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Palaeomagnetism of the Cappadocian Volcanic Succession, Central Turkey: Major ignimbrite emplacement during two short (Miocene) episodes and Neogene tectonics of the Anatolian collage

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ABSTRACT

The Central Anatolian Volcanic Province in Cappadocia includes 13 high volume calc-alkaline ignimbrite sheets emplaced by plinian eruptions within a succession (the Ürgüp Formation) after ~10 Ma recording the last phase of Neotethyan subduction and accompanying emplacement of the Tauride orogen in southern Turkey. To evaluate magnetostratigraphy in the context of recent revisions of the chronostratigraphy we have extended palaeomagnetic investigation to 32 new sites yielding significant ChRM directions. Integrated rock magnetic and palaeomagnetic investigations identify magnetic remanence residing predominantly in Ti-poor titanomagnetites although secondary processes within the ignimbrite sheets, notably post-emplacement oxidation, have locally produced hematisation expressed by composite IRM spectra and variable reduction in intensity of magnetisation. The ignimbrite sheets possess weak anisotropies of magnetic susceptibility (AMS, mostly < 5%) describing tensors with axial distributions close to bedding and minimum axes predominantly perpendicular to this plane; collectively directions show weak imbrication correlating with palaeoflow during emplacement predominantly towards the north and east away from the Erdas Dağ, an inferred topographic palaeohigh at the southern margin of the basin. The precise control provided by magnetostratigraphy and radiometric age dating now shows that the bulk of Cappadocian ignimbrite magmatism was concentrated into two short episodes. An older Cardak Centre (Kavak Group and Zelve ignimbrites) produced in excess of 200 km^3 of pyroclastic deposits during polarity chron C4r.1n between 9.31 and 9.43 Ma. Subsequent activity from the Acıgöl Centre further to the south west (Cemilköy, Gelveri, Gördeles, and Kızılkaya) produced in excess of 620 km^3 of pyroclastic deposits during polarity chrons between 5.3 and 7.1 Ma. The younger İncesu ignimbrite was sourced in the Sultansazlığı pull-apart basin to the east during the Gauss Chron (2.58–3.60 Ma). All pre-İncesu ignimbrites are rotated uniformly anticlockwise and the overall (reversed) group mean direction of magnetisation is $D/I = 170.8/-52.4°$ ($N = 9, R = 8.91, \alpha_{95} = 5.4°, k = 91$). The implied tectonic rotation in this sector of central Anatolia ($16 \pm 4°$ relative to Eurasia) is young and postdates the 5.3–7.1 Ma Acıgöl Centre whilst largely predating emplacement of the İncesu ignimbrite. Whilst rotational deformation within Anatolia is young, it proves to be distributed with a temporal variation from block to block. It is embraced by a complex post-Miocene tectonic regime of strike slip and extension during tectonic escape and suction towards the Hellenic Arc to the west.

1. Introduction

Convergence of the Eurasian and Afro-Arabian plates in the region of present day Anatolia accompanied consumption of the NeoTethys Ocean and culminated in continental collision along the Bitlis–Zagros Suture Zone (Fig. 1(A)) in Miocene (Langhian–Serravalian) times. The prolonged ocean closure produced multiphase collision with successive emplacement of terranes derived from the northern perimeter of Gondwana during subduction between Jurassic and Early Miocene times (e.g. Şengör and Yılmaz, 1981; Görür et al., 1984); it terminated to define a three-fold subdivision of orogens grouped from north to south into the Pontides, Anatolides and Taurides (Fig. 1(B)). Continuing indentation of Arabia into the weak collage of accreted terranes south of the Pontides combined with suction body forces directed towards the South Aegean (Cretan) Arc has controlled the contemporary tectonic regime in which blocks are being extruded and rotated away from the indenter as a signature of distributed deformation (Piper et al., 2010). This latest phase of Neogene deformation is largely constrained to the weak crust between the North Anatolian Fault

