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Linking slab break-off, Hellenic trench retreat, and uplift of the Central and Eastern Anatolian plateaus

T.F. Schildgen [a,*], C. Yıldırım [b], D. Cosentino [c,d], M.R. Strecker [a]

[a] Institut für Erd- und Umweltwissenschaften, and DFG Leibniz Center for Surface Processes and Climate Studies, Universität Potsdam, 14476 Potsdam-Golm, Germany
[b] Eurasia Institute of Earth Sciences, Istanbul Technical University, Istanbul, Turkey
[c] Dipartimento di Scienze Geologiche, Università degli Studi Roma Tre, Rome, Italy
[d] Istituto di Geologia Ambientale e Geoingeneria (IGAG-CNR), Rome, Italy

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ABSTRACT

The Central and Eastern Anatolian plateaus are integral parts of the world's third largest orogenic plateau. In the past decade, geophysical surveys have provided insights into the crust, lithosphere, and mantle beneath Eastern Anatolia. These observations are now accompanied by recent surveys in Central Anatolia and new data constraining the timing and magnitude of uplift along its northern and southern margins. Together with predictions from geodynamic models on the effects of various processes on surface deformation and uplift, the observations can be integrated to identify probable mechanisms of Anatolian Plateau growth.

A changeover from shortening to extension along the southern margin of Central Anatolia that is coeval with the start of uplift can be most easily associated with oceanic slab break-off and tearing. This interpretation is supported by tomography, deep seismicity (or lack thereof), and gravity data. Based on the timing of uplift, geophysical and geochemical observations, and model predictions, slab break-off likely occurred first beneath Eastern Anatolia in middle to late Miocene time, and propagated westward toward Cyprus by the latest Miocene. Alternatively, the break-off near Cyprus could have occurred in late Pliocene to early Pleistocene time, in association with collision of the Eratosthenes Seamount (continental fragment) with the subduction zone. Uplift at the northern margin of Central Anatolia appears to result from crustal shortening starting in the late Miocene or early Pliocene, which has been linked to the broad restraining bend of the North Anatolian Fault. The uplift history of the interior of Central Anatolia since the late Miocene is unclear, although shortening there appears to have ended by the late Miocene, followed by NE–SW extension. This change in the deformation style broadly coincides with faster retreat of the Hellenic trench as well as uplift of the northern and southern margins of Central Anatolia.

These different events throughout the plateau may be linked, as faster retreat of the Hellenic trench has been predicted to occur after slab break-off, which could have induced extension of Central Anatolia and helped to form the North Anatolian Fault through accelerated westward movement of Anatolia relative to Eurasia. Correlative geochronologic evidence that we summarize here supports the hypothesis that the geodynamic activity throughout the Aegean–Anatolian domain starting in latest Miocene to early Pliocene time defines a series of events that may all be linked to slab break-off.

Contents

* Corresponding author. Tel.: +49 331 977 5849.
E-mail address: tschild@uni-potsdam.de (T.F. Schildgen).

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1. Introduction

A wide range of geodynamic mechanisms has been invoked to explain the growth of high topography in orogenic belts and plateaus. In some cases, a single mechanism capable of inducing broad, regional uplift, such as lithospheric delamination, has emerged as a favored interpretation, for example in the Sierra Nevada (Jones et al., 2004; Zandt et al., 2004) and the southern Central Andes (Kay and Kay, 1993; Kay et al., 1994; Yuan et al., 2002). Often, however, delamination only occurs after significant crustal and lithospheric shortening and thickening, which itself should produce isostatic uplift. Such temporal changes in uplift mechanisms have spurred investigations into the relative contributions of crustal shortening, lithospheric thinning, lower crustal flow, magmatic addition, or other processes in producing uplift (e.g., Dewey and Burke, 1973; Froidevaux and Isacks, 1984; Allmendinger et al., 1997; Şengör et al., 2008). Further complications arise in regions near oceanic subduction zones, where the subduction of oceanic ridges, seamounts, or oceanic plateaus (Livaccari et al., 1981; Cloos, 1991; Espurt et al., 2008), changes in slab dip (Jordan et al., 1983; Gutscher et al., 2000), magmatic underplating (Brown, 1993), and slab break-off (Davies and von Blanckenburg, 1995) may all potentially deform and elevate the overriding plate. More recently, the effects of upper mantle flow in producing dynamic topography have been considered capable of producing km-scale uplift (Boschi et al., 2010; Faccenna and Becker, 2010; Karlstrom et al., 2012), while the development of large, mantle-scale convection cells may be responsible for the initial shortening seen in major orogenic plateaus like the Andes and Tibet (Faccenna et al., 2013).

The world's largest orogenic plateaus in Tibet and the Andes are typically viewed as resulting from a combination of these deep-seated processes, and appear to have grown in both elevation and areal extent through time (e.g., Isacks, 1988; Allmendinger et al., 1997; Tapponnier et al., 2001). Once attaining critical elevations, the influence of local topographic highs on the distribution and amount of rainfall and consequent erosion and deposition patterns (e.g., Bookhagen and Strecker, 2008; Roe et al., 2008) can also help to create a regional plateau morphology (Sobel et al., 2003). In some cases, these feedbacks between tectonics and surface processes appear to strongly influence the evolution of plateau margins (e.g., Hodges et al., 2004; Strecker et al., 2007, 2009).

If orogenic plateaus grow gradually through time, the relatively small Anatolian Plateau may be an early-stage analog for the world's larger orogenic plateaus. High-elevation (2 to 2.5 km average), high-relief topography in Eastern Anatolia transitions to lower elevation (1.5 to 2 km average), low-relief topography in Central Anatolia, with high-relief mountain ranges bounding the northern and southern margins of both regions (Figs. 1 and 2). While Eastern Anatolia exhibits symmetric plateau morphology in a N–S topographic swath profile (Fig. 1C), Central Anatolia has a lower interior compared to its margins, and shows a distinct asymmetry in its minimum elevations, reflecting the predominantly northward-directed drainage (Fig. 1B).

The Arabia–Eurasia collision at the eastern end of the Aegean–Anatolian domain is inferred to have started in late Eocene/Oligocene time (e.g., Jolivet and Faccenna, 2000; Agard et al., 2005; Dargahi et al., 2010; Ballato et al., 2011; McQuarrie and van Hinsbergen, 2013), or more specifically in two stages between 36 and 20 Ma and after 20 Ma (Ballato et al., 2011), and was followed by crustal shortening across Eastern Anatolia (Şengör et al., 2008). Despite a late Cretaceous to Eocene history involving shortening and the accretion of several continental fragments (e.g., Şengör and Yılmaz, 1981; Dixon and Robertson, 1984; Tekeli et al., 1984; Şengör et al., 1985; Polat, 1992; Şengör and Natal'in, 1996; Okay and Tüysüz, 1999; Tüysüz, 1999; Andrew and Robertson, 2001; Sunal and Tüysüz, 2002; Parlak and Robertson, 2004; Okay et al., 2006; Pourteau et al., 2010; Robertson et al., 2012; Pourteau et al., 2013), Central Anatolia has predominantly moved westward relative to Eurasia since the time of Arabian collision, accommodated along the North and East Anatolian strike–slip faults (Ketin, 1948; McKenzie, 1976; Şengör, 1979; Dewey and Şengör, 1979; Şengör et al., 1985). Continued Arabia–Eurasia convergence may contribute to this westward "escape" of Anatolia, but roll-back of the Hellenic trench is likely the predominant force (Le Pichon, 1982; Jolivet et al., 2013), particularly considering GPS data showing westward movement of Anatolia relative to Eurasia that increases toward the trench (Reilinger et al., 1997).

The tectonic links across the Aegean–Aantolian region are fairly clear, but less obvious have been the mechanisms that have contributed to the growth of the Anatolian Plateau over time, and if those mechanisms may be related to one another. While high topography in Eastern Anatolia is largely believed to result from lithospheric slab delamination and break-off (Keskin, 2003; Şengör et al., 2003; Keskin, 2007; Şengör et al., 2008), recent work in Central Anatolia points to multiple uplift mechanisms that vary across the region. Along the northern Central Anatolian Plateau margin, Yildirim et al. (2011) suggested that the most recent phase of uplift results from strain accumulation along the broad bend of the North Anatolian Fault. Along the southern plateau margin, uplift mechanisms that have been proposed include: (1) slab break-off (Cosentino et al., 2012); (2) upwelling asthenosphere through a slab tear (Schildgen et al., 2012b); and (3) a combination of slab break-off, slab tearing, and collision of a continental fragment with the subduction zone south of Cyprus (Schildgen et al., 2012a). Uplift in the interior of Central Anatolia is difficult to constrain, but has been suggested to result from lithospheric delamination (Bartol et al., 2012), or mantle flow

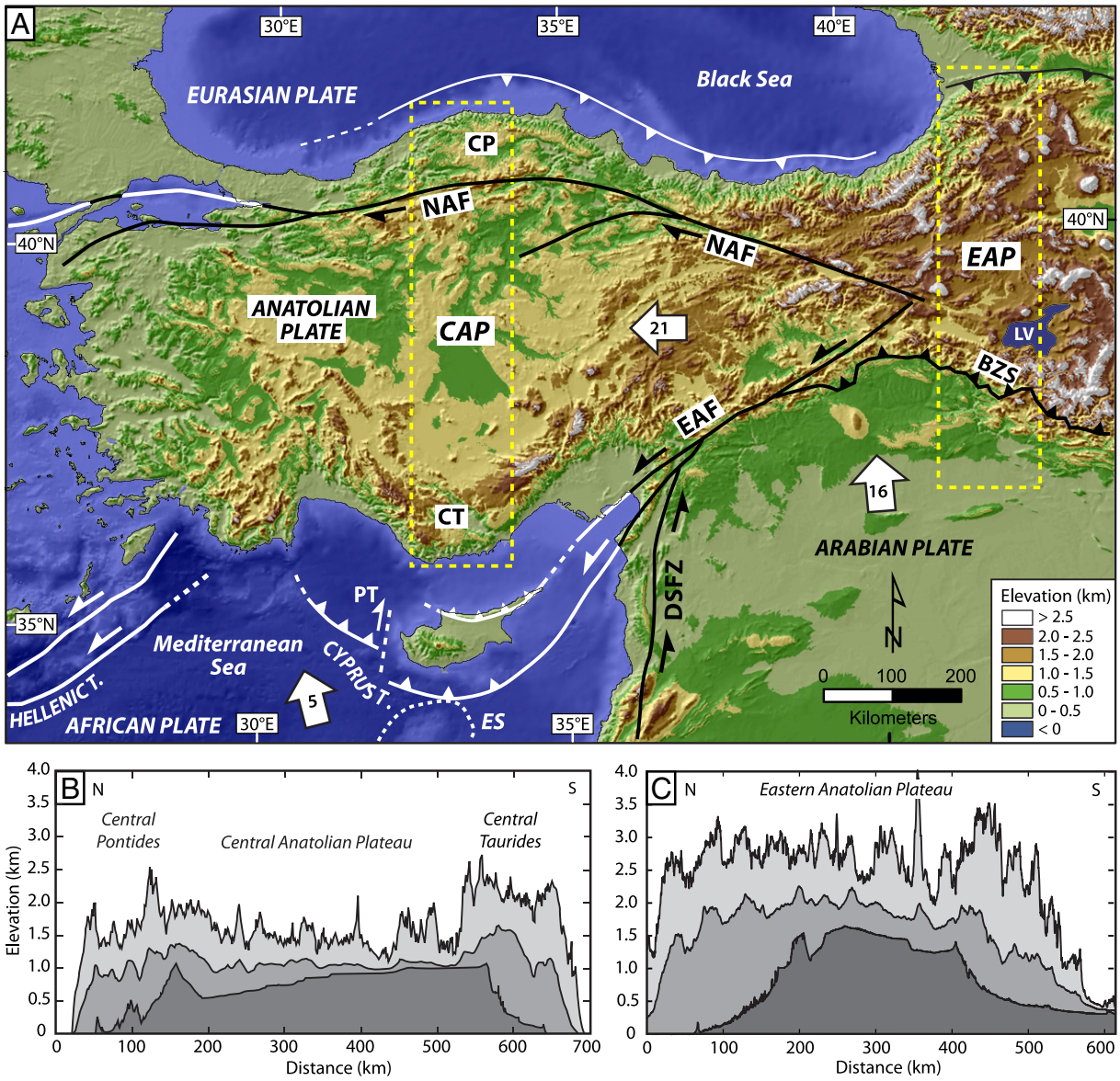

Fig. 1. (A): Regional map showing topography (Shuttle Radar Topography Mission level 3 data, Jarvis et al., 2008) and major tectonic boundaries. CAP: Central Anatolian Plateau; EAP: Eastern Anatolian Plateau; CP: Central Pontides; CT: Central Taurides; BZS: Bitlis–Zagros suture; NAF: North Anatolian Fault; EAF: East Anatolian Fault; DSFZ: Dead Sea Fault Zone; ES: Eratosthenes Seamount; PT: Paphos Transform; LV: Lake Van. White arrows with numbers inside represent plate movement (mm/yr) with respect to a stable Eurasia (Reilinger et al., 2006). Dashed yellow rectangles show 150-km wide regions sampled for topographic swath profiles (minimum, mean, and maximum elevations) across Central Anatolia (B) and Eastern Anatolia (C).

patterns (Boschi et al., 2010; Faccenna and Becker, 2010). These various processes may be linked to one another, as slab break-off has been suggested to help induce rollback of the Hellenic trench, which could in turn pull Anatolia westward and help create the North Anatolian Fault (Faccenna et al., 2006) and also affect mantle flow patterns (Le Pichon and Kreemer, 2010).

The wealth of recent data from Central Anatolia that inspired these interpretations spans a range of structural, geophysical, geochemical, geomorphological, and geochronological observations. In this review, we attempt to synthesize the data that have contributed to various proposed uplift mechanisms and explore their feasibility in the context of published geodynamic models and refinements to the chronology of events throughout the region. We particularly focus on how recent data from Central Anatolia help link extensional processes in the Aegean with collisional processes in the east, all within the context of orogenic plateau formation.

Following a detailed reconstruction of paleotopography in southern Central Anatolia, we summarize uplift constraints from other parts of Anatolia: the northern margin of the Central Anatolia, its interior, and Eastern Anatolia. From this surface perspective, we move to deeper indications of uplift mechanisms, including structural deformation, volcanic geochemistry, and geophysical data. Specifically, we explore how processes related to lithospheric slab subduction, mantle flow, and plate boundary interactions may have constituted a series of linked events that together generated the Central and Eastern Anatolian plateaus, while also inducing extension from the Aegean to Central Anatolia.

2. Paleotopography along the southern margin of the Central Anatolian Plateau (Central Taurides)

Paleoelevation studies have primarily focused on areas where multi-kilometer-scale uplift has given rise to changes in stable carbon and oxygen isotope compositions recorded in paleosols (e.g., Chamberlain and Poage, 2000; Blisniuk and Stern, 2005; Rowley and Currie, 2006; Garzione et al., 2008), or where changes in relief are large and

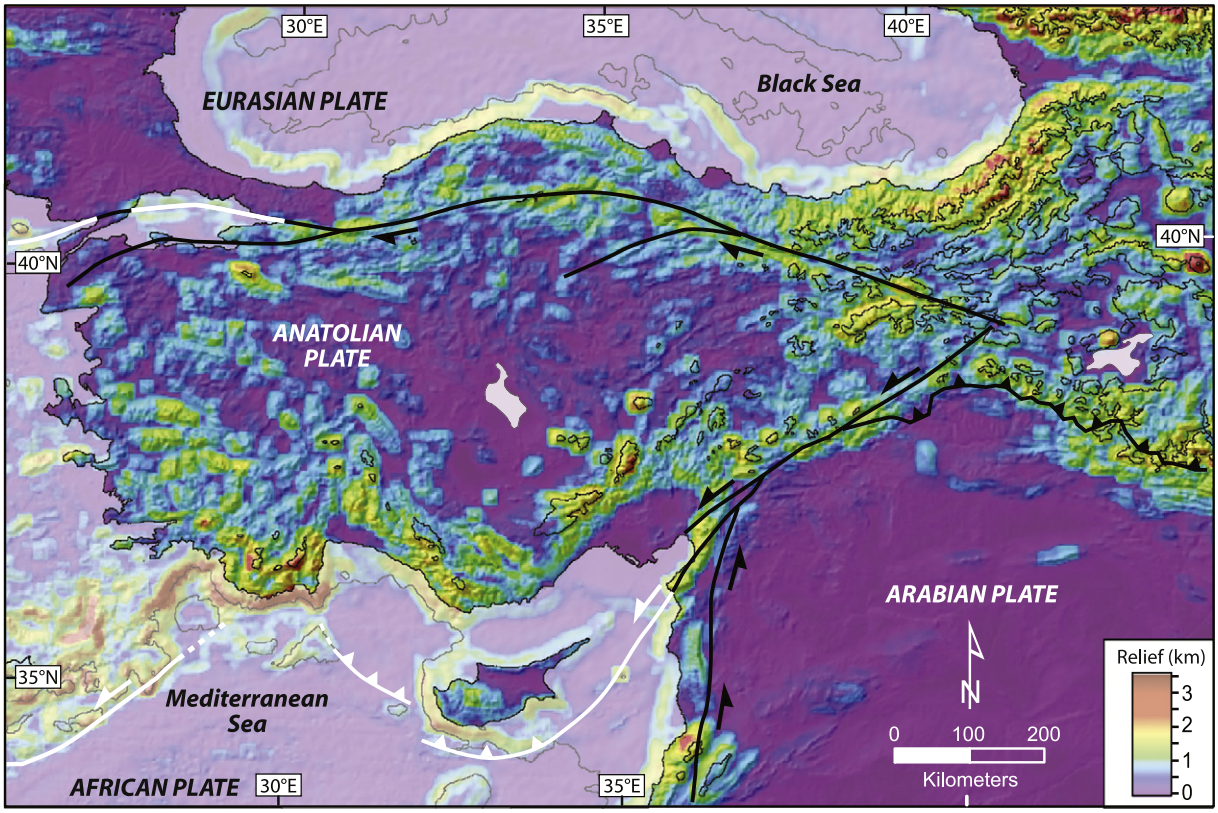

Fig. 2. Topographic relief map created with a 15-km-wide moving window. Major tectonic boundaries (as in Fig. 1) are shown for reference. Thin black lines show 2000-m elevation and −2000-m bathymetric contours.

fast enough to impact cooling-age patterns in low-temperature thermochronometers (e.g., House et al., 1998; Clark et al., 2005a,b; Schildgen et al., 2007; Flowers et al., 2008; Schildgen et al., 2009; Richardson et al., 2010; Schildgen et al., 2010; Valla et al., 2010). The Central Anatolian Plateau, with its low relief, modest elevations (typically < 1 km), and limited Miocene exhumation, is near the limit of the sensitivity of stable isotopes and thermochronology to record uplift and/or relief development. Fortunately, the region offers a range of alternatives for reconstructing topography. For example, sedimentary facies changes with transitions from marine to continental deposition offer clear and datable horizons to pinpoint the rise of topography above sea level, while landforms such as paleosurfaces, fluvial terraces, lake paleoshorelines, and marine terraces can serve as reference levels or strain markers that locally record surface uplift and deformation. For large rivers close to their outlets, incision rates derived from dated fluvial terraces and deltas may be viable proxies for surface uplift rates (e.g., Demir et al., 2004; Westaway et al., 2004; Seyrek et al., 2008; Schildgen et al., 2012a; Yıldırım et al., 2013a, 2013b). The high density of these landforms and sedimentary deposits in Central Anatolia offer an opportunity to reconstruct surface uplift with high spatial and temporal resolution, providing unique insights into the geodynamic mechanisms of uplift.

