AF, Almus Fault Zone: EFZ (CAFZ), Ecemiş Fault Zone (Central Anatolian Fault Zone); CATB, Central Anatolian Thrust Belt and DSF, Dead Sea Fault Zone. The vertically hatched area comprises deformed terranes within the Isparta Angle; this was formed mainly during the Palaeotectonic era by interference of verging allochthonous units during final stages of Tethyan convergence. Subsequent deformation included pre-Miocene and post-Eocene orogenic bending in the Isparta region shown by the angle of this figure (Kissel et al., 1993). (B) The orogenic framework of Turkey and adjoining regions.

Alıcı et al., 2001; Alpaslan, 2007; Keskin, 2007; Keskin et al., 1998; Kurt et al., 2008; Lustrino et al, 2010; Pearce et al., 1990; Yılmaz et al., 1998). Koçyiğit et al. (2001) divided the post-collisional compression in eastern Anatolia into two main tectonic phases comprising compressional–contractional and compressional–extensional regimes; these are considered to correspond broadly to N–NNW compression during continuing indentation and to tectonic escape as dominant strike slip has succeeded compression. Locally the extension has permitted access to mantle melts which have been emplaced as laterally-extensive subaerial lava flows and pyroclastic products of variable composition and eruptive style (Keskin et al., 1998; Pearce et al., 1990; Yılmaz et al., 1998). On the Arabian foreland a distributed volcanic activity focussed on the impactogen faulting has occurred from Late Miocene to Recent times and produced large volumes of alkaline basic volcanics (Lustrino et al., 2012; Pearce et al., 1990). The present study reports a palaeomagnetic investigation of the Karacadağ centre, the largest of these volcanic complexes. It complements results from smaller Miocene volcanic fields further to the west on the Arabian Plate (Gürsoy et al., 2009) and evaluates the collective evidence from this plate in the context of rotational deformation relative to the terranes to the north.

2. Regional tectonic framework

The present tectonic framework of Eastern Anatolia comprises three major lithospheric segments separated by major tectonic structures; these are the Eastern Anatolian High Plateau-EAHP of terranes accreted during closure of Neotethys, the Anatolian Convergent Zone, and the Foreland to the Arabian Plate (see Fig. 1, inset box). In the Anatolian Convergent Zone the Eastern Anatolian High Plateau is bounded by a collisional belt comprising the Bitlis Suture Zone which is succeeded to the south by a complicated southward-prograding and S-vergent system of shallow-dipping thrusts including thin sheets of basement, ophiolites, ophiolitic flysch and thick Tortonian flysch sequences. At the margin of the Arabian Foreland deformation of the platform cover sequences during the collision has produced S-vergent folds and thrusts. Passing into the undeformed sector of the foreland there are several major post-collisional volcanic centres, the largest of which is found immediately SW of the city of Diyarbakır and forms the subject of this study (Fig. 1, boxed area). A distributed suite of small volcanic centres here has erupted from fissures trending approximately N–S which are part of an array of impactogen faults widely distributed across the northern periphery of the Arabian Plate; these all trend approximately N–S and evidently related to the ongoing Neogene collision between Arabia and the Anatolian collage (Dewey et al, 1986; Şengör, 1976).

From examination of collision features between irregular continental margins and foreland structures, Şengör (1976) concluded that the complexity and intensity with which horst-graben fracture systems (impactogens) can develop depend primarily on variations in thickness of the brittle upper crustal layer. Where crustal domes exist in the foreland area of an orogen they localize the formation of extensional structures such as grabens, and corresponding variations in crustal thickness across this region correlate with the rift development and the incidence of Neogene volcanism. The crust between the easternmost part of the Anatolian Plate and the Eastern Anatolian–Iranian high plateau has been thickened by collision to 40–50 km; it is underlain by a reduced lithospheric mantle ranging from 0 to 30 km in thickness (Al-Lazki et al., 2003; Angus et al., 2006; Şengör et al., 2003, 2008). This contrasts with an average crustal thickness of ~40 km at the northern margin of the Arabian Plate but ranging from 36 to 44 km (Elitok and Dolmaz, 2011; Gök et al., 2007) and this variation seems likely to have influenced