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Palaeomagnetic evidence for the neotectonic evolution of the Erzincan Basin, North Anatolian Fault Zone, Turkey

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ABSTRACT

Ongoing motion of Anatolia towards the west is caused by convergence of the Arabian and Eurasian plates coupled with suction towards the retreating Hellenic Arc. This regime is controlling the development of neotectonic structures in Turkey with the resulting distributed deformation accommodated primarily between the East and North Anatolian Intracontinental Transform Faults. The Erzincan Basin is developed along the eastern part of the latter fault and although it incorporates one of the largest Quaternary basins in Turkey, the duration and tectonic evolution are disputed. Tectonic models proposed to explain the basin range from simple rhomboidal pull-apart to a complex multi-phase evolution. To help constrain the age and tectonic regime(s) forming the basin we have conducted a palaeomagnetic and geochronologic study of volcanic domes which occur mainly in proximity to strike-slip faulting along the northern margin of the basin. The investigated sample comprises 27 lava sites located within 14 cones, 13 to the north and one in the south. Although difficult propositions for palaeomagnetic investigation because the young predominantly-pyroclastic constructive topography is susceptible to collapse, all sites show positive inclinations and mainly northerly declinations showing that they are the consequence of a tectonic regime confined to the Brunhes Chron. Whilst the limitation of directional data from these young constructive features is stressed, ten cones are found to show clockwise rotations ranging from 12° to 195° with three cones showing no significant rotation. Geochronological studies from 13 samples yield a range of ages with 6 providing meaningful results <0.3 Myr in age and consistent with young ages evident from morphology and paleomagnetism. AMS (Anisotropy of Magnetic Susceptibility) studies identify a fabric related to downslope flow at most sites with the majority moving away from conduits controlled by fractures paralleling the dominant NW-SE trend of the master fault. The palaeomagnetic and geochronologic results show that the history of the Erzincan Basin has involved at least two phases with the later phase incoporating an extensional component permitting access to mantle melts and confined to the last ~300,000 years. The earlier phase commenced in Late Miocene or Early Pliocene times and initiated the rift infill which currently attains a maximum thickness in excess of 2.7 km. We propose that the Erzincan Basin is now segmented as a mature basin by strike-slip cross faults although these cannot explain the consistent clockwise rotations observed within the small blocks incorporating the volcanic cones because these are confined to a narrow zone between two master faults and appear to be subject to ball-bearing style rotation.

1. Introduction

The North Anatolian Fault Zone (NAFZ) in northern Turkey is one of the largest active strike-slip fault zones in the world and comprises a major intracontinental transform within the plate tectonic framework of the Alpine-Himalayan orogenic belt (Fig. 1). It extends eastwards for 1200 km from the Gulf of Saros in the northern Aegean Sea to the town of Karlıova in Eastern Turkey (Şengör et al., 2005). Estimates of the age of initiation range from late Miocene to late Pliocene with strike-slip tectonics commencing during the early Pliocene in the central NAFZ west of Erzincan, and possibly during the late Miocene in the western part; this was followed by a clear change in the kinematics during the Quaternary. Between 1939 and 1999 seven large earthquakes occurred

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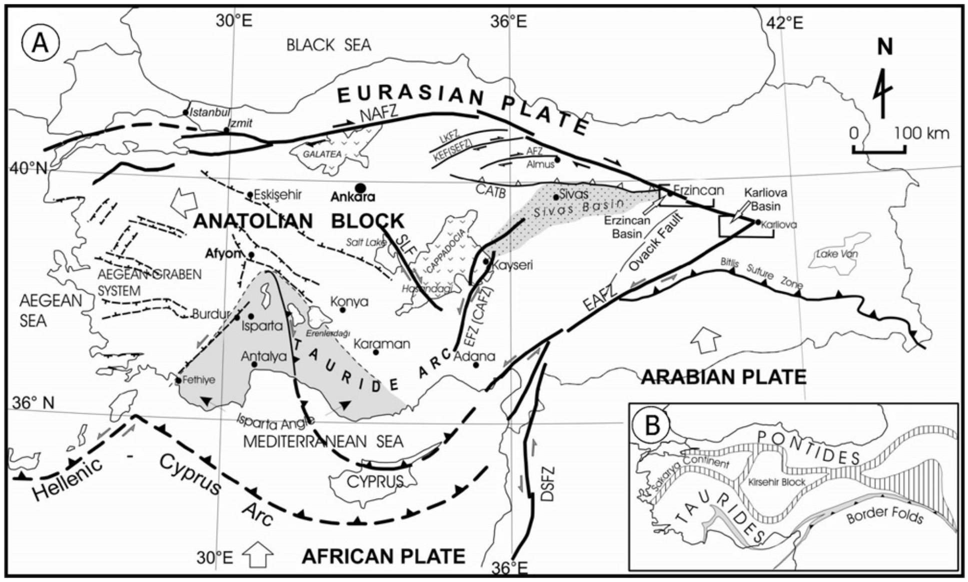