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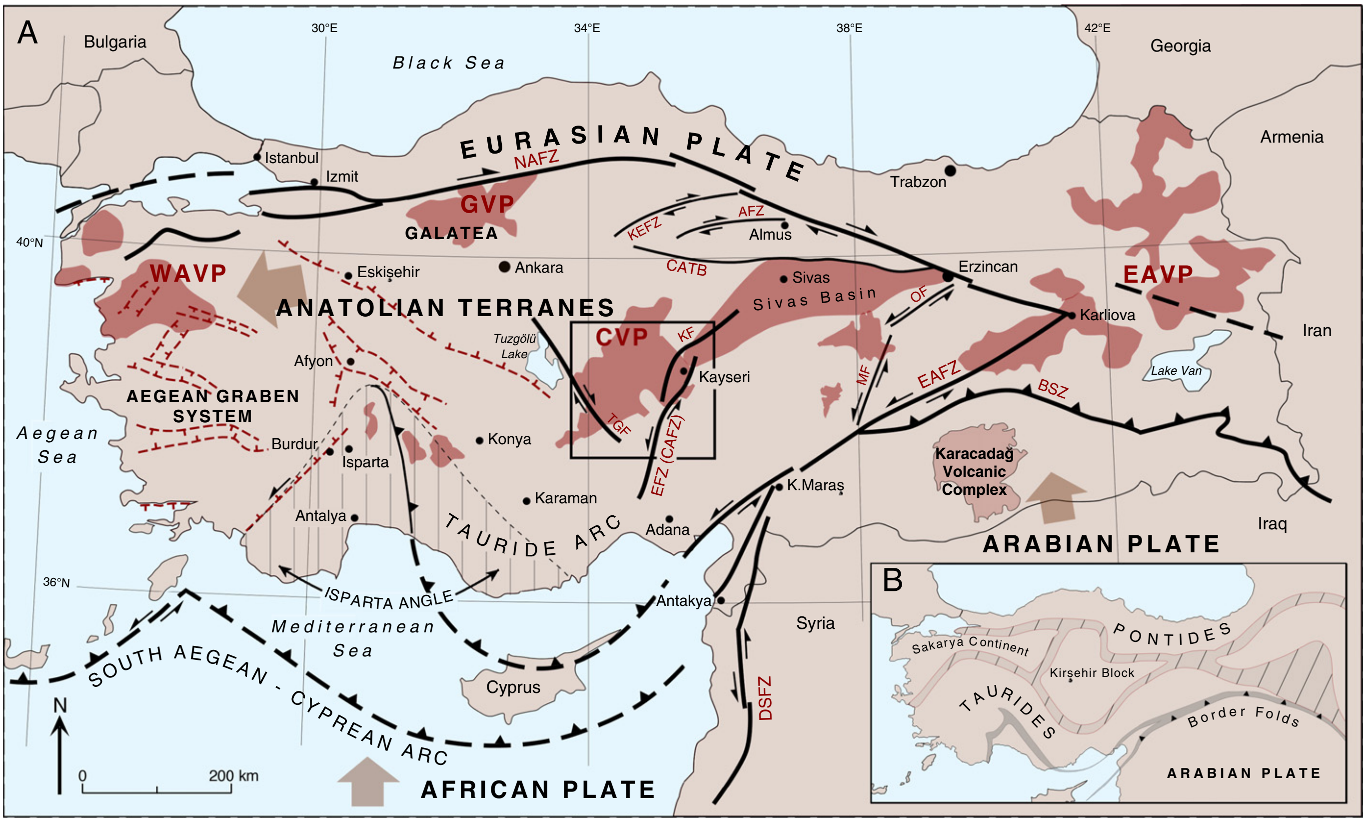