Reconstructions of paleogeography of the southern margin of Central Anatolia (e.g., Robertson et al., 2003; Flecker et al., 2005; Jaffey and Robertson, 2005) and for the Tethys region as a whole (Şengör and Yılmaz, 1981; Robertson and Dixon, 1984; Dercourt et al., 1993; Şengör and Natal'in, 1996; Popov et al., 2004, 2006) have used ophiolite outcrops, changes in sediment facies, and paleomagnetic rotations to reconstruct the evolution of depositional environments and shoreline morphology. We extend these efforts by studying multiple steps in the evolution of topography along the southern margin of Central Anatolia. Our reconstructions of paleotopography in this region utilize: (1) biostratigraphy of marine sediments; (2) radiometric dating of tufa deposits and ashes; (3) cosmogenic nuclide exposure dating of fluvial strath terraces; and (4) subsurface seismic reflection and well log data. Next, we summarize the data that we used to reconstruct paleotopography at 7 Ma, 5 Ma, and 1.6 Ma, as particularly good constraints exist for those times. The period encompassing the Messinian Salinity Crisis (5.96 to 5.33 Ma) is excluded, as widespread changes from marine to brackish or continental deposits and erosion of the basin margins during that interval were related to rapid, km-scale sea-level fall in the Mediterranean (e.g., Clauzon et al., 1996; Krijgsman et al., 1999; Cosentino et al., 2013) rather than to surface uplift.

2.1. Paleotopographic constraints at 7 Ma

Much of the modern relief along the southern plateau margin postdates the deposition of late Miocene marine sediments, which rise to over 2 km elevation in the Central Taurides. Biostratigraphy on these sediments has yielded Langhian (15.97–13.65 Ma, Ocakoğlu, 2002; Bassant et al., 2005) to Serravallian (13.65–11.61 Ma, Tanar and Gökçen, 1990; Cipollari et al., 2013a) ages in the Mut Basin, although Cosentino et al. (2012) reported late Tortonian ages of 8.35 to 8.10 Ma from the ca. 2-km-high marls near the village of Başyayla (Fig. 3). The additional ~100 m of marine limestones above the 8.35 to 8.10 Ma marls imply that the youngest marine sediments near Başyayla are even younger than 8 Ma (Cosentino et al., 2012). Similarly, the age of patches of late Miocene marine sediments along the SW plateau margin near the village of Sarıalan (Deynoux et al., 2005; Flecker et al., 2005) was refined with bio- and lithostratigraphy to 6.7 Ma for the uppermost sediments at 1.5 km elevation (Schildgen et al., 2012b). Because marine sedimentation continued to at least 6.7 Ma at Sarıalan, and more recently than 8 Ma near Başyayla, uplift in the area above sea level started sometime after ca. 7 Ma.

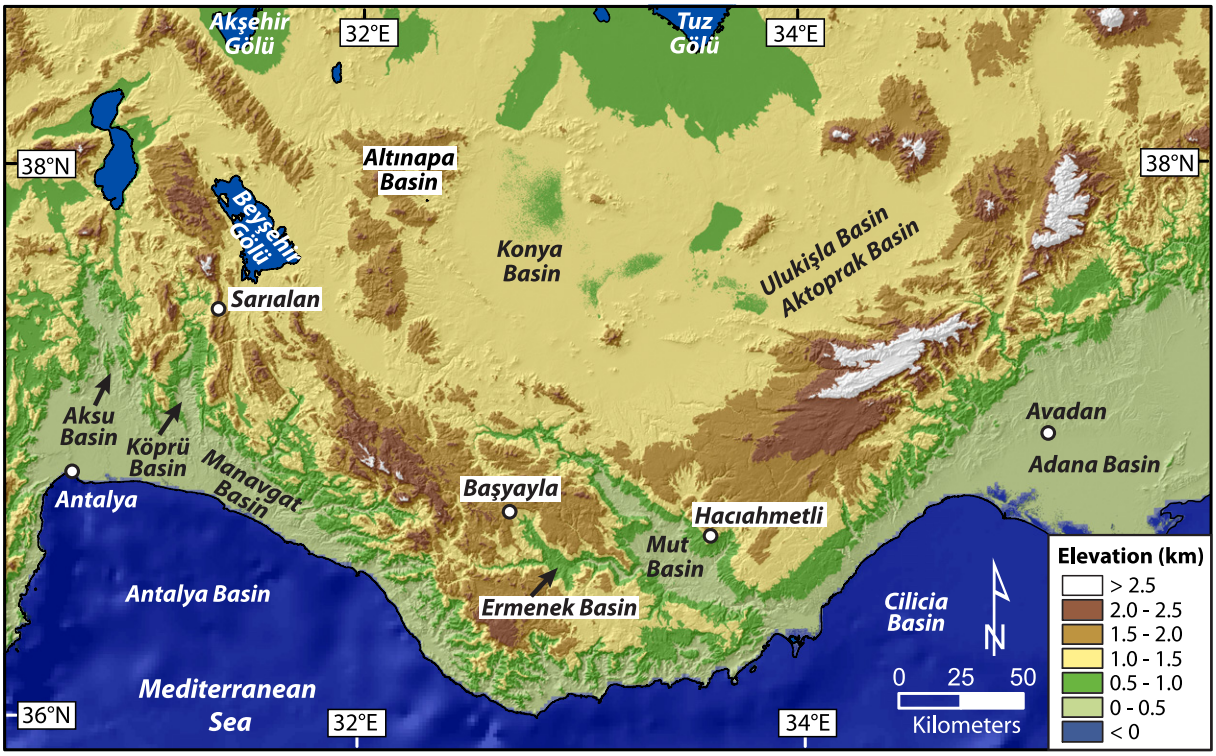

Fig. 3. Map of the southern margin of the Central Anatolian Plateau illustrating locations from which data are derived to reconstruct paleotopographic maps.

Onlap of late Miocene marine sediments onto Mesozoic basement rocks reveals the existence of paleotopographic highs during the late Miocene (Cosentino et al., 2011, 2012). Such areas were the source for Miocene conglomerates delivered to the margins of the Köprü and Manavgat basins (Flecker et al., 1995, 1998; Karabıyıkoğlu et al., 2000; Deynoux et al., 2005; Monod et al., 2006; Çiner et al., 2008).

Areas farther north were predominantly terrestrial during the late Miocene. Only continental sedimentation occurred since the late Oligocene in the Aktoprak and Ulukışla basins (Clark and Robertson, 2002, 2005; Jaffey and Robertson, 2005), which are bounded to the south by the Central Taurides. In the Altınapa Basin, lacustrine sediments revealed late Miocene to Pliocene biostratigraphic ages (Göger and Kıral, 1969; Görmüs, 1984; Eren, 1993; Özkan, 1998), while ashes dated with $^{40}Ar/^{39}Ar$ geochronology yielded middle Miocene and older dates (Koç et al., 2012). Finally, Koçyiğit et al. (2000) described early Miocene to Quaternary fluvial lacustrine sediments in the Akşehir graben, implying the existence of a terrestrial plateau interior, while areas to the south were predominantly marine.

2.2. Paleotopographic constraints at 5 Ma

While the marine sedimentation within the Taurides implies that the onset of uplift occurred sometime after 7 Ma, coarse fluvial conglomerate deposition in several basins flanking the Central Taurides starting in the latest Miocene indicates that uplift likely started prior to ca. 5.5 Ma. North of the Central Taurides, fluvial conglomerates of the Aktoprak Basin overlie late Miocene lacustrine sediments (Jaffey and Robertson, 2005). South of the Taurides in the Adana Basin, the age of the thick fluvial conglomerates of the Handere Formation (previously associated with the Pliocene, Gürbüz and Kelling, 1993; Nazik, 2004; Darbaş and Nazik, 2010) has been refined through biostratigraphy to be associated with the latest Messinian "Lago-Mare" event (5.60 to 5.33 Ma, CIESM, 2008) (Cosentino et al., 2010a, 2010b; Cipollari et al., 2013b; Faranda et al., 2013). Pliocene ages had also been inferred for coarse deposits overlying the "M-reflector" in the offshore Cilicia (Aksu et al., 2005) and Antalya basins (İşler et al., 2005). However, Cipollari et al. (2013b) argued that similarities with the seismic stratigraphy of the Adana Basin could mean that the conglomerates overlying the M-reflector instead correlate with the late Messinian conglomerates of the Adana Basin.

The Adana, Manavgat, and Aksu basins remained marine into the early Pliocene. In the Adana Basin, early Zanclean marine marls outcrop near the village of Avadan (Fig. 3; Cipollari et al., 2013b). In the southern half of the Aksu Basin, marine sediments are as young as early to middle Pliocene (Bizon et al., 1974; Akay and Uysal, 1985; Poisson et al., 2003; Sagular, 2009; Sagular and Çoban, 2009; Poisson et al., 2011). In the Manavgat Basin, shallow marine deposition continued up to ~10 km inland from the modern coastline through early Pliocene time (Akay and Uysal, 1985; Glover and Robertson, 1998), and finally ended during the late Zanclean (Glover and Robertson, 1998).

2.3. Paleotopographic constraints at 1.6 Ma

Near the village of Hacıahmetli in the Mut Basin (Fig. 3), marine sediments as young as 1.6 Ma outcrop at up to 1.2 km elevation (Yıldız et al., 2003; Schildgen et al., 2012a). The rapid generation of relief after 1.6 Ma that is implied by the high present-day elevation of the sediments is corroborated by rapid (0.52 to 0.66 mm/yr) incision rates of the Göksu River from ca. 130 ka to today, based on cosmogenic exposure ages of fluvial strath terraces (Schildgen et al., 2012a). In the Adana Basin, lower Pleistocene marine sediments were identified from well-log cuttings a few tens of meters above sea level (Cipollari et al., 2013b). In the Antalya Basin, Glover and Robertson (2003) estimated that freshwater tufa deposits started to be deposited in the region by 1.5 to 2 Ma, implying that most of the present coastal area was above sea level by early Pleistocene time.

2.4. Creating paleotopographic maps

Schildgen et al. (2012b) showed that by fitting a spline surface to uplifted late Miocene neritic limestones, the cumulative post-late Miocene uplift is greatest parallel to the modern plateau margin, and

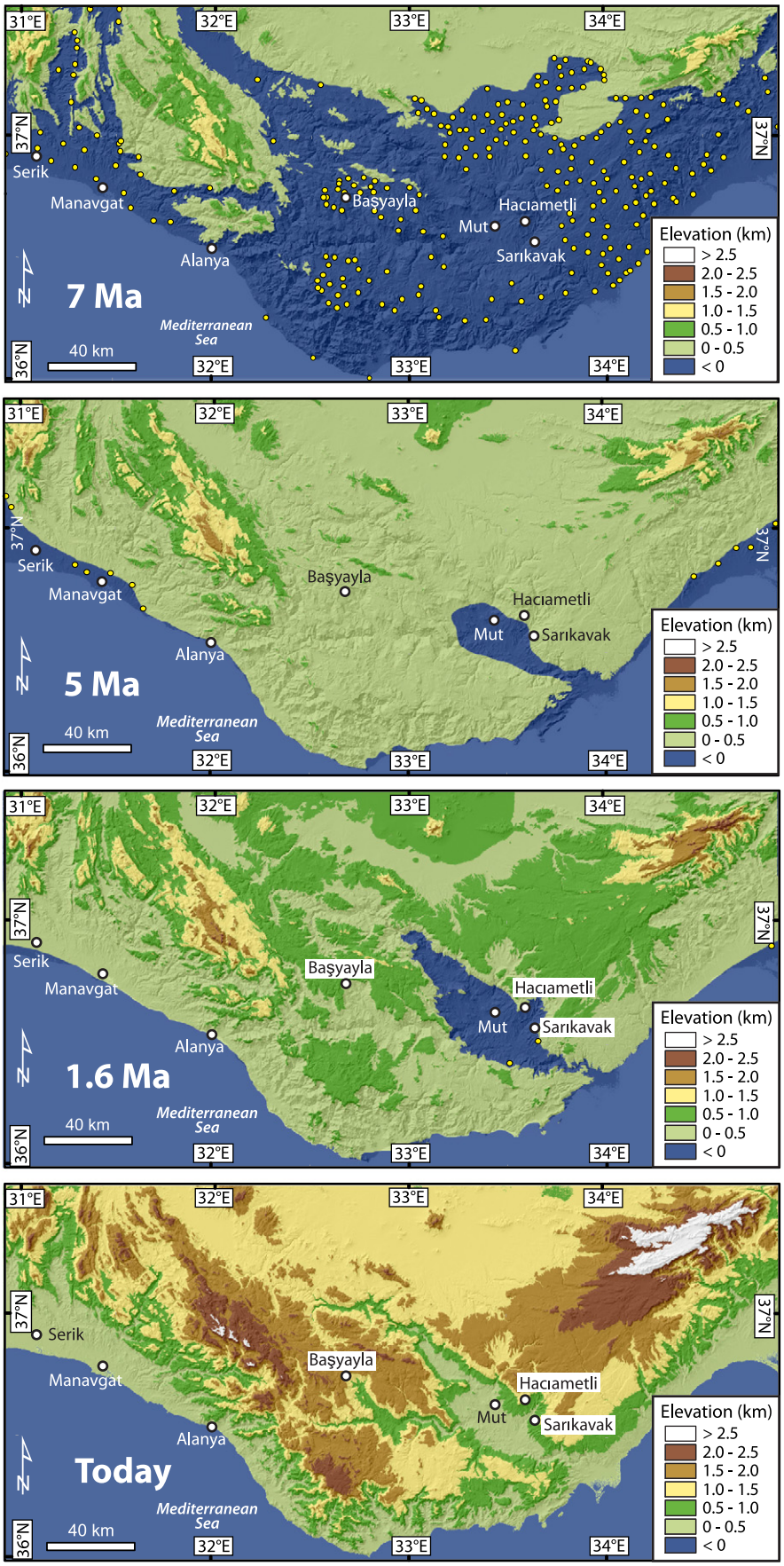

Fig. 4. Paleotopographic maps of the southern margin of the Central Anatolian Plateau. (A): 7 Ma paleotopography; (B): 5 Ma paleotopography; (C): 1.6 Ma paleotopography; D: present topography.

decreases toward the coast and toward the plateau interior. The spline surface can then be subtracted from the modern topography to reconstruct the late Miocene (ca. 7 Ma) paleotopography (Schildgen et al., 2012b). We constructed additional paleotopographic maps (Fig. 4) by subtracting fractions of the spline surface from the modern topography. We assumed that the pattern of uplift revealed by the late Miocene sediments has not changed through time, so that throughout our reconstruction, the plateau margin is uplifted faster compared with coastal and interior regions. This assumption is difficult to test, but the occurrence of the highest early Pleistocene marine sediments (Yıldız et al., 2003; Schildgen et al., 2012a) in a similar location as the highest late Miocene marine sediments (along the axis of the Central Taurides) suggests that a broadly similar pattern of deformation persisted. We reconstructed the map for 5 Ma by assuming that an uplift rate of 0.2 mm/yr started in the Mut Basin at 7 Ma, to be consistent with results reported by Cosentino et al. (2012) and Schildgen et al. (2012a, 2012b). Because this would lead to 0.4 km of uplift by 5 Ma, or 20% of the 2-km elevation of the marine sediments today, we subtracted 80% of the spline surface from the modern topography. For the 1.6 Ma time slice, we assumed that 1.2 km of uplift occurred after 1.6 Ma (Yıldız et al., 2003; Schildgen et al., 2012a). The 0.8 km of uplift that occurred between ca. 7 and 1.6 Ma represents 40% of the total 2-km of uplift, therefore, we subtracted 60% of the spline surface from the modern topography.

After creating the initial maps, we corrected any inconsistencies between the paleoshoreline positions and published descriptions of marine versus continental sediments that were summarized in the previous sections. We also attempted to remove some artifacts of modern relief. For example, after subtracting fractions of the smooth spline surface from the modern topography, we reduced elevations over long wavelengths, but the short-wavelength relief of the modern landscape remained. This problem was most prominent where deeply incised river valleys drain to the coast. In those areas, the river valleys were below sea level after subtracting the spline surface, resulting in irregular shorelines resembling drowned topography. Because the shorelines were more likely to be relatively smooth (assuming that the modern relief was generated after that region was uplifted), we manually changed the shorelines in our final paleotopographic maps. A similar problem occurs in some inland areas. For example, the Ermenek Basin was below sea level after the spline subtraction; however, the middle to late Miocene marine stratigraphy suggests that sediments along what is now the southern side of the valley represent deeper sediments deposited lateral to a platform, which is on the northern side of the valley (Janson et al., 2010; Cipollari et al., 2013a). These observations support a scenario where the modern relief of the valley was only generated following uplift and fluvial incision through the middle to late Miocene sediments. For that reason, we changed the elevations of the Ermenek Basin to lie above sea level for the 5 Ma map. Despite these corrections, smaller artifacts persist, which can be seen in topographic profiles extracted along transects that cross the southern plateau margin (Fig. 5).

3. Uplift constraints from other regions

3.1. Uplift of the northern margin of the Central Anatolian Plateau (Central Pontides)

Topographic growth of the northern margin of the Central Anatolian Plateau, which comprises the Central Pontides, is more ambiguous compared with the southern margin. The youngest marine sediments reported from the region are at 1040 m elevation in the Devrekâni Basin (Fig. 6), with an estimated early to middle Miocene age (Tunoğlu, 1991a,b), implying ca. 1-km of uplift since that time. Stable isotope compositions from the 12 to 8 Ma Tuğlu lacustrine section of the Çankırı Basin (Mazzini et al., 2013), south of the North Anatolian Fault, furthermore show less depletion compared with modern precipitation (Schemmel et al., 2013), implying that the Central Pontides did not constitute a significant orographic barrier to precipitation by that time (Mazzini et al., 2013). Analyses of Oligocene to early Miocene stable isotopes across the plateau reveal similar results, with an apparent absence of significant orographic barriers at both the northern and southern Central Anatolian Plateau margins by 20 to 16 Ma (Lüdecke et al., 2013). Finally, a series of low-relief, elevated paleo-erosion surfaces that extend from Istanbul through the Central Pontides have been suggested to represent the vestiges of a paleosurface that has undergone differential uplift (Yılmaz, 2007). Near Istanbul, the low-relief surface remnants lie at 40 to 300 m elevation (Yılmaz et al., 2010), while within the Central Pontides, they occur at ca. 1000 to 1500 m elevation (Fig. 6). Without knowing the age or potentially diachronous nature of the surface, it cannot be used to quantify uplift rates in the Central Pontides. Nonetheless, the preservation of the early to middle Miocene marine sediments, together with the lack of isotopic evidence of a rain shadow by 8 Ma and the paleosurface remnants, implies surface uplift and incision of no more than 1 to 1.5 km since the late Miocene.

Geomorphic data provide some clues to recent deformation patterns and rates in the Central Pontides. In the Kastamonu Basin (Fig. 6), incised fluvial strath terraces and pediments were used to define an average incision rate of 0.27 to 0.29 mm/yr since ca. 340 ka (Yıldırım et al., 2013b). Locally faster incision rates occur near active thrusts, indicating that uplift and incision were driven by motion on thrust faults (Yıldırım et al., 2013b). Moreover, late Pleistocene marine terraces along the Black Sea coast around the Sinop Peninsula indicate uplift rates that decrease from 0.2 mm/yr at the southern end of the peninsula to 0.02 mm/yr at the northern end (Yıldırım et al., 2013a). Similarly, Quaternary paleo-deltas of the Kızılırmak River (~120 km downstream from the outlet of the Kastamonu Basin, e.g., Akkan, 1970) were correlated with relative sea-level highstands to indicate a coastal uplift rate of 0.2 to 0.3 mm/yr during the last 340 ka (Demir et al., 2004). These uplift and river-incision rate estimates are consistent with modern vertical velocities of less than 1 mm/yr (0.4 $\pm$ 0.7 mm/yr) constrained with Persistent Scatterers InSAR and GPS velocities for the same region (Peyret et al., 2013). Together, the data support the hypothesis of late Pleistocene uplift throughout the Central Pontides relative to the Black Sea. Given that total uplift in the region since the late Miocene is only ca. 1 to 1.5 km, the recent incision/uplift rates recorded in the Central Pontides could not have been active for more than 4 to 5 Myr.