Fig. 1. (A) Tectonic framework and location map of the Turkish sector of the Alpine-Himalayan orogenic belt. Large open arrows show directions of current relative plate motions and the smaller half arrows are directions of movement on major strike-slip faults. Tectonic lineaments are abbreviated: SLF, Salt Lake Fault Zone; LKF (Laçin-Kızılırmak Fault Zone; KEF (SEF), 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 shaded area comprises deformed terranes within the Isparta Angle and was formed mainly during the Paleotectonic era by interference of verging allochthonous units during final stages of Tethyan convergence. (B) Outline tectonic framework of Turkey showing the distribution of the Pontide orogen (emplaced prior to Jurassic times) and the Sarkaya microplate, Kirsehir microplate and Tauride orogen which collectively comprise terranes emplaced during closure of the NeoTethyian Ocean; this closure was completed by collision with the Arabian Plate in the south east.

along the fault zone in a westward-migrating sequence along a >1000 km long zone of continuous surface breaks. From east to west, these earthquakes comprised the 1939 Erzincan, 1942 Erbaa-Niksar, 1943 Tosya, 1944 Bolu-Gerede, 1957 Abant, 1967 Mudurnu Valley, and 1999 Kocaeli earthquakes. The 1939 Erzincan earthquake (M = 7.9–8) was the largest earthquake to occur in central Anatolia for at least 300 years and it initiated the westward migration of large earthquakes comprising this 1939–1999 sequence along the NAFZ defining a ~360-km long rupture zone extending from the western end of the Erzincan basin to the south of Amasya (Barka, 1996). The historical earthquake records documented by Ambraseys (1970), Ambraseys and Finkel (1987, 1995) and Ambraseys et al. (1994) show that within the last 1000 yr there have been several clusters of events along the NAFZ that have also caused long ruptures. In general, the NAFZ becomes wider from east to west: around Erzincan and some 150–200 km to the west it is at its narrowest and hardly wider than 10 km, although near the eastern extremity at Karlıova it seems to widen again (Herece and Akay, 2003).

The 50 km long Erzincan basin (see regional location in Fig. 1) strikes WNW-ESE parallel to the eastern end of the NAFZ and several interpretations have been invoked to explain its evolution. It was initially interpreted as a simple pull-apart basin at a releasing step-over by Şengör (1979) and Hempton and Dunne (1984), although some more recent studies have recognized a more complex composite basin development incorporating the ENE striking left-lateral Ovacık Fault which terminates in the southeast corner of the basin (Linneman, 2002). From remotely-sensed imagery Chorowicz et al. (1999) suggested a two stage evolution in which the basin first developed in the Pliocene via SW directed movement on the Ovacık Fault (Fig. 1) followed by ENE motion in the Quaternary as the NAFZ took up the strain. Westaway and Arger (2001) investigated the left-lateral slip on the 240-km-long, NE-SW-trending, Malatya-Ovacik fault zone in eastern Turkey. They proposed that this fault zone was active during ~5–3 Ma, when it took up 29 km of relative motion between the Turkish and Arabian plates; it ceased to be active when the East Anatolian fault zone formed at ~3 Ma. The geometry of the former Erzincan triple junction, which differs from the modern Karliova triple junction, where the North and East Anatolian fault zones intersect, suggests a possible explanation for why slip on the Malatya-Ovacik fault zone was unable to continue. In a detailed tectonomorphological study of the central and eastern NAFZ, Hubert-Ferrari et al. (2002) concluded that the geologically-constrained Neogene slip rate of 6.5 mm/yr (over 13 Myr) has been succeeded by a higher Holocene slip rate of about 20 mm/yr consistent with the contemporary GPS-determined rate (McClusky et al., 2000). The localization of NAFZ deformation is considered by Hubert-Ferrari et al. (2002) to imply a fault extension below the seismogenic zone and these authors favour an elastoplastic model for the lithosphere here.

2. Geological background

The NAFZ is considered by Şengör et al. (2005) to be a diachronous structure formed by progressive strain localization in a westerly-widening right-lateral shear zone. Its localisation in northern Turkey approximates to the southern margin of the Pontide Orogen (see Fig. 1b) which had consolidated against the Eurasian margin by Jurassic times (Channell et al., 1996). To the south juxtaposed subduction-accreted terranes comprise the Sakarya and Kırşehir microcontinents and multiple smaller blocks. These were emplaced during northward subduction of the NeoTethys Ocean which culminating with the collision of Arabia along the Bitlis Zone in SE Turkey at ~12 Ma. The Erzincan Basin is also sited within the Izmir–Ankara–Erzincan Suture Zone (IAESZ) which delimits the northern border of the East Anatolian Accetionary Complex (EAAC) as defined by Şengör and Yılmaz (1981), see also Şengör et al. (1985, 2003); Okay and Şahintürk (1997); Yılmaz et al. (1997); Koçyiğit et al. (2001). This accreted crust south of the NAFZ is inherently weaker than the older Pontide basement to the north and appears to have accomodated the bulk of deformation during the post-collision (neotectonic) phase of deformation (Piper et al., 2010). The North Anatolian Fault System" as a definition, is a widely accepted use and represents the boundary