Fig. 1. (A) Tectonic framework and location map of the Turkish sector of the Alpine–Himalayan orogenic belt. Large brown arrows show directions of relative plate motions at the present time and the smaller half arrows are directions of movement on major strike–slip faults. The major volcanic provinces are highlighted as WAVP: Western Anatolian Volcanic Province, CAVP: Central Anatolian Volcanic Province, GVP: Galatean (Northern) Volcanic Province and EAVP: East Anatolian Volcanic Province. Tectonic lineaments are abbreviated: NAFZ, North Anatolian fault Zone; EAFZ, East Anatolian Fault Zone; TGF, Tuz Gölü Fault Zone; KEFZ, Kırıkkale–Erbaa Fault Zone (becoming Sungurlu–Ezinepazarı Fault Zone to the west); AFZ, Almus Fault Zone: MF, Malatya Fault; OF, Ovacık Fault; EFZ (CAFZ), Ecemiş Fault Zone (Central Anatolian Fault Zone); CATB, Central Anatolian Thrust Belt; KF, Kızılırmak Fault and DSFZ; Dead Sea Fault Zone. The shaded area comprises deformed terranes within the Isparta Angle formed mainly during the Paleotectonic era by interference of verging allochthonous units during final stages of Tethyan convergence. The rectangle embraces the region of the present study of Cappadocia shown in Fig. 2. (B) Outline tectonic framework of Turkey showing the distribution of the Pontide orogen (emplaced prior to Jurassic times) and the Sakarya Microplate, Kırşehir Microplate and Tauride Orogen collectively comprising terranes emplaced during closure of the NeoTethyan Ocean; the latter event was concluded by collision with the Arabian Plate in the south east. Subsequent deformation included pre-Miocene and post-Eocene orogenic bending in the Isparta region shown by the angle in this figure and in (A).

Zone (NAFZ, the boundary of the Eurasian Plate) in the north and the East Anatolian Fault Zone (EAFZ, the most important on-land active tectonic boundary of the Afro-Arabian Plate) to the southeast (Fig. 1). The Arabian Plate is currently rotating anticlockwise and moving northwards faster than Africa with the differential movement taken up by opening of the Red Sea and slippage along the Dead Sea Fault Zone (DSFZ, Hempton, 1987; Barka and Reilinger, 1997; McClusky et al., 2000; Gürsoy et al., 2009; Koçbulut et al., in press).

Hence the Anatolides is not a plate sensu stricto. Instead it comprises a collage of accreted terranes divided into fault-bounded crustal blocks on a ~10^2 km scale undergoing comprehensive internal deformation. The differential character of the contemporary deformation, now dominated by strike–slip and rotation and expressed as tectonic escape, is now well established by regional palaeomagnetic studies (e.g. Tatar et al., 1996, 2002, 2004; Gürsoy et al., 1997, 1998, 2009; Piper et al., 2006, 2010). The overall regional effect has been to contract crust north of the indenter and progressively expand the curvature of the Tauride Arc to the west; as a result crustal block rotations produced by high strains north of the indenter are strongly counter clockwise (CCW) but they become relatively less CCW as strain diminishes to the west and near-zero in central Anatolia (Tatar et al., 2002, 2004; Gürsoy et al., 1999, 2009; Piper et al., 2010). Further to the west in the central Anatolian region crustal block rotations become systematically clockwise (CW) by up to values of ~20° in a zone where extensional basins ('ovas') bounded by oblique-slip faults have developed and merge laterally into the Aegean Graben System, a broad zone of exceptionally rapid extension (Fig. 1(A)). Across Anatolia the Neogene rotational motions recognised from palaeomagnetism are presumably accommodated on a network of block-bounding faults extending through the upper crust, although the boundaries are rarely well defined due to a combination of superficial cover and presence of over-thrusting in bordering regions; as a result the sizes of the crustal blocks involved in the tectonic escape are still poorly understood (Fig. 1(A)) but it seems unlikely that they extend deeper than the brittle upper crust (e.g. Şengör, 1976).

Late stages of ocean consumption and ensuing post-collisional deformation have been accompanied by widespread volcanic activity across Anatolia. This falls broadly into four provinces (sensu lato) comprising the Western Anatolian, Central Anatolian, Eastern Anatolian and (northern) Galatean (Şengör and Yılmaz, 1981; Yılmaz, 1990; Toprak et al., 1994 and Fig. 1(A)). The Central Anatolian Volcanic Province (CAVP) is concentrated in Cappadocia and embraces a high K calc-alkaline ignimbrite succession (e.g. Temel, 1992; Temel et al., 1998; Aydar et al., 2012) with spectacular areal and topographic development. It is usually considered to record the extended terminal activity above the zone of subducting NeoTethyan ocean crust (e.g. Toprak and Göncüoğlu, 1993; Viereck-Götte et al., 2010) and