3.2. Uplift of the interior of the Central Anatolian Plateau

Few firm constraints exist for the uplift history of the interior of the Central Anatolian Plateau. Poisson et al. (1997, 2010) described evidence of an early Miocene marine transgression in the Sivas Basin, which is now at ca. 1300 m elevation, at a location that transitions between Eastern and Central Anatolia. Because current mean elevations in the Central Anatolian Plateau interior are close to 1 km (Fig. 1B), and much of the region was terrestrial since at least early Miocene time (Dercourt et al., 1993; Popov et al., 2004, 2006; Akgün et al., 2007 and references within; also see Section 2.1), the interior must have experienced <1 km of surface uplift since the late Miocene.

River terraces along the northward-flowing Kızılırmak River in the central part of the plateau reveal a mean incision rate of 0.08 mm/yr averaged over the last 1.99 Ma, or 0.07 mm/yr averaged over the last 404 ka (Doğan, 2011), which is 4× slower than incision through the northern plateau margin since ca. 340 ka (Yıldırım et al., 2013b), and 8× slower than incision through the southern plateau margin since ca. 130 ka (Schildgen et al., 2012a). The slower incision in the interior indicates that either the northward-flowing Kızılırmak River is currently in a transient state, with upstream portions of the river not yet adjusted to faster uplift throughout the region, or that faster uplift has occurred along the plateau margins compared to the plateau interior since the late Pleistocene (Yıldırım et al., 2013b).

Overall, it remains unclear how much surface uplift occurred in the Central Anatolian Plateau interior since the late Miocene, but it appears

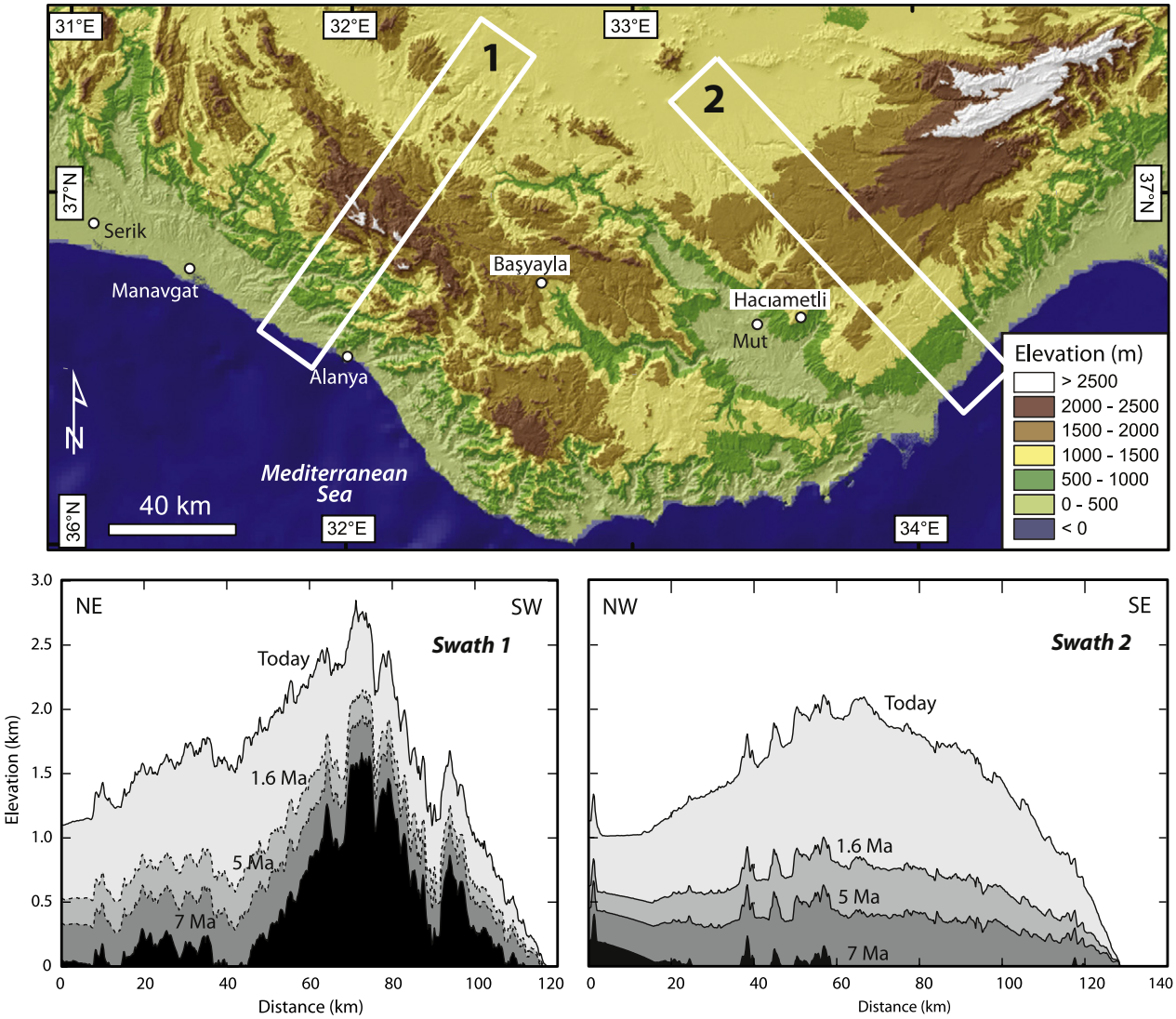

Fig. 5. Swath profiles across four sections of the southern margin of the Central Anatolian Plateau. Each profile was extracted from the modern topography and the three paleotopographic maps, to illustrate the temporal evolution of topography in each region. Note that the long-wavelength topography changes over time, however, little change occurs to short-wavelength relief, due to the methods used in reconstructing the paleotopography. In Swath 1, lines marking the elevation profiles at 5 Ma and 1.6 Ma are dashed, to indicate uncertainty related to the lack of information on changes in uplift rates through time for the SW plateau margin.

to have experienced less uplift compared with both the Central Pontides in the north and the Central Taurides in the south.

3.3. Uplift of the Eastern Anatolian Plateau

The 2- to 3-km average elevations of the Eastern Anatolian Plateau rise significantly higher than those of the Central Anatolian Plateau. In Eastern Anatolia, the end of marine sedimentation near Lake Van during the Serravallian (ca. 12 Ma) (Fig. 1, Gelati, 1975; Popov et al., 2004) and at ca. 11 Ma in the Kahramanmaraş Basin (south of the Bitlis-Zagros suture zone) (Hüsing et al., 2009), coupled with large-scale underthrusting of the 11 Ma sediments (Hüsing et al., 2009) attests to the final closure of the Neotethys Ocean and limits the start of more regional surface uplift (e.g., Şengör and Kidd, 1979; Şengör et al., 1985, 2008; Hüsing et al., 2009). A recent apatite fission-track study indicates accelerated exhumation in the Bitlis–Zagros thrust zone at the suture between the Arabian and Eurasian plates at ca. 12 Ma (Okay et al., 2010), which may also indicate the start of an uplift phase.

Consistent with the estimated onset of uplift is the timing and nature of volcanism in the region (Fig. 7). Earliest eruptions at ca. 11 Ma were generally calc-alkaline in composition and clustered in the north (Pearce et al., 1990; Keskin et al., 1998, Keskin, 2007). By 6 to 7 Ma, predominantly alkaline volcanism had spread southwards and eastwards (Pearce et al., 1990; Keskin et al., 1998; Sumita and Schmincke, 2013). This volcanism and the changes in volcanic geochemistry have been used to infer that fundamental changes in the mantle lithosphere and/or upper mantle were coeval with the start of uplift in Eastern Anatolia (Keskin, 2003; Şengör et al., 2003; Keskin, 2007; Şengör et al., 2008).

4. Crustal scale deformation

Apart from surface-uplift studies, structural and geophysical studies provide insights into the processes that contribute to topographic evolution, including clues about crustal stress patterns, plate-boundary interactions, the geometry of lithospheric slabs, and the likelihood of delamination of the mantle lithosphere. In the following sections, we summarize the structural evolution of different sectors of the Central and Eastern Anatolian plateaus before moving on to geophysical constrains in Section 5.

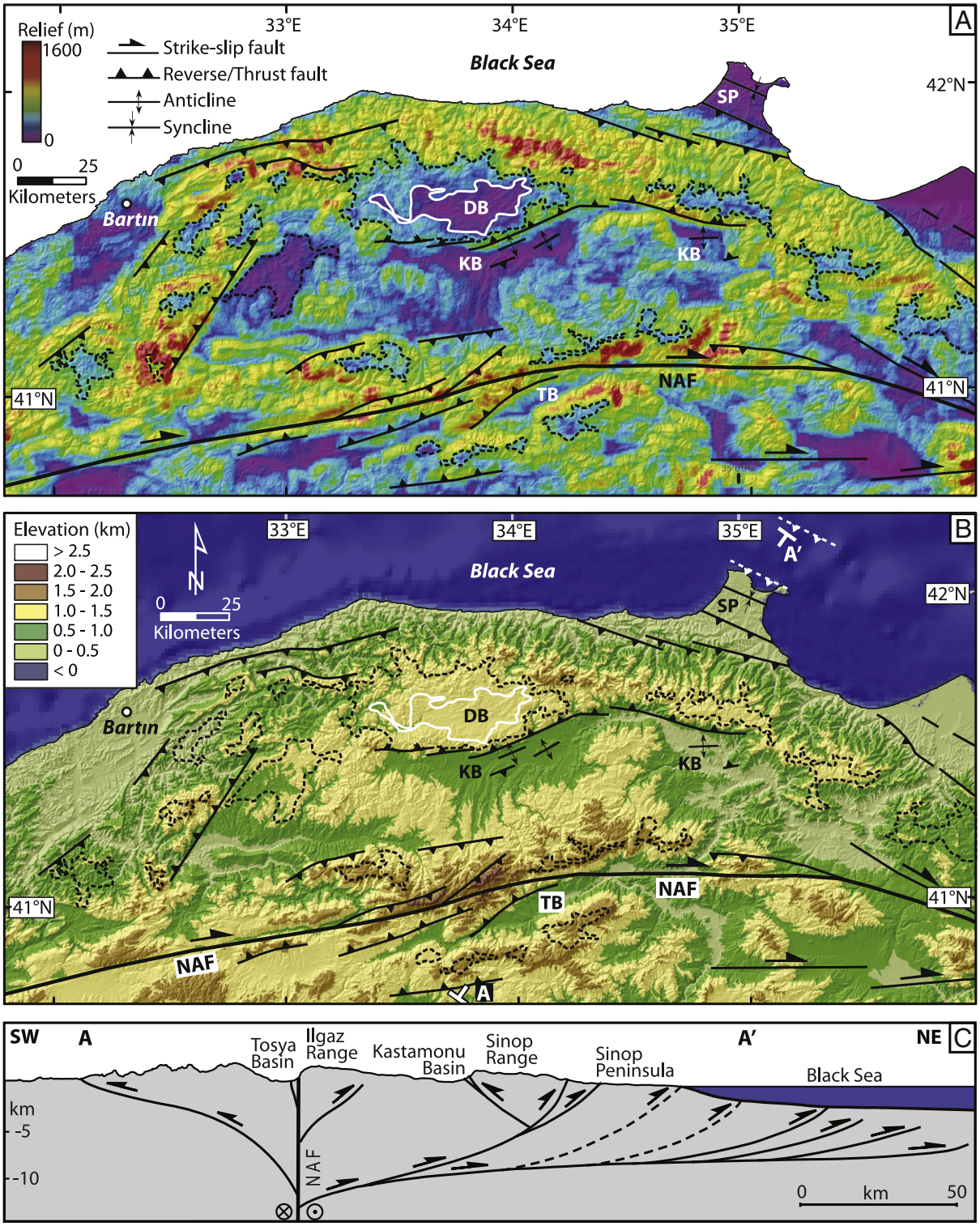

Fig. 6. Relief map (A) and topographic map (B) of the Central Pontides along the northern margin of the Central Anatolian Plateau. Black dashed lines outline high-elevation regions of low relief in both maps. These low-relief, elevated surfaces are interpreted to be remnants of a differentially-uplifted erosional paleosurface that spans the northern margin of Turkey. White line outlines the perched Devrekani Basin. SP: Sinop Peninsula; KB: Kastamonu Basin; TB: Tosya Basin; DB: Devrekani Basin; NAF: North Anatolian Fault. (C): Conceptual model for the Central Pontides as a bivergent orogenic wedge related to a positive flower structure developed over a shallow detachment surface linked to the North Anatolian Fault (modified after Yildirim et al., 2011).

4.1. Crustal shortening at the northern margin of the Central Anatolian Plateau

Following closure of the northern branch of the Neotethys and collision of the Pontide island arc with the Sakarya continent to the south mainly during late Cretaceous time, the Central Pontides were shortened and thickened along a north-vergent detachment associated with a foreland fold-and-thrust-belt from the Paleocene to the Eocene (e.g., Şengör et al., 1985; Şengör, 1995; Okay and Tüysüz, 1999; Tüysüz, 1999; Sunal and Tüysüz, 2002; Okay et al., 2006). North of the Pontides, the south-central and southeastern Black Sea margin is currently undergoing shortening (Barka and Reilinger, 1997; Cloetingh

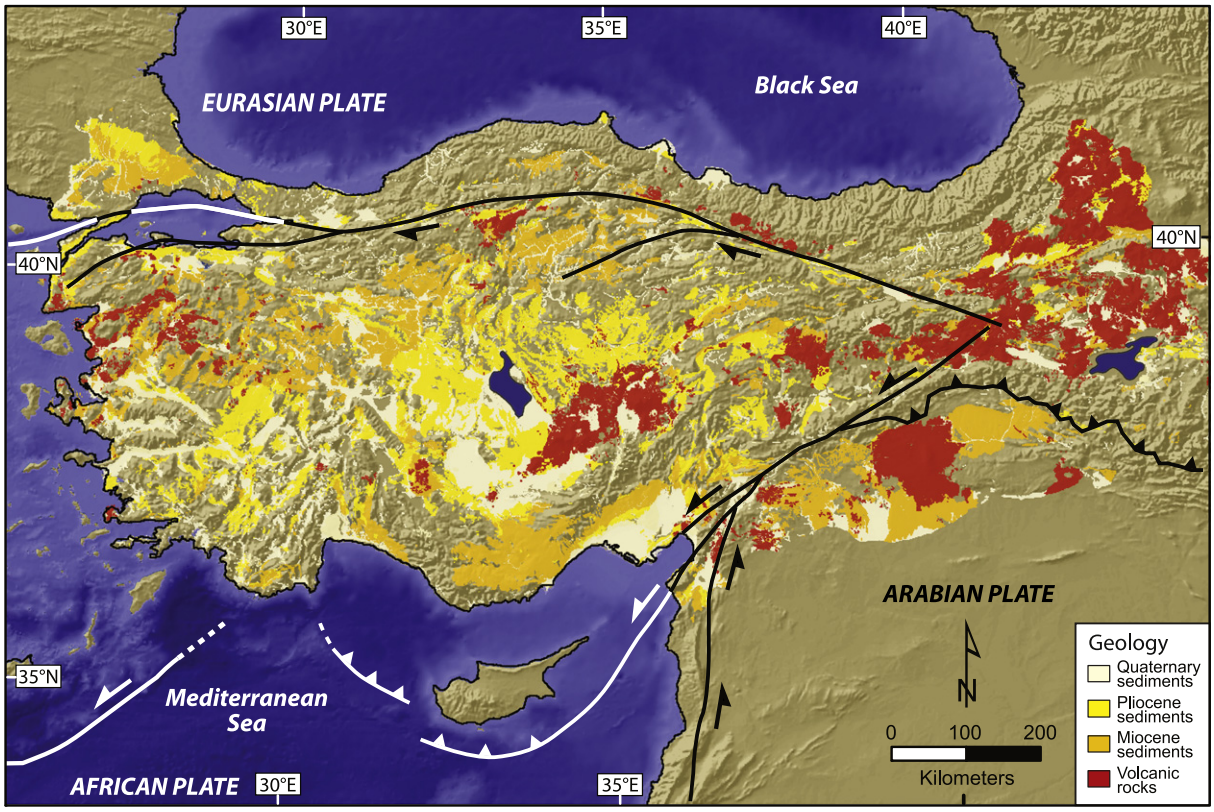

Fig. 7. Simplified geological map of Turkey derived from 1:500,000 scale mapping from the Maden Tetkik ve Arama Genel Müdürlüğü (MTA), Ankara, Turkey. All brown regions indicate pre-Miocene rocks. Major tectonic boundaries (as in Fig. 1) are shown for reference.

et al., 2003). At the southern border of the Central Pontides, which marks the northern boundary of the Anatolian microplate, the North Anatolian Fault (NAF) forms a wide northward-convex bend (Fig. 6) that is undergoing dextral displacement of 24 mm/yr (Reilinger et al., 2006). Variations in the lateral and fault-normal component of motion occur along the broad restraining bend, with fault-normal shortening (up to 8 mm/yr) occurring between Ereğli and the Sinop Peninsula (31.5 to 35°E latitude) (Yildirim et al., 2011). The Central Pontides of that region are characterized by thrust faults that deform Quaternary sediments (Andrieux et al., 1995; Yildirim et al., 2011) as well as active seismicity, such as the Ms 6.5 Bartın earthquake of 1968, which showed a thrusting focal mechanism (Ketin and Abdüsselamoğlu, 1969; McKenzie, 1972). South of the NAF, the reactivation of structures after late Miocene time in the Çankırı Basin appears to relate to local block rotations along faults with strike–slip components (Lucifora et al., 2013).

Seismic reflection studies have revealed deep thrust faults along the southern margin of the Black Sea and within the Central Pontides. Across the southern margin of the Black Sea, thrust faults deform Quaternary sediments, typically with progressive southward migration of deformation (Finetti et al., 1988). Similar southward-migrating deformation patterns were observed within the Central Pontides (Aydın et al., 1995; Şengör, 1995; Damcı et al., 2004). Yildirim et al. (2011) integrated the seismic reflection lines from the Black Sea and from within the Central Pontides with surface evidence of active thrusting to suggest that the Central Pontides constitute an orogen-scale, bivergent, wedge-shaped transpressive structure, with a shallow detachment horizon that merges with the NAF at depth (Fig. 6C). In support of this inferred importance and deep extent of the NAF, recent waveform inversions of teleseismic and regional data reveal a low velocity zone along the eastern and central sections of the NAF that extend through the crust and into the upper mantle, likely reflecting a structurally weak zone that corresponds to Tethyan sutures (Fichtner et al., 2013).

4.2. Structural evolution of the southern margin of the Central Anatolian Plateau

The Central Taurides along the southern plateau margin consist of multiple oceanic and continental units shortened in late Cretaceous–Eocene time during the closure of the Neotethys and subsequent collision of the Taurus carbonate platforms with the crystalline complex of Central Anatolia (Şengör and Yılmaz, 1981; Dixon and Robertson, 1984; Pourteau et al., 2010, 2013). The Bozkır and Aladağ nappes were emplaced from the north in late Cretaceous to middle–late Eocene time (Özgül, 1976, 1997; Monod, 1977; Akay and Uysal, 1988; Bozkaya and Yalçin, 2000; Andrew and Robertson, 2001). Topographic growth from middle Eocene to late Oligocene time led to widespread fluvial and lacustrine sedimentation (Clark and Robertson, 2002, 2005; Eriş et al., 2005; Şafak et al., 2005), with localized extension and basin formation suggested to result from southward retreat of the African slab (Kempler and Ben-Avraham, 1987; Robertson, 1998, 2000; Jolivet and Faccenna, 2000). Subsidence that resulted in a change from terrestrial to marine sedimentation in southern Turkey and formation of the Cilicia Basin has also been explained by slab retreat (Robertson, 1998). A final stage of shortening deformed Oligocene lake sediments, but since late Miocene time, small-scale normal and strike–slip faulting have predominated within the Central Taurides (Glover and Robertson, 1998; Ilgar and Nemec, 2005; Schildgen et al., 2012b). More substantial deformation, and most of the post-late Miocene surface uplift, appears to have accumulated through long-wavelength upwarping of the region (Cosentino et al., 2012).

Offshore seismic reflection lines in the central portions of the Antalya and Cilicia basins reveal minor thrusts that may be related to salt tectonics (Evans et al., 1978; Bridge et al., 2005). Along the northern margin of the Cilicia Basin between Cyprus and southern Turkey (line A of Aksu et al., 2005), low-angle, south-directed thrusts affect Unit 2,

but do not cut the M-reflector. The M-reflector was correlated by Cipollari et al. (2013b) with the ca. 5.56 Ma Messinian Erosional Surface (Cosentino et al., 2013), implying that shortening had ended by that time. Seismic reflection lines also reveal normal faults along the northern margins of the offshore basins that deform early Pliocene (or latest Miocene, see Cipollari et al., 2013b) to recent sediments (Aksu et al., 2005; İşler et al., 2005). South-directed shortening and transpression have deformed the southern margins of the Cilicia and Antalya basins (Aksu et al., 2005; İşler et al., 2005), which is consistent with the shortening expected from the vector analysis by Şengör et al. (1985) of the Kahramanmaraş triple junction. In Cyprus, shortening and strike-slip faulting have predominated since the late Miocene in the north (Robertson and Woodcock, 1986; Harrison et al., 2004; Calon et al., 2005) and the southwest (Wdowinski et al., 2006), while normal faults and associated grabens have formed in other parts of the island (Robertson, 2000; Payne and Robertson, 2000). Shortening is generally seen in seismicity along the collision zone south of Cyprus (Imprescia et al., 2012), and also to a lesser degree by the deep earthquakes beneath the Antalya Basin associated with the subducting "Western Cyprus slab" (Kalyoncuoğlu et al., 2011; Imprescia et al., 2012; Schildgen et al., 2012b).

4.3. Structural evolution of the interior of Central Anatolia and the Aegean

Since at least late Miocene time, the plateau interior appears to have also undergone predominantly extension (Dhont et al., 1998b; Cemen et al., 1999; Dirik et al., 1999; Dilek and Whitney, 2000; Ocakoğlu, 2004; Jaffey and Robertson, 2005; Rojay and Karaka, 2008; Genç and Yürür, 2010; Özsayın et al., 2013) with localized strike–slip faulting (Şengör et al., 1985; Koçyiğit and Beyhan, 1998; Umhoefer et al., 2007; Özsayin and Dirik, 2011). In a few locations, the timing of a changeover from shortening to extension/strike–slip faulting has been constrained to the late Miocene. For example, in the Akşehir graben, seismic reflection lines reveal reverse faulting of upper Miocene sediments, but uppermost Miocene and younger sediments are only affected by extension (Koçyiğit et al., 2000). Also, in the Tuz Gölü Basin, volcanic ashes dated with $^{40}Ar/^{39}Ar$ geochronology indicate that a phase of NE–SW shortening had ended by 6.81 ± 0.24 Ma, and was followed by NE–SW extension, which continues today (Özsayın et al., 2013). Changes in the geochemistry of volcanic rocks from calc-alkaline compositions in the middle to late Miocene to alkaline compositions have also been related to decreasing influence of crustal contamination and/or subduction coeval with the onset of crustal extension (Innocenti et al., 1975; Deniel et al., 1998; Dhont et al., 1998a; Temel et al., 1998; Kürkçüoğlu et al., 2001; Aydar and Gourgaud, 2002; Kürkçüoğlu et al., 2004; Şen et al., 2004; Kuscu and Geneli, 2010).

Coincident with the onset of extension in Central Anatolia was a change in deformation of the Aegean region. Most notably, right-lateral strike–slip faulting associated with the Kephalonia transform, which accommodates faster retreat of the southern Hellenic subduction zone compared to the north and has been linked to the North Anatolian Fault through paleomagnetic and geochronologic constraints (Vassilakis et al., 2011; Bradley et al., 2013), appears to have initiated in the latest Miocene or early Pliocene (Royden and Papanikolaou, 2011; Bradley et al., 2013).

4.4. Structural evolution of Eastern Anatolia

Eastern Anatolia marks the tectonically active collision zone between Eurasia in the north with various southern crustal fragments that were accreted throughout Mesozoic and Cenozoic time (Şengör and Yılmaz, 1981; Barazangi et al., 2006). The Neotethys was consumed along a north-dipping subduction zone beneath the southern margin of Eurasia (Yılmaz et al., 1997), above which formed the Eastern Pontide arc. After final closure during the late Paleocene (Şengör and Yılmaz, 1981; Bozkurt and Mittwede, 2001), the Pontide arc was accreted to a series of Cretaceous ophiolitic mélange nappes with Paleocene to late Oligocene flysch sequences of the Eastern Anatolian Accretionary Complex (Şengör and Yılmaz, 1981). The flysch units decrease in age to the south, where they abut the Bitlis–Pötürge Massif, the easternmost extension of the Menderes–Taurus block. A southern branch of the Neotethys continued to be subducted until its final closure in middle Miocene time, marking the collision between Arabia and Eurasia (Şengör and Kidd, 1979; Dewey et al., 1986; Bozkurt and Mittwede, 2001; Hüsing et al., 2009).

Much of the late Miocene to recent deformation in Eastern Anatolia has been dominated by strike–slip and thrust faulting (Şengör et al., 1985; Şaroğlu and Yılmaz, 1987; Bozkurt, 2001; Koçyiğit et al., 2001; Philip et al., 2001; Şengör et al., 2008), including shortening of Pliocene–Pleistocene sediments (Şengör et al., 1985; Dewey et al., 1986; Şaroğlu and Yılmaz, 1987), recent seismicity on thrust faults (Tan et al., 2008; Doğan and Karakaş, 2013), and earthquake focal mechanisms revealing mostly strike–slip and shortening deformation (Şengör et al., 2008). A minor amount of extension appears to be limited to small-scale N–S-oriented structures (Şengör et al., 1985; Toker, 2006). Within the Greater Caucasus to the north, shortening and rapid exhumation has been active since the early Pliocene (Forte et al., 2010; Avdeev and Niemi, 2011).

5. Geophysical perspectives on the crust, lithosphere, and subducting slabs

Many of the early geophysical studies of the Anatolian Plateau to determine characteristics of the crust, lithosphere, and subducting slabs were focused on Eastern Anatolia. The region is characterized by strong *Sn* and *Pn* wave attenuation in the upper mantle (Gök et al., 2003; Al-Damegh et al., 2004), slow-shear wave speeds (Maggi and Priestley, 2005; Gök et al., 2007), and slow *Pn* wave speeds (Al-Lazki et al., 2003, 2004; Lei and Zhao, 2007; Elitok and Dolmaz, 2008). Together with moderate crustal thicknesses of ca. 40 to 50 km derived from P- and S-wave receiver functions (Zor et al., 2003; Çakir and Erduran, 2004) but consistently very negative Bouguer gravity anomalies (Fig. 8; Ates et al., 1999), the observations indicate an absent or thinned mantle lid beneath Eastern Anatolia (Şengör et al., 2003, 2008). Angus et al. (2006) estimated a mantle lid only 60 to 80 km thick beneath the central part of Eastern Anatolia. Furthermore, the lack of subcrustal earthquakes (Türkelli et al., 2003) and the termination of the lithosphere–asthenosphere boundary of the Arabian plate beneath the Bitlis–Zagros suture (Angus et al., 2006) imply very little or no underthrusting of Arabia beneath Eurasia. Together with the break in the high-velocity anomaly beneath Eastern Anatolia at around 100 km depth imaged through teleseismic (Lei and Zhao, 2007) and body-wave tomography (Piromallo and Morelli, 2003), the observations are consistent with delamination of the lithosphere beneath Eastern Anatolia and break-off of the Tethyan slab.

Interestingly, surface heat flow measurements in the regions around the Anatolian microplate tend to be relatively low (<30 mW/m^2, Artemieva and Mooney, 2001), although the estimated temperatures at 50 km depth are unusually high (ca. 900–1000 °C) and the depth to the 550 °C isotherm (or the Curie point depth) is shallow (typically < 30 km, Artemieva, 2006; Bektaş et al., 2007; Aydın et al., 2008). To explain these patterns in the context of potential delamination and slab break-off, we can consider that the timescale required for hotter temperatures at the base of the crust following delamination to reach the surface through diffusion can be estimated by L^2 / D (Turcott and Schubert, 2002, p. 149), where L is the crustal thickness and D is the thermal diffusivity. Assuming a crustal thickness of 40 km and average diffusivity of 40 km^2/Myr (typical for granodiorite, Arndt et al., 1997), approximately 40 Myr are required for hotter temperatures to reach the surface. The modern thermal characteristics of the Anatolian crust are

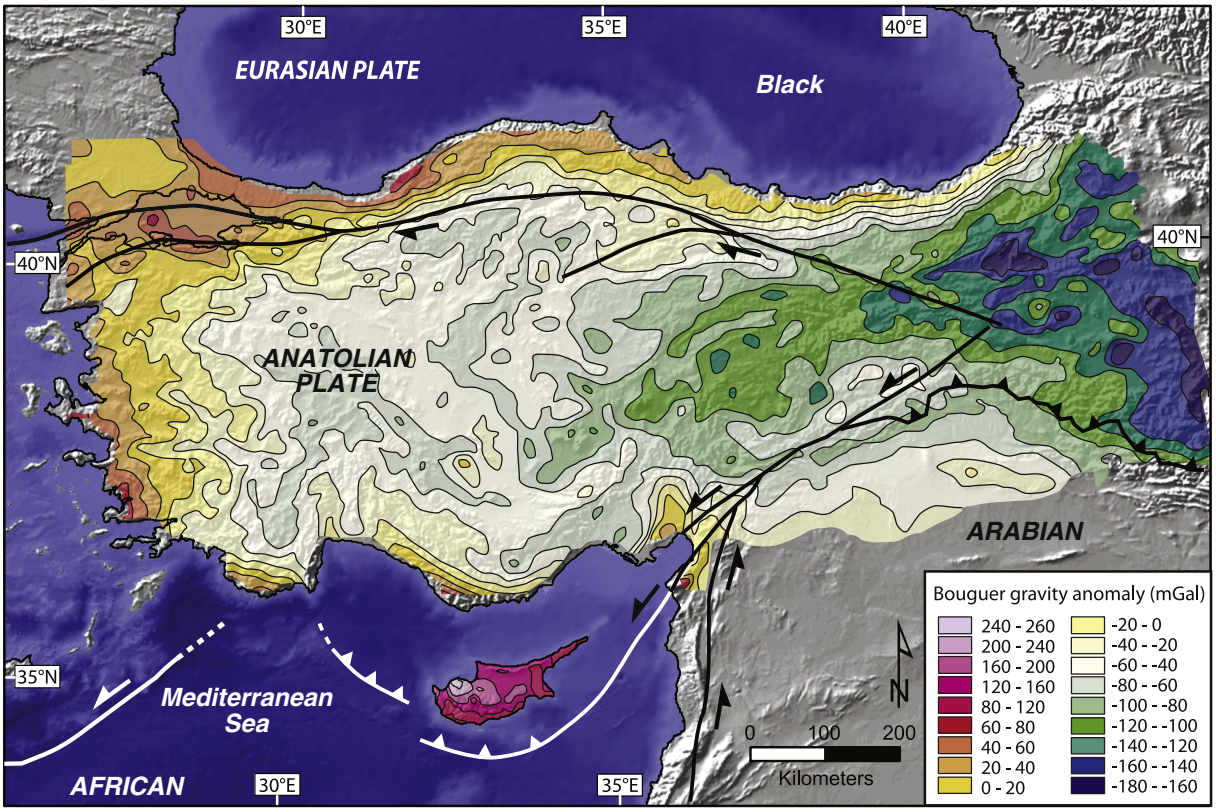

Fig. 8. Bouger gravity anomaly map across Turkey and Cyprus. Gravity anomalies from Turkey are reprojected and simplified from Ates et al. (1999), and those from Cyprus are redrawn from Gass and Masson-Smith (1963).

therefore consistent with delamination/slab break off and upwelling asthenosphere that occurred much more recently than 40 Ma.

Faccenna et al. (2006) noted that the slab break-off inferred from beneath Eastern Anatolia may extend to Cyprus or even farther west, based on tomography from Piromallo and Morelli (2003). Since that time, higher-resolution tomography has been extended westward into Central Anatolia. Each of the three recently published P-wave and Pn tomography models (Gans et al., 2009; Biryol et al., 2011; Mutlu and Karabulut, 2011) shows a low-velocity zone extending from Eastern Anatolia into the southern part of Central Anatolia, in the region of the Central Anatolian Volcanic Province and the SE margin of the Central Anatolian Plateau. Overall, the pattern broadly matches the mapped pattern of volcanic rocks (Fig. 7). This pattern is consistent with slab delamination and break-off that extends westward from beneath Eastern Anatolia to Cyprus (Gans et al., 2009; Biryol et al., 2011; Mutlu and Karabulut, 2011). Although tomography alone does not provide firm evidence for slab break-off (Doglioni et al., 2007; Foulger et al., 2013), Imprescia et al. (2012) and Kalyoncuoğlu et al. (2011) noted a near absence of seismicity within 50 km north of Cyprus, in the region of a near-vertical, 200-km low velocity zone. Lack of subduction-related deep seismicity (>55 km depth) also characterizes the region immediately east of Cyprus (Kalyoncuoğlu et al., 2011), where deformation is instead associated with left-lateral strike–slip faulting and transpression (Harrison et al., 2004; Imprescia et al., 2012).

In contrast, continued subduction of the "Western Cyprus slab" between western Cyprus and the Hellenic arc is supported by recent analyses of gravity and seismic data (Kalyoncuoğlu et al., 2011; Imprescia et al., 2012; Schildgen et al., 2012b), with earthquakes extending down to at least 138 km depth. Barka and Reilinger (1997) suggested that a tear between the Cyprus and Aegean slabs could explain the greater extension above the Aegean slab compared to above the Cyprus slab. Later studies using P-wave (Biryol et al., 2011), S-wave (Bakırcı et al., 2012), and surface wave (Salaün et al., 2012) tomography, as well as earthquake focal mechanisms (Özbakır et al., 2013) similarly inferred a major tear to exist between the two slabs.

Few studies have constrained the crustal thickness of Central Anatolia, although Mutlu and Karabulut (2011) used station delays to estimate crustal thicknesses of 35 ± 2 km across most of Central Anatolia, and 40 to 45 km within the Central Taurides. More recently, Tezel et al. (2013) used receiver functions to estimate Moho depths of 38 to 42 km in both the Central Taurides and Central Pontides (Fig. 9). No estimates have yet been made for the mantle lithosphere thickness beneath Central Anatolia.

6. Discussion

Given what is now a fairly detailed picture of the crustal deformation history in Central Anatolia, regional geophysical observations, and local constraints on the uplift history, we next explore the likelihood of various geodynamic mechanisms that might explain the observations. Afterwards, we discuss how our favored set of mechanisms along the northern and southern margins of the Central Anatolian Plateau may relate to more regional patterns of uplift and deformation, and whether or not several of the processes may be geodynamically linked.

6.1. Crustal shortening and thickening

Along the northern margin of Central Anatolia, if shortening along a broad restraining bend of the NAF induced surface uplift in the Central Pontides, then the establishment of the NAF should be coeval with the start of an uplift phase. Unfortunately, the onset of activity along the NAF is imprecisely known, particularly as deformation appears to have

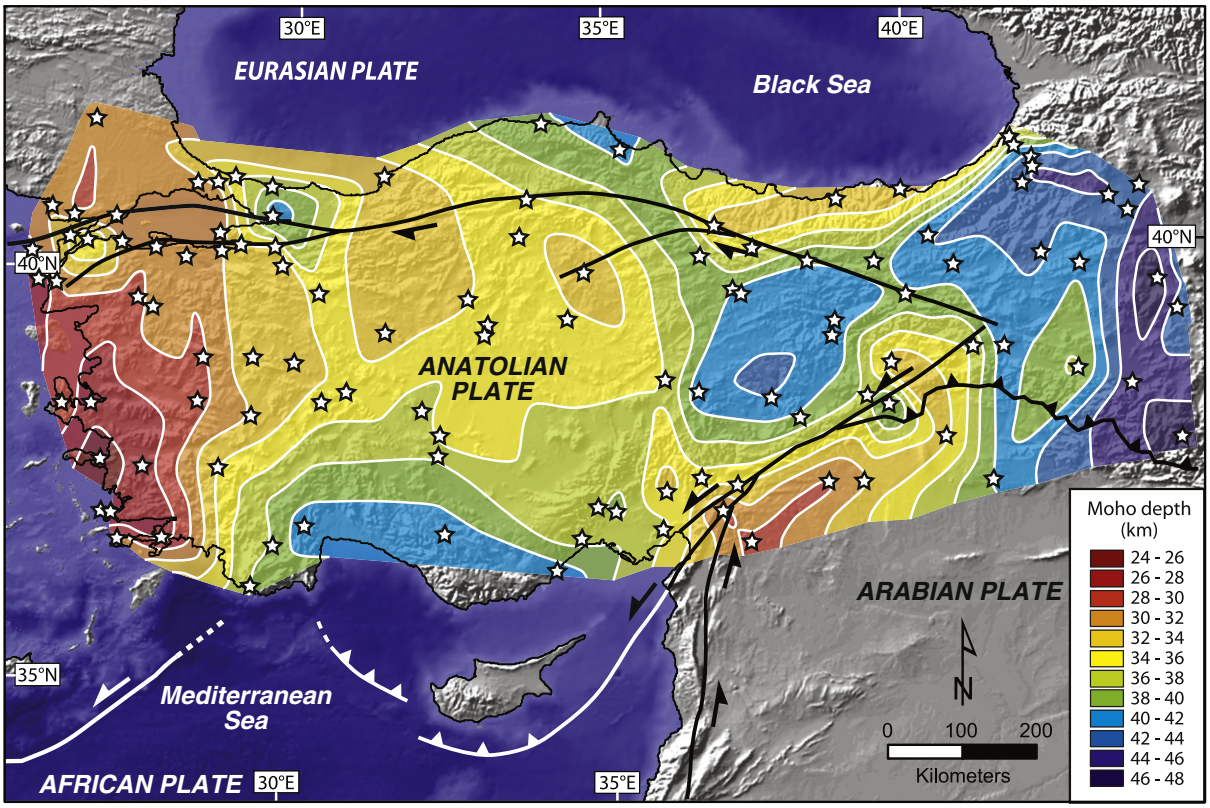

Fig. 9. Map of Moho depths across Turkey based on receiver functions (reprojected and redrawn from Tezel et al., 2013). White stars show station locations.

initiated at different times along the structure (e.g., Armijo et al., 1999; Şengör et al., 2005 and references within). Within the Central Pontides, deposition and folding of the lacustrine and fluvial strata of the Pontus Formation (Irrlitz, 1972) in pull-apart basins along the NAF have been interpreted to indicate activity of the NAF (Barka and Hancock, 1984; Andrieux et al., 1995). The age of the Pontus Formation has been estimated at 2 to 4 Ma from charophytes and ostracods (Över et al., 1993) and mammals (Ünay and de Bruijn, 1998), although Barka and Hancock (1984) considered the base of the formation to be 5 Ma. In the Tosya Basin (Fig. 6), 8.5 Ma volcanic rocks underlie the formation (Adıyaman, 2000). Folding of the Pontus Formation related to the NAF, therefore, must have started after 5 Ma (Hubert-Ferrari et al., 2002). Coarse sediments of no older than medial Pliocene age in the obliquely shortening Çerkeş–Kurşunlu Basin within the North Anatolian Shear Zone indicate that fault activity had started by that time in the region (Şengör et al., 2005 and references within). The reactivation of strike–slip structures in the Çankırı Basin (south of the NAF in the Central Pontides) after the late Miocene (Lucifora et al., 2013) is consistent with these general constraints. Because the total uplift since the late Miocene is on the order of 1 to 1.5 km (see Section 3.1), the ca. 0.3 mm/yr uplift rates that have elevated Pleistocene geomorphic features (Demir et al., 2004; Yıldırım et al., 2013a,b) could not have been active for more than 4 to 5 Myr, which is consistent with a latest Miocene to early Pliocene onset of NAF-related transpression and uplift. Although more precise constraints are needed to test the relationship between the onset of the NAF and uplift of the Central Pontides, the currently available data are consistent with recent uplift in the Pontides related to movement along the NAF.

To test the feasibility of this mechanism, we can calculate the uplift rate that would likely occur along the Pontide wedge as a result of crustal shortening and thickening. Following the argument summarized in Garzione et al. (2008), when shortening leads to crustal thickening, the product of the shortening rate, u, and the crustal thickness, H, should equal the product of the width of the deforming region, W, and the average rate of crustal thickening, dH / dt. If Airy isostasy is maintained, then the uplift rate, dh/ dt, is given by:

$$\frac{dh}{dt} = \frac{(\rho_m - \rho_c)}{\rho_c}\frac{dH}{dt} = \frac{(\rho_m - \rho_c)}{\rho_c}\frac{uH}{W} \approx \frac{1}{5.5}\frac{uH}{W} \quad (1)$$

where ρ_c (2800 kg/m^3) is the crustal density and ρ_m (3300 kg/m^3) is the mantle density. Assuming a maximum NAF-normal shortening rate u of 8 mm/yr (Yildirim et al., 2011), a width of the deforming wedge W of 200 to 250 km, and an initial crustal thickness H of 35 km, the average uplift rate, dh / dt, should be between 0.20 and 0.25 mm/yr, which is broadly consistent with the 0.28 mm/yr river incision rates (Yıldırım et al., 2013b) and 0.2 mm/yr uplift rates (based on marine terraces, Yıldırım et al., 2013a) from the region.

Along the southern margin of the Central Anatolian Plateau, shortening and thickening above the subducting African slab could result also in uplift. The main opposing argument is that uplift appears to be coeval with minor extension and regional monoclinal warping rather than with shortening (see Section 4.2). However, if deformation of the overriding plate occurred above a broad region of thermal weakening at the base of an accreting subduction wedge (e.g., Fuller et al., 2006; Fernández-Blanco et al., 2012), surface-breaking thrusts may not be required. An appealing aspect of this mechanism is that it can explain both uplift of the forearc (southern Turkey) and Cyprus as well as subsidence of the intervening Cilicia Basin. However, an important factor limiting the feasibility of rapid thickening through accretion is the slow convergence rate between Africa and Eurasia (<10 mm/yr since ca. 25 Ma, McQuarrie et al., 2003, with modern convergence of 5 mm/yr, Reilinger et al., 2006). Given that the convergence rate is 5 times slower than that modeled by Fuller et al. (2006), deformation in their model that required 6.4 Myr to achieve would require 32 Myr in southern Turkey (5 times longer), assuming an equivalent 2.5-km thickness of material being accreted.

In a more extreme case, we can calculate the uplift rate that would result if all convergence between Africa and Eurasia were taken up through shortening of the Central Taurides; this should provide a maximum limit to shortening-related uplift. Considering a shortening rate of 5 mm/yr (modern convergence between Africa and Eurasia, Reilinger et al., 2006), an initial crustal thickness of 35 km, and a 100-km width of the deforming region, Eq. (1) yields an uplift rate of 0.32 mm/yr. Based on this calculation, shortening cannot explain the faster uplift rates in the Central Taurides (ca. 0.7 mm/yr) that characterized the region after 1.6 Ma (Schildgen et al., 2012a), but may have contributed to the slow uplift rates (ca. 0.1 to 0.2 mm/yr, Schildgen et al., 2012a) that occurred before 1.6 Ma.

6.2. Eratosthenes Seamount (continental fragment) subduction/collision

Schildgen et al. (2012a) suggested that the faster Pleistocene uplift of the S and SW plateau margin in Central Anatolia (after 1.6 Ma) could relate to the collision of the Eratosthenes Seamount with the subduction zone south of Cyprus (Kempler and Ben-Avraham, 1987; Ben-Avraham et al., 1988), as they noted a general coincidence in the timing of: (1) rapid seamount subsidence in the late Pliocene to early Pleistocene (Robertson, 1998, 2000); (2) the start of faster uplift of southern Cyprus (Robertson, 1998, 2000); and (3) a tectonic transition throughout the easternmost Mediterranean (Schattner, 2010). The Eratosthenes Seamount is underlain by ca. 28 km of continental crust (Aal et al., 2001; Ben-Avraham et al., 2002); as buoyancy analysis suggests that continental crust >15 km thick is sufficient to increase the coupling of the lower and upper plate (Cloos, 1991), collision of the continental fragment with the subduction zone may have influenced the overriding plate.

The existence of the Cilicia Basin, which separates southern Turkey from Cyprus, may argue against linking seamount collision to uplift as far north as southern Turkey; however, the basin itself could have also been uplifted. A remarkable 1-km drop in sea floor bathymetry occurs on the west side of the N–S-striking Anamur Kormakiti Zone (e.g., Fig. 2 in İşler et al., 2005), which could separate the uplifted Cilicia Basin from the deeper Antalya Basin to the west. Interestingly though, the Adana Basin, which lies at the eastern end of the Cilicia Basin (Fig. 3), appears to have only experienced 0.02 to 0.13 mm/yr of uplift since the early Pleistocene (Cipollari et al., 2013b). Studies indicating emergence of the Troodos Massif in Cyprus in late Pliocene time (<2.58 Ma, McCallum and Robertson, 1990, 1995; Robertson, 1998; Kinnaird et al., 2011), moderate middle to late Pleistocene uplift rates (>0.08 mm/yr, Kinnaird et al., 2011) and very fast Holocene uplift rates (ca. 2 to 4 mm/yr, Harrison et al., 2013) have started to provide a useful framework to further assess uplift chronology and mechanisms in the region, but more constraints together with modeling studies are necessary to assess the importance of seamount collision in contributing to Quaternary uplift.

6.3. Lithospheric slab break-off and tearing

The overall pattern of uplift since the late Miocene in Central Anatolia, detailed in Sections 2 and 3, includes focused uplift along the plateau margins, with greater uplift of the S and SE margins compared to the SW (Schildgen et al., 2012b). Slab break-off has been suggested to explain the greater uplift along the S and SE margins (Cosentino et al., 2012; Schildgen et al., 2012a), potentially linking uplift in Eastern Anatolia with that in Central Anatolia. Numerical modeling has shown that >20 Myr may elapse between the onset of continental collision and break-off of the 200-Ma Neotethyan slab (van Hunen and Allen, 2011), which is broadly consistent with a late Eocene/Oligocene collision of Arabia with Eurasia (Jolivet and Faccenna, 2000; Agard et al., 2005; Dargahi et al., 2010; Ballato et al., 2011; McQuarrie and van Hinsbergen, 2013) and the ca. 11 Ma inferred onset of uplift related to slab break-off beneath Eastern Anatolia (Keskin, 2003; Şengör et al., 2003; Keskin, 2007; Şengör et al., 2008). Cosentino et al. (2012) noted that the 4- to 6-Myr later start of uplift along the southern margin of Central Anatolia compared with Eastern Anatolia, together with the 600 to 700 km distance between the apex of the Bitlis–Zagros suture zone and the SE margin of Central Anatolia, would imply a lateral propagation rate of slab break-off of 100 to 175 mm/yr (Fig. 10). This difference in the timing of uplift agrees well with numerical modeling of the lateral propagation rate of a tear within the Tethyan slab, which yielded estimates of 100 to 150 mm/yr (van Hunen and Allen, 2011). The geochronological and geophysical observations are therefore consistent with model predictions of slab break-off starting beneath Eastern Anatolia and propagating westward over time (Cosentino et al., 2012).

The recent constraints on the pattern and rates of uplift in southern Central Anatolia can be used to further test the hypothesis of slab break-off inducing uplift. Duretz et al. (2011) illustrated that by including Peierls creep within the slab in their simulations, the resulting topography following slab break-off forms two uplifted peaks with an intervening trough, with greater uplift occurring in the overriding plate. To a first order, this prediction matches the pattern of uplift since the late Miocene, with greatest uplift of southern Turkey, less uplift of Cyprus, and the Cilicia Basin trough lying between. If slab break-off occurred at depths of 200 to 300 km ("intermediate" or "deep" slab break-off), surface uplift in the overriding plate above the break-off should occur at ca. 0.2 to 0.4 mm/yr (Duretz et al., 2011). This prediction is broadly consistent with the 0.1 to 0.2 mm/yr uplift rate along the SE margin of the Central Taurides between ca. 7 to 1.6 Ma (Schildgen et al., 2012a). Alternatively, "shallow" break-off at depths of ca. 100 km should result in faster uplift of ca. 0.7 mm/yr (Duretz et al., 2011), which is consistent with the faster uplift that occurred after 1.6 Ma (Schildgen et al., 2012a). A primary remaining question, therefore, is if a deep slab break-off event coincided with the start of uplift in southern Turkey (between 7 and 5.5 Ma), or if a shallow break-off event occurred later, potentially associated with locking of the subduction zone following collision of the Eratosthenes Seamount. One argument supporting the shallow slab break-off scenario is that the ca. 120 km width of the uplifted region (Fig. 5) is more consistent with a shallow break-off event (ca. 100 km expected width), compared with an intermediate (ca. 300 km width) or deep break-off event (ca. 400 km width) (Duretz et al., 2011).

Along the SW margin of the Central Anatolian Plateau, near Sarıalan, 6.7 Ma marine sediments at 1.5 km elevation (Schildgen et al., 2012b) attest to important uplift over a similar time span as the uplift of the S and SE margins. However, the Western Cyprus slab appears to be experiencing active subduction beneath the SW plateau margin (see Section 5), arguing against slab break-off there. Nonetheless, low velocity anomalies between the Aegean and Cyprus slabs (Biryol et al., 2011; Bakırcı et al., 2012; Salaün et al., 2012), differences in GPS-derived velocity vectors (Barka and Reilinger, 1997) and earthquake focal mechanisms (Özbakır et al., 2013) have led several authors to interpret a tear with upwelling asthenosphere between the Cyprus and Aegean slabs. Schildgen et al. (2012b) suggested based on coeval extension of the crust and alkaline volcanism in the region that the upwelling asthenosphere could have induced uplift along the SW plateau margin. To date, no modeling studies have explored if the amount and rate of observed uplift can be realistically explained with this mechanism.

6.4. Lithospheric delamination and upper mantle convection

After the Central Anatolian Plateau margins were uplifted, one way to subsequently create a plateau morphology is through increased aridity between the two uplifted ranges, which could lead to sediment infilling and reduction of relief in the interior (e.g., Sobel et al., 2003). Although Pliocene and Quaternary sedimentation have helped to create the low relief that characterizes the interior of the Central Anatolian Plateau in areas such as the Konya and Tuz Gölü basins (Figs. 2, 3), numerous basement outcrops occur throughout the plateau interior. For this

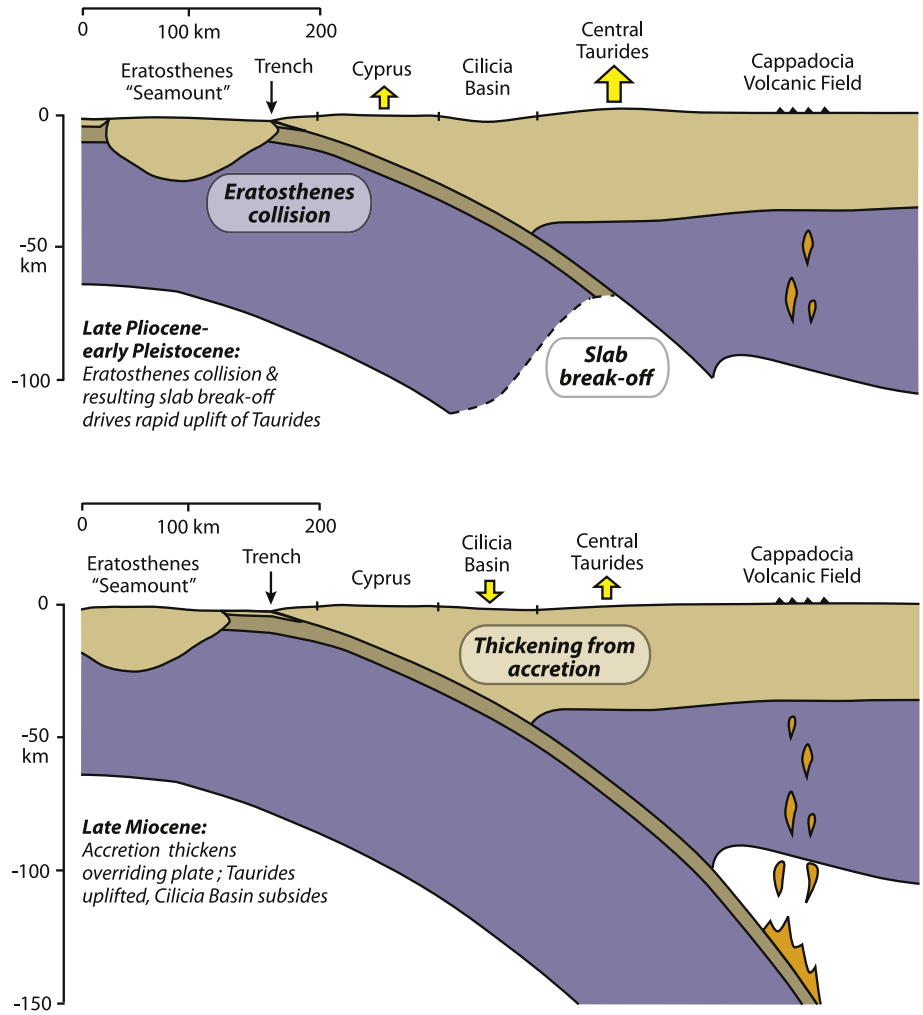

Fig. 10. Preferred scenario to explain the change from slow (ca. 0.1 to 0.2 mm/yr from late Miocene to early Pleistocene time) to rapid (ca. 0.7 mm/yr after 1.6 Ma) surface uplift in south central Turkey. In this scenario, initial slow uplift results from thickening of the Central Taurides through accretion within a subduction wedge (based on modeling by Fuller et al., 2006); later rapid uplift results from shallow slab break-off, which could have been partly induced by collision of the Eratosthenes Seamount (continental fragment) with the subduction zone south of Cyprus (based on modeling by Duretz et al., 2011). Crustal thicknesses for Turkey are derived from Tezel et al. (2013), and for the Eratosthenes Seamount from Aal et al. (2001) and Ben-Avraham et al. (2002). Subduction geometry and position of slab dehydration are based on typical geometries from active margins around the world and from the common occurrence of subduction-related volcanic rocks occurring ca. 100 to 150 km above the dehydration zone (Isacks and Barazangi, 1977). Base of the lithosphere for the subducting plate is drawn at ca. 60 to 80 km depth following arguments in Segev et al. (2006).

reason, alternative mechanisms should be considered to create the plateau morphology in Central Anatolia and its 1 to 1.5 km interior elevations.

Bartol et al. (2012) suggested that both Central and Eastern Anatolia may have been affected by a similar sequence of events, i.e., north-to-south delamination of the lithosphere followed by slab break-off, as Şengör et al. (2003, 2008) and Keskin (2003, 2007) suggested for Eastern Anatolia. Numerical modeling has shown that delamination and slab break-off, combined with crustal shortening, could result in plateau-like uplift with surface elevations consistent with those currently found in Eastern Anatolia (Göğüş and Pysklywec, 2008). These models also predict that in the absence of crustal shortening, greater uplift should occur above the slab break-off, resulting in an asymmetric uplift pattern. As summarized in Sections 2.1 and 3.1, greater uplift has indeed occurred since the late Miocene along the southern margin of Central Anatolia (ca. 1.5 to 2 km) compared with the northern margin (ca. 1 to 1.5 km). Given that the interior of Central Anatolia has not experienced significant shortening since the late Miocene (Section 4.3), the uplift pattern in Central Anatolia is consistent with slab break-off and possibly localized delamination. However, the disparate pattern of volcanism in Central Anatolia, in stark contrast with its widespread occurrence throughout Eastern Anatolia (Fig. 7), together with the narrowing of the zone of negative Bouguer gravity anomalies in Central Anatolia (Fig. 8), calls into question the regional extent over which Central Anatolia could have been delaminated.

Recent models of upper mantle flow patterns in the Mediterranean have helped to test how upwelling mantle may contribute to the elevations of the Central and Eastern Anatolia. Faccenna and Becker (2010) and Boschi et al. (2010) noted the existence of km-scale residual topography in Central and Eastern Anatolia after correcting for crustal isostatic adjustment, which suggests that dynamic topography is important in the region. Faccenna and Becker (2010) reconstructed mantle flow driven by temperature (density) variations from seismic tomography, assuming that the seismic velocity anomalies are related to temperature. They predicted strong upwelling in the upper mantle beneath the Middle East and westward flow toward the Aegean that would lead to dynamic topography on the order of 1 to 2 km in Eastern Anatolia, with values decreasing to zero toward Central Anatolia. Modeling by Boschi et al. (2010) incorporated more recent constraints on crustal density and thicknesses and explored results from four different seismic tomography models. They predicted from 1 to >2 km of dynamic topography in Eastern Anatolia and 0.5 to 1.5 km for Central Anatolia. Although these studies demonstrate the potential for mantle flow to explain the high elevations in Central and Eastern Anatolia, the large difference in

uplift predicted for the different models highlights the sensitivity of the results to the rather weakly constrained input parameters. Nonetheless, it is possible that mantle upwelling has contributed to the high elevations in Eastern and Central Anatolia.

6.5. Linking slab break-off, Hellenic trench retreat and uplift of the Central and Eastern Anatolian plateaus

To summarize, current geological and geophysical constraints are consistent with various mechanisms contributing to uplift since the late Miocene along the southern and northern margins of the Central Anatolian Plateau.

At the S and SE margins of Central Anatolia, an end of crustal shortening that coincides with the start of uplift appears to rule out crustal thickening through shortening as a possibility. Instead, two different scenarios may explain the uplift history. In the first scenario, thickening of the accretionary wedge above a subduction zone induced the initial slow uplift of the southern margin, and faster uplift following shallow slab break-off occurred after the collision of the Eratosthenes Seamount (continental fragment) with the subduction zone in the late Pliocene to early Pleistocene (Fig. 10). In the second scenario, deep slab break-off induced the start of slow uplift between ca. 7 and 5.5 Ma, with later, faster uplift associated with the collision of the Eratosthenes Seamount starting in the late Pliocene to early Pleistocene. Given that the width of the uplifted region in south Central Turkey is more consistent with predictions of shallow slab break-off (e.g., Duretz et al., 2011), which in turn is associated with fast (ca. 0.7 mm/yr) uplift rates, we currently favor the first scenario.

Interpreting uplift mechanisms along other sectors of Central Anatolia is somewhat less ambiguous. Farther west along the SW margin, mantle upwelling through a slab tear is currently the only viable proposed mechanism that explains the observed extension, volcanism, and surface uplift. Along the northern plateau margin, uplift related to strain accumulation along the restraining bend in the North Anatolian Fault can explain the observed shortening deformation and uplift. Within the Central Anatolian Plateau interior, if significant uplift has occurred since the Miocene, it is most likely associated with upper mantle convection and possibly localized delamination.

The broadly similar start of the most recent uplift phase along the northern and southern margins of the Central Anatolian Plateau raises the question of whether uplift mechanisms in the two regions may be linked. Faccenna et al. (2006) showed through analog experiments that slab break-off results in acceleration of Hellenic trench rollback and faster westward movement of Anatolia relative to Eurasia. In the Faccenna et al. (2006) model, faster rollback was induced by greater slab pull, which occurred because the subducting African–Arabian slab remained coherent at depth: the load that had been distributed across a broad subduction zone became focused on the Hellenic trench. Alternatively, retreat of the Hellenic trench may simply be considered relative to retreat of the Cyprus trench (Doglioni et al., 2002; Agostini et al., 2010). Hence, a slowing of the Cyprus trench retreat following slab break-off could have had the same effects on surface deformation. This scenario may be more realistic compared to that proposed by Faccenna et al. (2006), given that the relatively gentle dip of the Aegean slab today casts doubt on the role of slab pull in Hellenic trench retreat (Doglioni et al., 2002; Agostini et al., 2010). But in either scenario, faster (relative) Hellenic trench retreat should induce extension and accelerated westward motion of Anatolia compared to Eurasia (e.g., Reilinger et al., 1997; Jolivet, 2001; Mart, 2013), which in turn could facilitate the localization of strain along the North Anatolian Fault Zone (Faccenna et al., 2006) to create the single-strand North Anatolian Fault (Şengör et al., 2005). More recent analyses of geodetic strain rates and lithospheric depth-integrated deviatoric stresses are compatible with motion along the NAF being facilitated by slab break-off and dynamic uplift of the Eastern Anatolian Plateau (Özeren and Holt, 2010). Faster westward movement of Anatolia relative to Eurasia may also be facilitated by westward flow of asthenosphere, which Le Pichon and Kreemer (2010) noted could be enhanced by toroidal flow around the edge of the subducting African slab; hence, an effect also brought about by slab break-off (Fig. 11). The latest Miocene initiation of: (1) uplift along the southern margin of Central Anatolia (Cosentino et al., 2012); (2) uplift along the northern margin of Central Anatolia (Yildirim et al., 2011); (3) extension in Central Anatolia (Dhont et al., 2006; Özsayın et al., 2013); and (4) accelerated retreat of the Hellenic trench (Royden and Papanikolaou, 2011; Bradley et al., 2013) provides chronological support for this possible geodynamic linkage (Fig. 12).

7. Conclusions

Our review of geological, structural, and geophysical data from Central Anatolia highlights a number of likely uplift mechanisms that appear to link the development of the Central Anatolian Plateau with processes that started beneath Eastern Anatolia and extend as far west as the Hellenic trench. Although previous numerical and analog

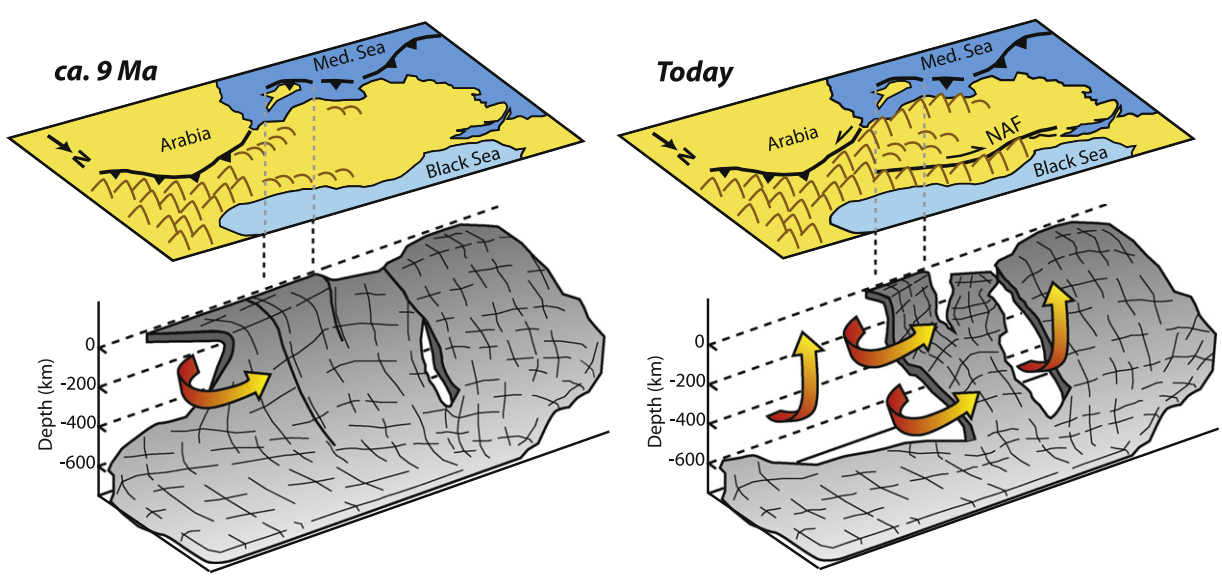

Fig. 11. Lateral propagation of slab break-off beneath Anatolia. Arrows illustrate mantle upwelling and toroidal flow around the edge of the Cyprus slab. Modified from Cosentino et al. (2012) with present slab geometry from Biryol et al. (2011).

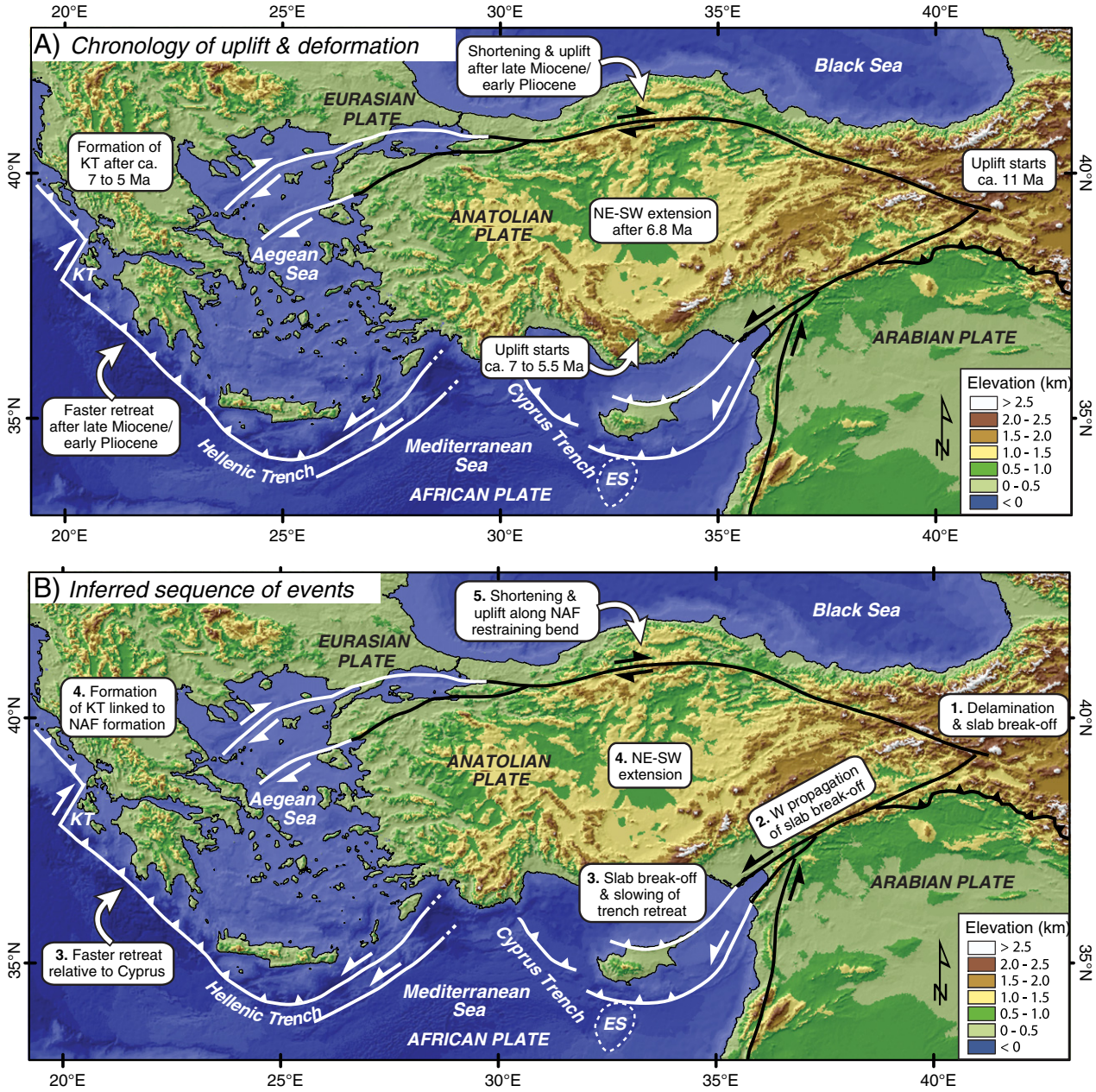

Fig. 12. (A) Summary of chronology of middle Miocene to late Miocene/early Pliocene uplift and deformation and (B) inferred sequence of events throughout the Aegean–Anatolian region. (1) Delamination and slab break-off started beneath Eastern Anatolia. (2) Slab break-off propagated westward over time, leading to (3) uplift of the southern margin of Central Anatolia and slowing of Cyprus trench retreat. Slowing of Cyprus trench retreat implies a relative increase in Hellenic trench retreat, which triggered (4) extension in the Aegean and Central Anatolia, formation of the North Anatolian Fault (NAF) and Kephalonia Transform (KT), and (5) subsequent uplift of the northern margin of Central Anatolia along the restraining bend of the NAF. ES: Eratosthenes Seamount.

modeling studies hinted at some of these links, improvements in the constraints on: (1) the timing of surface uplift; (2) structures that accommodated uplift; and (3) crustal thicknesses and slab geometries allow us now to more rigorously test the likelihood of various uplift mechanisms and their possible linkages.

Overall, multiple lines of evidence suggest that delamination first stripped Eastern Anatolia of its mantle lithosphere, followed by slab break-off (Keskin, 2003; Şengör et al., 2003; Keskin, 2007; Şengör et al., 2008). Surface uplift started several million years later in the latest Miocene beneath Central Anatolia (Cosentino et al., 2012), and can be explained by a westward propagation of the break-off of the old Neotethyan slab (van Hunen and Allen, 2011), with probable contributions by subduction accretion and entrance of the Eratosthenes Seamount into the subduction zone south of Cyprus. Slab break-off is likely to have helped accelerate Hellenic trench retreat (Faccenna et al., 2006); the subsequent extension and westward movement of Anatolia in turn could have localized strain along the North Anatolian Fault (Şengör et al., 2005; Faccenna et al., 2006; Özeren and Holt, 2010), leading to uplift along its broad restraining bend at the northern margin of the Central Anatolian Plateau (Yildirim et al., 2011).

Although the primary geodynamic mechanisms that appear to be responsible for uplift in the various regions occurred over entirely different domains, i.e., upper crustal shortening at the northern margin of Central Anatolia versus slab break-off and mantle upwelling in southern and interior regions, the mechanisms can be linked through predictable changes in tectonic plate movements and mantle flow patterns

following slab break-off. Our summary of the timing of these various events provides geochronological support for these inferred geodynamic linkages. In this context, additional mechanisms that may have contributed to uplift, such as slab tearing, crustal thickening above the subducting African plate, and uplift of the overriding plate following seamount collision, may help to explain local variations in the temporal and spatial patterns of uplift, but most likely did not have such important regional geodynamic implications.

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References

Aal, A.A., Barkooky, A.E., Gerrits, M., Meyer, H.-J., Schwander, M., Zaaki, H., 2001. Tectonic evolution of the eastern Mediterranean Basin and its significance for the hydrocarbon prospectivity of the Nile River deepwater area. Geo. Arabia 6, 363–384.

Adıyaman, O., 2000. Relations entre volcanisme et tectonique en contextes de collision et de De`crochement (Turquie). (Ph.D. Thesis) Univ. of Cergy-Pontoise, Cergy-Pontoise, France (155 pp.).

Agard, P., Omrani, J., Jolivet, L., Mouthereau, F., 2005. Convergence history across Zagros (Iran): constraints from collisional and earlier deformation. Int. J. Earth Sci. (Geologische Rundschau) 94, 401–419.

Agostini, S., Doglioni, C., Innocenti, F., Manetti, P., Tonarini, S., 2010. On the geodynamics of the Aegean rift. Tectonophysics 488, 7–21.

Akay, E., Uysal, S., 1985. Orta torosların batısındaki (Antalya) Neojen çökellerinin stratigrafisi, sedimentolojisi ve yapısal jeolojisi. Report Maden Tetkik ve Arama Genel Müdürlüğü. M.T.A, Turkey.

Akay, E., Uysal, Ş., 1988. Post-Eocene tectonics of the central Taurus Mountains. Miner. Res. Explor. Bull. 108, 23–34.

Akgün, F., Kayseri, M.S., Akkiraz, M.S., 2007. Palaeoclimatic evolution and vegetational changes during the Late Oligocene–Miocene period in Western and Central Anatolia (Turkey). Palaeogeogr. Palaeoclimatol. Palaeoecol. 253, 56–90.

Akkan, E., 1970. Bafra burnu-Delice kavsağı arasında Kızılırmak vadisinin jeomorfolojisi. Ankara Üniv. DTC. Fak. Yay (158 pp.).

Aksu, A.E., Calon, T.J., Hall, J., Mansfield, S., Yaşar, D., 2005. The Cilicia–Adana basin complex, Eastern Mediterranean: Neogene evolution of an active fore-arc basin in an obliquely convergent margin. Mar. Geol. 221, 121–159.

Al-Damegh, K., Sandvol, E., Al-Lazki, A., Barazangi, M., 2004. Regional seismic wave propagation (Lg and Sn) and Pn attenuation in the Arabian plateau and surrounding regions. Geophys. J. Int. 157, 775–795.

Al-Lazki, A., Seber, D., Sandvol, E., Turkelli, N., Mohamad, R., Barazangi, M., 2003. Tomographic Pn velocity and anisotropy structure beneath the Anatolian plateau (eastern Turkey) and surrounding regions. Geophys. Res. Lett. 30. http://dx.doi.org/10.1029/2003GL017391.

Al-Lazki, A., Sandvol, E., Seber, D., Barazangi, M., Turkelli, N., Mohamad, R., 2004. Pn tomographic imaging of mantle lid velocity and anisotropy at the junction of the Arabian, Eurasian and African plates. Geophys. J. Int. 158, 1024–1041.

Allmendinger, R.W., Jordan, T.E., Kay, S.M., Isacks, B.L., 1997. The evolution of the Altiplano–Puna plateau of the Central Andes. Annu. Rev. Earth Planet. Sci. 25, 139–174.

Andrew, T., Robertson, A.H.F., 2001. The Beyşehir–Hoyran–Hadım Nappes: genesis and emplacement of Mesozoic marginal and oceanic units of the northern Neotethys in southern Turkey. J. Geol. Soc. Lond. 159, 529–543.

Andrieux, J., Over, S., Poisson, A., Bellier, O., 1995. The North Anatolian fault zone: distributed Neogene deformation in its northward convex part. Tectonophysics 243, 135–154.

Angus, D.A., Wilson, D.C., Sandvol, E., Ni, J.F., 2006. Lithospheric structure of the Arabian and Eurasian collision zone in eastern Turkey from S-wave receiver functions. Geophys. J. Int. 166, 1335–1346.

Armijo, R., Meyer, B., Hubert, A., Barka, A., 1999. Westward propagation of the North Anatolian fault into the northern Aegean: timing and kinematics. Geology 27 (3), 267–270.

Arndt, J., Bartel, T., Scheuber, E., Schilling, F., 1997. Thermal and rheological properties of granodioritic rocks from the central Andes, north Chile. Tectonophysics 271, 75–88.

Artemieva, I.M., 2006. Global 1° × 1° thermal model TC1 for the continental lithosphere: implications for lithosphere secular evolution. Tectonophysics 416, 245–277.

Artemieva, I.M., Mooney, W.D., 2001. Thermal thickness and evolution of Precambrian lithosphere: a global study. J. Geophys. Res. 106 (B8), 16,387–16,414.

Ates, A., Kearey, P., Tufan, S., 1999. New gravity and magnetic anomaly maps of Turkey. Geophys. J. Int. 136, 499–502.

Avdeev, B., Niemi, N.A., 2011. Rapid Pliocene exhumation of the central Greater Causasus constrained by low-temperature thermochronometry. Tectonics 30, TC2009. http://dx.doi.org/10.1029/2010TC002808.

Aydar, E., Gourgaud, A., 2002. Garnet-bearing basalts: an example from Mt. Hasan, Central Anatolia, Turkey. Mineral. Petrol. 75 (3–4), 185–201.

Aydın, M., Demir, O., Serdar, H.S., Özaydın, S., Harput, B., 1995. Tectono-sedimentary evolution and hydrocarbon potential of the Sinop–Boyabat Basin, North Turkey. In: Erler, A. (Ed.), Geology of the Black Sea Region. Gen. Dir. of Miner. Res. and Expl, Ankara, pp. 254–263.

Aydın, İ., Karat, H.İ., Koçak, A., 2008. Curie-point depth map of Turkey. Geophys. J. Int. 162, 633–640.

Bakırcı, T., Yoshizawa, K., Özer, M.F., 2012. Three-dimensional S-wave structure of the upper mantle beneath Turkey from surface wave tomography. Geophys. J. Int. 190, 1058–1076.

Ballato, P., Uba, C.E., Landgraf, A., Strecker, M.R., Sudo, M., Stockli, D.F., Friedrich, A., Tabatabaei, S.H., 2011. Arabia–Eurasia continental collision: insights from late Tertiary foreland-basin evolution in the Alborz mountains, northern Iran. Geol. Soc. Am. Bull. 123, 106–131.

Barazangi, M., Sandvol, E., Seber, D., 2006. Structure and tectonic evolution of the Anatolian plateau in eastern Turkey. In: Dilek, Y., Pavlides, S. (Eds.), Postcollisional Tectonics and Magmatism in the Mediterranean Region and Asia. Geological Society of America Special Papers, 409, pp. 463–473.

Barka, A.A., Hancock, P., 1984. Neotectonic deformation patterns in the convex-northwards arc of the North Anatolian fault zone. Geol. Soc. Spec. Publ. 17, 763–774.

Barka, A., Reilinger, R., 1997. Active tectonics of the Eastern Mediterranean region: deduced from GPS, neotectonic and seismicity data. Ann. Geofis. X2 (3), 587–610.

Bartol, J., Govers, R., Wortel, M.J.R., 2012. Mantle delamination as the cause for the Miocene–Recent evolution of the Central and Eastern Anatolian Plateau. Geophysical Research Abstracts, 14. EGU General Assembly 2012, Vienna, Austria, pp. EGU2012–EGU11778.

Bassant, P., van Buchem, F.S.P., Görür, N., 2005. The stratigraphic architecture and evolution of the Burdigalian carbonate–siliciclastic sedimentary systems of the Mut Basin, Turkey. Sediment. Geol. 173, 187–232.

Bektaş, Ö., Ravat, D., Büyüksaraç, A., Bilim, F., Ateş, A., 2007. Regional geothermal characterization of East Anatolia from aeromagnetic, heat flow and gravity data. Pure Appl. Geophys. 164, 975–998.

Ben-Avraham, Z., Kempler, D., Ginsburg, A., 1988. Plate convergence in the Cyprus Arc. Tectonophysics 146, 231–240.

Ben-Avraham, Z., Ginzburg, A., Makris, J., Eppelbaum, L., 2002. Crustal structure of the Levant Basin, eastern Mediterranean. Tectonophysics 346, 23–43.

Biryol, C.B., Beck, S.L., Zandt, G., Özacar, A.A., 2011. Segmented African lithosphere beneath the Anatolian region inferred from teleseismic P-wave tomography. Geophys. J. Int. 184, 1037–1057.

Bizon, G., Biju-Duval, B., Letousey, J., Monod, O., Poisson, A., Özer, B., Öztümer, E., 1974. Nouvelles précision stratigraphiques concernant les basin tertiaires du sud de la Turquie (Antalya, Mut, Adana). Rev. Inst. Fr. Pétrol. Paris 29, 305–320.

Blisniuk, P.M., Stern, L.A., 2005. Stable isotope paleoaltimetry: a critical review. Am. J. Sci. 305, 1033–1074.

Bookhagen, B., Strecker, M.R., 2008. Orographic barriers, high-resolution TRMM rainfall, and relief variations along the eastern Andes. Geophys. Res. Lett. 35 (6), L06403. http://dx.doi.org/10.1029/2007GL032011.

Boschi, L., Faccenna, C., Becker, T.W., 2010. Mantle structure and dynamic topography in the Mediterranean Basin. Geophys. Res. Lett. 37, L20303. http://dx.doi.org/10.1029/2010GL045001.

Bozkaya, Ö., Yalçin, H., 2000. Very low grade metamorphism of upper Paleozoic–lower Mesozoic sedimentary rocks related to burial and thrusting in the central Taurus Belt, Konya, Turkey. Int. Geol. Rev. 42 (4), 353–367.

Bozkurt, E., 2001. Neotectonics of Turkey — a synthesis. Geodin. Acta 14, 3–30.

Bozkurt, E., Mittwede, S., 2001. Introduction to the geology of Turkey — a synthesis. Int. Geol. Rev. 43, 578–594.

Bradley, K.E., Vassilakis, E., Hosa, A., Weiss, B.P., 2013. Segmentation of the Hellenides recorded by Pliocene initiation of clockwise block rotation in Central Greece. Earth Planet. Sci. Lett. 362, 6–19.

Bridge, C., Calon, T.J., Hall, J., Aksu, A.E., 2005. Salt tectonics in two convergent-margin basins of the Cyprus arc, Northeastern Mediterranean. Mar. Geol. 221, 223–259.

Brown, M., 1993. The generation, segregation, ascent and emplacement of granite magma — the migmatite-to-crustally-derived-granite connection in thickened orogens. Earth Sci. Rev. 36 (1–2), 83–130.

Çakir, Ö., Erduran, M., 2004. Constraining crustal and uppermost mantle structure beneath station TBZ (Trabzon, Turkey) by receiver function and dispersion analyses. Geophys. J. Int. 158, 955–971.

Calon, T.J., Aksu, A.E., Hall, J., 2005. The Ologocene–Recent evolution of the Mesaoria Basin (Cyprus) and its western marine extension, Eastern Mediterranean. Mar. Geol. 221, 95–120.

Cemen, I., Goncuoglu, M.C., Dirik, K., 1999. Structural evolution of the Tuzgolu basin in Central Anatolia, Turkey. J. Geol. 107 (6), 693–706.

Chamberlain, C.P., Poage, M.A., 2000. Reconstructing the paleotopography of mountain belts from the isotopic composition of authigenic minerals. Geology 28, 115–118.

CIESM (Commission Internationale pour l'Exploration de la Mer Mediterranee, Monaco), 2008. The Messinian salinity crisis from mega-deposits to microbiology: a consensus report. CIESM Workshop Monograph. 33 (168 pp.).

Çiner, A., Karabıyıkoğlu, M., Monod, O., Deynoux, M., Tuzcu, S., 2008. Late Cenozoic sedimentary evolution of the Antalya Basin, southern Turkey. Turk. J. Earth Sci. 17, 1–41.

Cipollari, P., Halásová, E., Gürbüz, K., Cosentino, D., 2013a. Middle–Upper Miocene paleogeography of southern Turkey: insights from stratigraphy and calcareous nannofossil biochronology of the Olukpınar and Başyayla sections (Mut–Ermenek Basin). Turk. J. Earth Sci. 22, 820–838.

Cipollari, P., Cosentino, D., Radeff, G., Schildgen, T.F., Faranda, C., Grossi, F., Gliozzi, E., Smedile, A., Gennari, R., Darbaş, G., Dudas, F.Ö., Gürbüz, K., Nazik, A., Echtler, H.P., 2013b. Easternmost Mediterranean evidence of the Zanclean flooding event and subsequent surface uplift: Adana Basin, southern Turkey. In: Robertson, A.H.F., Parlak, O., Ünlügenç, U.C. (Eds.), Geological Development of Anatolia and the Easternmost Mediterranean Region. Geological Society of London Special Publications, 372, pp. 473–494.

Clark, M.S., Robertson, A.H.F., 2002. The role of the Early Tertiary Ulukişla Basin, southern Turkey in suturing of the Mesozoic Tethys ocean. J. Geol. Soc. 159, 673–690.

Clark, M., Robertson, A.H.F., 2005. Uppermost Cretaceous–Lower Tertiary Ulukişla Basin, south-central Turkey: sedimentary evolution of part of a unified basin complex within an evolving Neotethyan suture zone. Sediment. Geol. 173, 15–51.

Clark, M.K., House, M.A., Royden, L.H., Whipple, K.X., Burchfiel, B.C., Zhang, X., Tang, W., 2005a. Late Cenozoic uplift of southeastern Tibet. Geology 33, 525–528.

Clark, M.K., Maheo, G., Saleeby, J., Farley, K.A., 2005b. The non-equilibrium landscape of the southern Sierra Nevada, California. GSA Today 15, 4–10.

Clauzon, G., Suc, J.-P., Gautier, F., Berger, A., Loutre, M.-F., 1996. Alternate interpretation of the Messinian salinity crisis: controversy resolved? Geology 24 (4), 363–366.

Cloetingh, S., Spadini, G., Van Wees, J.D., Beekman, F., 2003. Thermo-mechanical modelling of Black Sea Basin (de)formation. Sediment. Geol. 156, 169–184.

Cloos, M., 1991. Lithospheric buoyancy and collisional orogenesis — subduction of oceanic plateaus, continental margins, island arcs, spreading ridges, and seamounts. Geol. Soc. Am. Bull. 105 (6), 715–737.

Cosentino, D., Darbaş, G., Gliozzi, E., Grossi, F., Gürbüz, K., Nazik, A., 2010a. How did the Messinian salinity crisis impact the Adana Basin? Paper Presented at 7th International Symposium on Eastern Mediterranean Geology, Adana, Turkey, 18–22 October 2010.

Cosentino, D., Radeff, G., Darbaş, G., Dudas, F., Gürbüz, K., Schildgen, T., 2010b. Late Miocene geohistory of the Mut and Adana basins (southern Turkey): insight for the uplift of the southern margin of the Central Anatolia plateau. Tectonic Crossroads: Evolving Orogens of Eurasia–Africa–Arabia-GSA Global Meeting, Ankara, Turkey, 2–4 October 2010. 1556-4800, vol. 12-2 (Abstract).

Cosentino, D., Schildgen, T., Caruso, A., Faranda, C., Yıldırım, C., 2011. Quantifying post-Tortonian relief change at the southern margin of the Central Anatolian plateau (Turkey). EGU General Assembly 2011, Vienna, Austria. Geophysical Research Abstracts, 13 (EGU2011 5743,2011).

Cosentino, D., Schildgen, T.F., Cipollari, P., Faranda, C., Gliozzi, E., Hudáčková, N., Lucifora, S., Strecker, M.R., 2012. Late Miocene surface uplift of the southern margin of the Central Anatolian plateau, Central Taurides, Turkey. Geol. Soc. Am. Bull. 124, 133–145.

Cosentino, D., Buchwaldt, R., Sampalmieri, G., Iadanza, A., Cipollari, P., Schildgen, T.F., Hinnov, L.A., Ramezani, J., Bowring, S.A., 2013. Refining the Mediterranean "Messinian gap" with high-precision U–Pb zircon geochronology, central and northern Italy. Geology 41, 323–326.

Damcı, E., Demirbağ, E., Sarıkavak, K., 2004. Interpretation of Seismic Reflection Data From Offshore Bartın–Amasra, Paper Presented at 16th International Geophysical Congress and Exhibition of Turkey. Maden Tetk. ve Arama Cultural Cent, Ankara.

Darbaş, G., Nazik, A., 2010. Micropaleontology and paleoecology of the Neogene sediments in the Adana Basin (South of Turkey). J. Asian Earth Sci. 39, 136–147.

Dargahi, S., Arvin, M., Pan, Y.M., Babaei, A., 2010. Petrogenesis of post-collisional A-type granitoids from the Urumieh–Dokhtar magmatic assemblage, Southwestern Kerman, Iran: constraints on the Arabian–Eurasian continental collision. Lithos 115 (1–4), 190–204.

Davies, J.H., von Blanckenburg, F., 1995. Slab breakoff — a model of lithosphere detachment and its test in the magmatism and deformation of collisional orogens. Earth Planet. Sci. Lett. 129 (1–4), 85–102.

Demir, T., Yeşilnacar, I., Westaway, R., 2004. River terrace sequences in Turkey: sources of evidence for lateral variations in regional uplift. Proc. Geol. Assoc. 115, 289–311.

Deniel, C., Aydar, E., Gourgand, A., 1998. The Hasan Dagi stratovolcano (Central Anatolia, Turkey): evolution from calc-alkaline to alkaline magmatism in a collision zone. J. Volcanol. Geotherm. Res. 87 (1–4), 275–302.

Dercourt, J., Ricou, L.E., Vrielynck, B. (Eds.), 1993. Atlas Tethys palaeoenvironmental maps. Commission for the Geological Map of the World (Commission pour le Carte Géologique du Monde). (Paris).

Dewey, J.F., Burke, K.C.A., 1973. Tibetan, Variscan, and Precambrian basement reactivation: products of continental collision. J. Geol. 81 (6), 683–692.

Dewey, J.F., Şengör, A.M.C., 1979. Aegean and surrounding regions: complex multi-plate and continuum tectonics in a convergent zone. Geol. Soc. Am. Bull. 90, 84–92.

Dewey, J.F., Hempton, M.R., Kidd, W.S.F., Saroglu, F., Şengör, A.M.C., 1986. Shortening of continental lithosphere: the neotectonics of Eastern Anatolia—a young collision zone. In: Coward, M.P., Ries, A.C. (Eds.), Collision Tectonics. Geological Society Special Publication, 19, pp. 3–36.

Deynoux, M., Çiner, A., Monod, O., Karabıyıkoğlu, M., Manatschal, G., Tuzcu, S., 2005. Facies architecture and depositional evolution of alluvial fan to fan-delta complexes in the tectonically active Miocene Köprüçay Basin, Isparta Angle, Turkey. Sediment. Geol. 173, 315–343.

Dhont, D., Chorowicz, J., Yurur, T., Froger, J.L., Kose, O., Gundogdu, N., 1998a. Emplacement of volcanic vents and geodynamics of Central Anatolia, Turkey. J. Volcanol. Geotherm. Res. 84 (1–4), 33–54.

Dhont, D., Chorowicz, J., Yurur, T., Kose, O., 1998b. Polyphased block tectonics along the North Anatolian fault in the Tosya basin area (Turkey). Tectonophysics 299, 213–277.

Dhont, D., Chorowicz, J., Luxey, P., 2006. Anatolian escape tectonics driven by Eocene crustal thickening and Neogene–Quaternary extensional collapse in the eastern Mediterranean region. In: Dilek, Y., Pavlides, S. (Eds.), Postcollisional tectonics and magmatism in the Mediterranean reion and Asia. Geological Society of America Special Papers, 409, pp. 441–462.

Dilek, Y., Whitney, D.L., 2000. Cenozoic crustal evolution in Central Anatolia: extension, magmatism and landscape development. In: Panayides, I., Xenophontos, C., Malpas, J. (Eds.), Proceedings of the Third International Conference on the Geology of the Eastern Mediterranean. Geological Survey Department, Republic of Cyprus, Nicosia, Cyprus (Sept. 23–26. 183–192 pp.).

Dirik, K., Göncüoğlu, M.C., Kozlu, H., 1999. Stratigraphy and pre-Miocene tectonic evolution of the southwestern part of the Sivas Basin, Central Anatolia, Turkey. Geol. J. 34 (3), 303–319.

Dixon, J.E., Robertson, A.H.F. (Eds.), 1984. The geological evolution of the eastern Mediterranean. Geological Society of London Special Publications, 17 (824 pp.).

Doğan, U., 2011. Climate-controlled river terrace formation in the Kızılırmak Valley, Cappadocia section, Turkey: inferred from Ar–Ar dating of Quaternary basalts and terraces stratigraphy. Geomorphology 126, 66–81.

Doğan, B., Karakaş, A., 2013. Geometry of co-seismic surface ruptures and tectonic meaning of the 23 October Mw 7.1 Van earthquake (East Anatolian Region, Turkey). J. Struct. Geol. 46, 99–114.

Doglioni, C., Agostini, S., Crespi, M., Innocenti, F., Manetti, P., Riguzzi, F., Savasçin, Y., 2002. On the extension in western Anatolia and the Aegean sea. In: Rosenbaum, G., Lister, G.S. (Eds.), Reconstruction of the Evolution of the Alpine–Himalayan Orogen. Journal of the Virtual Explorer, 8, pp. 161–176.

Doglioni, C., Carminati, E., Cuffaro, M., Scrocca, D., 2007. Subduction kinematics and dynamic constraints. Earth Sci. Rev. 83, 125–175.

Duretz, T., Gerya, T.V., May, D.A., 2011. Numerical modelling of spontaneous slab breakoff and subsequent topographic response. Tectonophysics 502, 244–256.

Elitok, O., Dolmaz, M.N., 2008. Mantle flow-induced crustal thinning in the area between the easternmost part of the Anatolian plate and the Arabian Foreland (E Turkey) deduced from the geological and geophysical data. Gondwana Res. 13 (3), 302–318.

Eren, Y., 1993. Eldes-Derbent-Tepeköy-Sögütözü Arasinin Jeolojisi. (PhD Thesis) S.Ü. Fen Bil. Enst, Konya, Turkey (224 pp.).

Eriş, K.K., Bassant, P., Ülgen, U.B., 2005. Tectono-stratigraphic evolution of an Early Miocene incised valley-fill (Derinçay Formation) in the Mut Basin, Southern Turkey. Sediment. Geol. 173, 151–185.

Espurt, N., Funiciello, F., Martinod, J., Guillaume, B., Regard, V., Faccenna, C., Brusset, S., 2008. Flat subduction dynamics and deformation of the South American plate: insights from analog modeling. Tectonics 27 (3), TC3011. http://dx.doi.org/10.1029/2007TC002175.

Evans, G., Morgan, P., Evans, W.E., Evans, T.R., Woodside, J.M., 1978. Faulting and halokinetics in the northeastern Mediterranean between Cypus and Turkey. Geology 6, 392–396.

Faccenna, C., Becker, T.W., 2010. Shaping mobile belts by small-scale convection. Nature 465 (7298), 602–605.

Faccenna, C., Bellier, O., Martinod, J., Piromallo, C., Regard, V., 2006. Slab detachment beneath eastern Anatolia: a possible cause for the formation of the North Anatolian fault. Earth Planet. Sci. Lett. 242, 85–97.

Faccenna, C., Becker, T.W., Conrad, C.P.P., Husson, L., 2013. Mountain building and mantle dynamics. Tectonics 32 (1), 80–93.

Faranda, C., Gliozzi, E., Cipollari, P., Grossi, F., Darbas, G., Gürbüz, K., Nazik, A., Gennari, R., Cosentino, D., 2013. Messinian paleoenvironmental changes in the easternmost Mediterranean Basin: Adana Basin, southern Turkey. Turkish J. Earth Sci. 22, 839–863.

Fernández-Blanco, D., Bertotti, G., Cassola, T., Willett, S., 2012. Neogene vertical tectonics of the south margin of the Central Anatolia plateau in relation to Cyprus Arc subduction. Abstract T33B-2663 presented at 2012 Fall Meeting, American Geophysical Union, San Francisco, CA, 3-7 December.

Fichtner, A., Saygin, E., Taymaz, T., Cupillard, P., Capdeville, Y., Trampert, J., 2013. The deep structure of the North Anatolian Fault Zone. Earth Planet. Sci. Lett. 373, 109–117.

Finetti, I., Bricchi, G., Del Ben, A.M., Pipan, M., Xuan, Z., 1988. Geophysical study of the Black Sea area. Boll. Geofis. Teor. Appl. 30, 197–324.

Flecker, R., Robertson, A.H.F., Poisson, A., Müller, C., 1995. Facies and tectonic significance of two contrasting Miocene basins in south coastal Turkey. Terra Nova 7, 221–232.

Flecker, R., Ellam, R.M., Müller, C., Poisson, A., Robertson, A.H.F., Turner, J., 1998. Application of Sr isotope stratigraphy and sedimentary analyses to the origin and evolution of the Neogene basins in the Isparta Angle, southern Turkey. Tectonophysics 298, 85–101.

Flecker, R., Poisson, A., Robertson, A.H.F., 2005. Facies and palaeogeographic evidence for the Miocene evolution of the Isparta Angle in its regional eastern Mediterranean context. Sediment. Geol. 173 (1–4), 277–314.

Flowers, R.M., Wernicke, B.P., Farley, K.A., 2008. Unroofing, incision, and uplift history of the southwestern Colorado Plateau from apatite (U–Th)/He thermochronometry. Geol. Soc. Am. Bull. 120 (5–6), 571–587.

Forte, A.M., Cowgill, E., Bernardin, T., Kreylos, O., Hamann, B., 2010. Late Cenozoic deformation of the Kura fold–thrust belt, southern Greater Caucasus. Geol. Soc. Am. Bull. 122, 465–486.

Foulger, G.R., Panza, G.F., Artemieva, I.M., Bastow, I.D., Cammarano, F., Evans, J.R., Hamilton, W.B., Julian, B.R., Lustrino, M., Thybo, H., Yanovskaya, T.B., 2013. Caveats on tomographic images. Terra Nova 25 (4), 259–281.

Froidevaux, C., Isacks, B., 1984. The mechanical state of the lithosphere in the Altiplano–Puna segment of the Andes. Earth Planet. Sci. Lett. 71 (2), 305–314.

Fuller, C.W., Willett, S.D., Brandon, M., 2006. Formation of forearc basins and their influence on subduction zone earthquakes. Geology 34 (2), 65–68.

Gans, C.R., Beck, S.L., Zandt, G., Biryol, C.B., Ozacar, A.A., 2009. Detecting the limit of slab break-off in central Turkey: new high-resolution Pn tomography results. Geophys. J. Int. 179, 1566–1577.
Garzione, C.N., Hoke, G.D., Libarkin, J.C., Withers, S., MacFaddan, B., Eiler, J., Ghosh, P., Mulch, A., 2008. Rise of the Andes. Science 320 (5881), 1304–1307.
Gass, I.G., Masson-Smith, D., 1963. The geology and gravity anomalies of the Troodos Massif, Cyprus. Phil. Trans. R. Soc. Lond. A 255, 417–466.
Gelati, R., 1975. Miocene marine sequence from Lake Van, Eastern Turkey. Riv. Ital. Paleontol. Stratigr. 81, 477–490.
Genç, Y., Yürür, T., 2010. Coeval extension and compression in Late Mesozoic and Recent thin-skinned extensional tectonics in central Anatolia. Turk. J. Struct. Geol. 32, 623–640.
Glover, C., Robertson, A., 1998. Neotectonic intersection of the Aegean and Cyprus tectonic arcs: extensional and strike–slip faulting in the Isparta Angle, SW Turkey. Tectonophysics 298, 103–132.
Glover, C., Robertson, A.H.F., 2003. Origin of tufa (cool-water carbonate) and related terraces in the Antalya area, SW Turkey. Geol. J. 38 (3–4), 329–358.
Göger, E., Kıral, K., 1969. Kizilören Dolayinin Jeolojisi. M.T.A. Rappor 5204.
Göğüş, O.H., Pysklywec, R.N., 2008. Mantle lithosphere delamination driving plateau uplift and synconvergent extension in eastern Anatolia. Geology 36, 723–726.
Gök, R., Sandvol, E., Turkelli, N., Seber, D., Barazangi, M., 2003. Sn attenuation in the Anatolian and Iranian plateau and surrounding regions. Geophys. Res. Lett. 30 (24), 8042. http://dx.doi.org/10.1029/2003GL018020.
Gök, R., Pasyanos, M.E., Zor, E., 2007. Lithospheric structure of the continent–continent collision zone: eastern Turkey. Geophys. J. Int. 169, 1079–1088.
Görmüs, M., 1984. Kizilören (Konya). Dolayinin Jeoloji Incelemesi. S. Ü. Fen Bil. Enst. M.Sc, Konya, Turkey (67 pp).
Gürbüz, K., Kelling, G., 1993. Provenance of Miocene submarine fans in the northern Adana Basin, southern Turkey: a test of discriminant function analysis. Geol. J. 28, 277–293.
Gutscher, M.A., Spakman, W., Engdahl, E.R., 2000. Geodynamics of flat subduction: seismicity and tomographic constraints from the Andean margin. Tectonics 19 (5), 814–833.
Harrison, R.W., Newell, W.L., Batıhanlı, H., Panayides, I., McGeehin, J.P., Mahan, S.A., Özhür, A., Tsiolakis, E., Necdet, M., 2004. Tectonic framework and Late Cenozoic tectonic history of the northern part of Cyprus: implications for earthquake hazards and regional tectonics. J. Asian Earth Sci. 23 (2), 191–210.
Harrison, R.W., Tsiolakis, E., Stone, B.D., Lord, A., Mcgeehin, J.P., Mahan, S.A., Chirico, P., 2013. Late Pleistocene and Holocene uplift history of Cyprus: implications for active tectonics along the southern margin of the Anatolian microplate. In: Robertson, A.H.F., Parlak, O., Ünlügenç, U.C. (Eds.), Geological Development of Anatolia and the Easternmost Mediterranean Region. Geological Society of London Special Publications, 372, pp. 547–560.
Hodges, K.V., Wobus, C., Ruhl, K., Schildgen, T., Whipple, K., 2004. Quaternary deformation, river steepening, and heavy precipitation at the front of the Higher Himalayan ranges. Earth Planet. Sci. Lett. 220 (3–4), 379–389.
House, M.A., Wernicke, B.P., Farley, K.A., 1998. Dating topography of the Sierra Nevada, California, using apatite (U–Th)/He ages. Nature 396 (6706), 66–69.
Hubert-Ferrari, A., Armijo, R., King, G., Meyer, B., Barka, A., 2002. Morphology, displacement, and slip rates along the North Anatolian Fault, Turkey. J. Geophys. Res. 107 (B10), 2235. http://dx.doi.org/10.1029/2001JB000393.
Hüsing, S.K., Zachariasse, W.-J., van Hinsbergen, D.J.J., Krijgsman, W., Inceöz, M., Harzhauser, M., Mandic, O., Kroh, A., 2009. Oligocene Miocene basin evolution in SE Anatolia, Turkey: constraints on the closure of the eastern Tethys gateway. In: van Hinsbergen, D.J.J., Edwards, M.A., Govers, R. (Eds.), Collision and Collapse at the Africa–Arabia–Eurasia Subduction Zone. Geological Society, London, Special Publications, 311, pp. 107–132.
Ilgar, A., Nemec, W., 2005. Early Miocene lacustrine deposits and sequence stratigraphy of the Ermenek Basin, Central Taurides, Turkey. Sediment. Geol. 173, 233–275.
Imprescia, P., Pondrelli, S., Vannucci, G., Gresta, S., 2012. Regional centroid moment tensor solutions in Cyprus from 1977 to the present and seismotectonic implications. J. Seismol. 16, 147–167.
Innocenti, P., Mazzuoli, R., Pasquare, G., Brozolo, F.R.D., Villare, L., 1975. The Neogene calc-alkaline volcanism of central Anatolia: geochronological data on Kayseri–Niğde area. Geol. Mag. 112 (4), 349–360.
Irrlitz, W., 1972. Lithostratigraphie und tektonische Entwicklung des Neogens in Nordostanatolien Känozoikum und Braunkohlen in der Turkei. Geol. Jahrb. Beih., 120 (111 pp.).
Isacks, B.L., 1988. Uplift of the Central Andean Plateau and bending of the Bolivian orocline. J. Geophys. Res. 93 (B4), 3211–3231.
Isacks, B.L., Barazangi, 1977. Geometry of Benioff zones: lateral segmentation and downwards bending of the subducted lithosphere. Island Arcs, Deep Sea Trenches, and Back-Arc Basins. American Geophysical Union, Washington, D.C, pp. 99–114.
İşler, F.I., Aksu, A.E., Hall, J., Calon, T.J., Yaşar, D., 2005. Neogene development of the Antalya Basin, Eastern Mediterranean: an active forearc basin adjacent to an arc junction. Mar. Geol. 221, 299–330.
Jaffey, N., Robertson, A., 2005. Non-marine sedimentation associated with Oligocene–Recent exhumation and uplift of the Central Taurus Mountains, S Turkey. Sediment. Geol. 173, 53–89.
Janson, X., van Buchem, F.S.P., Dromart, G., Eichenseer, H.T., Dellamonica, X., Boichard, R., Bonnaffe, F., Eberli, G., 2010. Architecture and facies differentiation within a Middle Miocene carbonate platform, Ermenek, Mut Basin, southern Turkey. In: van Buchem, F.S.P., Gerdes, K.D., Esteban, M. (Eds.), Mesozoic and Cenozoic Carbonate Systems of the Middle East: Stratigraphic and Diagenetic Reference Models. Geological Society of London, Special Publications, 329, pp. 265–290.
Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E., 2008. Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT). available from http://srtm.csi.cgiar.org.
Jolivet, L., 2001. A comparison of geodetic and finite strain pattern in the Aegena, geodynamic implications. Earth Planet. Sci. Lett. 187, 95–104.
Jolivet, L., Faccenna, C., 2000. Mediterranean extension and the Africa–Eurasia collision. Tectonics 19, 1095–1106.
Jolivet, L., Faccenna, C., Huet, B., Labrousse, L., Le Pourhiet, L., Lacombe, O., Lecomte, E., Burov, E., Denèle, Y., Brun, J.-P., Philippon, M., Paul, A., Salaün, G., Karabulut, H., Piromallo, C., Monié, P., Gueydan, F., Okay, A., Oberhänsli, R., Pourteau, A., Augier, R., Gadenne, L., Driussi, O., 2013. Aegean tectonics: strain localization, slab tearing and trench retreat. Tectonophysics 597–598, 1–33.
Jones, C.H., Farmer, G.L., Unruh, J., 2004. Tectonics of Pliocene removal of lithosphere of the Sierra Nevada, California. Geol. Soc. Am. Bull. 116 (11–12), 1408–1422.
Jordan, T., Isacks, B., Allmendinger, R.W., Brewer, J.A., Ramos, V.A., Ando, C.J., 1983. Andean tectonics related to geometry of subducted Nazca plate. Geol. Soc. Am. Bull. 94, 341–361.
Kalyoncuoğlu, Ü.Y., Elitok, Ö., Dolmaz, M.N., Anadolu, N.C., 2011. Geophysical and geological imprints of southern Neotethyan subduction between Cyprus and the Isparta Angle, SW Turkey. J. Geodyn. 52, 70–82.
Karabıyıkoğlu, M., Çiner, A., Monod, O., Deynoux, M., Tuzcu, S., Örçen, S., 2000. Tectonosedimentary evolution of the Miocene Manavgat Basin, western Taurides, Turkey. In: Bozkurt, E., Winchester, J.A., Piper, J.D.A. (Eds.), Tectonics and Magmatism in Turkey and the Surrounding Area. Geological Society of London Special Publications, 173, pp. 271–314.
Karlstrom, K.E., Coblentz, D., Dueker, K., Ouimet, W., Kirby, E., Van Wijk, J., Schmandt, B., Kelley, S., Lazear, G., Crossey, L.J., Crow, R., Aslan, A., Darling, A., Aster, R., MacCarthy, J., Hansen, S.M., Stachnik, J., Stockli, D.F., Garcia, R.V., Hoffman, M., McKeon, R., Feldman, J., Heizler, M., Donahue, M.S., 2012. Mantle-driven dynamic uplift of the Rocky Mountains and Colorado Plateau and its surface response: toward a unified hypothesis. Lithosphere 4 (1), 3–22.
Kay, R.W., Kay, S.M., 1993. Delamination and delamination magmatism. Tectonophysics 219 (1–3), 177–189.
Kay, S.M., Coira, B., Viramonte, J., 1994. Young mafic back arc volcanc rocks as indicators of continental lithospheric delamination beneath the Argentine Puna Plateau, Central Andes. J. Geophys. Res. Solid Earth 99 (B12), 24,323–24,339.
Kempler, D., Ben-Avraham, Z., 1987. The tectonic evolution of the Cyprean arc. Ann. Tectonicae 1, 58–71.
Keskin, M., 2003. Magma generation by slab steepening and breakoff beneath a subduction accretion complex: an alternative model for collision-related volcanism in Eastern Anatolia, Turkey. Geophys. Res. Lett. 30 (24), 8046. http://dx.doi.org/10.1029/2003GL018019.
Keskin, M., 2007. Eastern Anatolia: a hotspot in a collisional zone without a mantle plume. In: Foulger, G.R., Jurdy, D.M. (Eds.), Plates, Plumes, and Planetary Processes. Geological Society of America Special Papers, 430, pp. 693–722.
Keskin, M., Pearce, J.A., Mitchell, J.G., 1998. Volcano-stratigraphy and geochemistry of collision-related volcanism on the Erzurum–Kars Plateau, North Eastern Turkey. J. Volcanol. Geotherm. Res. 85, 355–404.
Ketin, I., 1948. Über die tektonisch-mechanischen Folgerungen aud den grossen anatolischen Erdbeben des letzten Dezenniums. Geol. Rundsch. 36, 77–83.
Ketin, I., Abdüsselamoğlu, S., 1969. Bartın depreminin etkileri. Bull. Geol. Soc. Turk. 12 (1–2), 66–76.
Kinnaird, C., Robertson, A.H.F., Morris, A., 2011. Timing of uplift of the Troodos massif (Cyprus) constrained by sedimentary and magnetic polarity evidence. J. Geol. Soc. 168, 457–470.
Koç, A., Kaymacki, N., van Hinsbergen, D.J.J., Kuiper, K.F., Vissers, R.L.M., 2012. Tectonosedimentary evolution and geochronology of the Middle Miocene Altınapa Basin, and implications for the Late Cenozoic uplift history of the Taurides, southern Turkey. Tectonophysics 532, 134–155.
Koçyiğit, A., Beyhan, A., 1998. A new intracontinental transcurrent structure: the Central Anatolian Fault Zone, Turkey. Tectonophysics 284 (3–4), 317–336.
Koçyiğit, A., Ünay, E., Saraç, G., 2000. Episodic graben formation and extensional neotectonic regime in west Central Anatolia and the Isparta Angle: a case study in the Akşehir–Afyon Graben, Turkey. In: Bozkurt, E., Winchester, J.A., Piper, J.D.A. (Eds.), Tectonics and Magmatism in Turkey and the Surrounding Area. Geological Society of London Special Publications, 173, pp. 405–421.
Koçyiğit, A., Yılmaz, A., Adamia, S., Kuloshvili, S., 2001. Neotectonics of East Anatolian Plateau (Turkey) and lesser Caucasus: implications for transition from thrusting to strike–slip faulting. Geodin. Acta 14, 177–195.
Krijgsman, W., Hilgen, F.J., Raffi, I., Sierro, F.J., Wilson, D.S., 1999. Chronology, causes and progression of the Messinian salinity crisis. Nature 400, 652–655.
Kürkçüoğlu, B., Şen, E., Temel, A., Aydar, E., Gourgaud, A., 2001. Trace-element modeling and source constraints for tholeiitic and calc-alkaline basalts from a depleted asthenospheric mantle source, Mt. Erciyes Stratovolcano, Turkey. Int. Geol. Rev. 43 (6), 508–522.
Kürkçüoğlu, B., Şen, E., Temel, A., Aydar, E., Gourgaud, A., 2004. Interaction of asthenospheric and lithospheric mantle: the genesis of calc-alkaline volcanism at Erciyes Volcano, central Anatolia, Turkey. Int. Geol. Rev. 46 (3), 243–258.
Kuscu, G.G., Geneli, F., 2010. Review of post-collisional volcanism in the Central Anatolian Volcanic Province (Turkey), with special reference to the Tepekoy Volcanic Complex. Int. J. Earth Sci. 99, 593–621.
Le Pichon, X., 1982. Land-locked oceanic basins and continental collision: the eastern Mediterranean as a case example. In: Hsu, K. (Ed.), Mountain Building Processes. Academic Press, London, pp. 129–146.
Le Pichon, X., Kreemer, C., 2010. The Miocene to Present kinematic evolution of the eastern Mediterranean and Middle East and its implications for dynamics. Ann. Rev. Earth Planet. Sci. 38, 323–351.
Lei, J., Zhao, D., 2007. Teleseismic evidence for a break-off subducting slab under Eastern Turkey. Earth Planet. Sci. Lett. 257, 14–28.

Livaccari, R.F., Burke, K., Şengör, A.M.C., 1981. Was the Laramide orogeny related to subduction of an oceanic plateau? Nature 289 (5795), 276–278.

Lucifora, S., Cifelli, F., Rojay, F.B., Mattei, M., 2013. Paleomagnetic rotations in the Late Miocene sequence from the Çankırı Basin (Central Anatolia, Turkey): the role of strike–slip tectonics. Turk. J. Earth Sci. 22, 778–792.

Lüdecke, T., Mikes, T., Rojay, B., Mulch, A., 2013. Stable isotope-based reconstruction of Oligo-Miocene paleoenvironment and paleohydrology of Central Anatolian lake basins (Turkey). Turk. J. Earth Sci. 22, 793–819.

Maggi, A., Priestley, K., 2005. Surface waveform tomography of the Turkish–Iranian plateau. Geophys. J. Int. 160, 1068–1080.

Mart, Y., 2013. Geodynamics of the Middle East domain since the Oligocene: research summary. J. Geol. Soc. 170 (3), 483–496.

Mazzini, I., Hudačová, N., Joniak, P., Kováčová, M., Mikes, T., Mulch, A., Rojay, F.B., Lucifora, S., Esu, D., Soulie-Marche, I., 2013. Paleoenvironmental and chronological constraints on the Tuğlu Formation (Çankırı Basin, Central Anatolia, Turkey). Turk. J. Earth Sci. 22, 747–777.

McCallum, J.E., Robertson, A.H.F., 1990. Pulsed uplift of the Troodos massif—evidence from the Plio-Pleistocene Mesaoria basin. In: Moores, E.M., Malpas, J., Panayiotou, Y., Xenophontos, C. (Eds.), Ophiolites: Crustal Analogues. Proceedings of the International Symposium 'Troodos 1987'. Cyprus Geological Survey Department, Nicosia, pp. 217–230.

McCallum, J.E., Robertson, A.H.F., 1995. Sedimentology of two fan delta systems in the Pliocene–Pleistocene of the Mesaoria Basin, Cyprus. Sediment. Geol. 98, 215–244.

McKenzie, D.P., 1972. Active tectonics of the Mediterranean region. Geophys. J. Royal Astron. Soc. 30 (2), 109–185.

McKenzie, D.P., 1976. East Anatolian Fault — major structure in Eastern Turkey. Earth Planet. Sci. Lett. 29 (1), 189-103.

McQuarrie, N., van Hinsbergen, D.J.J., 2013. Retrodeforming the Arabia–Eurasia collision zone: age of collision versus magnitude of continental subduction. Geology 41 (3), 315–318.

McQuarrie, N., Stock, J.M., Verdel, C., Wernicke, B., 2003. Cenozoic evolution of Neotethys and implications for the causes of plate motions. Geophys. Res. Lett. 30 (2), 2036. http://dx.doi.org/10.1029/2003GL017992.

Monod, O., 1977. Rechercher geologiques dans le Taurus Occidental du sud de Beyşehir (Turquie). Ph.D. Thesis, 1'universite de Paris sud "Centre d'Orsay", (unpublished), Orsay, France, 442 pp.

Monod, O., Kuzucuoğlu, C., Okay, A.I., 2006. A Miocene palaeovalley network in the Western Taurus (Turkey). Turk. J. Earth Sci. 15, 1–23.

Mutlu, A.K., Karabulut, H., 2011. Anisotropic Pn tomography of Turkey and adjacent regions. Geophys. J. Int. 187, 1743–1758.

Nazik, A., 2004. Planktonic foraminiferal biostratigraphy of the Neogene sequence in the Adana Basin, Turkey, and its correlation with standard biozones. Geol. Mag. 141, 379–387.

Ocakoğlu, F., 2002. Palaeoenvironmental analysis of a Miocene basin in the high Taurus Mountains (southern Turkey) and its palaeogeographical and structural significance. Geol. Mag. 139 (4), 473–487.

Ocakoğlu, F., 2004. Mio-Pliocene basin development in the eastern part of the Cappadocian Volcanic Province (Central Anatolia, Turkey) and its implications for regional tectonics. Int. J. Earth Sci. 93 (2), 314–328.

Okay, A.I., Tüysüz, O., 1999. Tethyan sutures of northern Turkey. In: Durand, B., Jolivet, L., Horvath, F., Seranne, M. (Eds.), The Mediterranean Basins: Tertiary Extension Within the Alpine Orogen. Geological Society, London, Special Publications, 156, pp. 475–515.

Okay, A.I., Tüysüz, O., Satir, M., Özkan-Altıner, S., Altıner, D., Sherlock, S., Eren, R.H., 2006. Cretaceous and Triassic subduction–accretion, high-pressure–low-temperature metamorphism, and continental growth in the Central Pontides. Turk. Geol. Soc. Am. Bull. 118 (9–10), 1247–1269.

Okay, A.I., Zattin, M., Cavazza, W., 2010. Apatite fission-track data for the Miocene Arabia–Eurasia collision. Geology 38 (1), 35–38.

Över, S., Bellier, O., Poisson, A., Andrieux, J., Tutkun, Z., 1993. Late Cenozoic fault kinematics within basins along the central North Anatolian fault zone (Turkey). C. R. Acad. Sci. II 317 (6), 827–833.

Özbakır, A., Şengör, A.M.C., Wortel, M.J.R., Govers, R., 2013. The Pliny–Strabo trench region: a large shear zone resulting from slab tearing. Earth Planet. Sci. Lett. 375, 188–195.

Özeren, M.S., Holt, W.E., 2010. The dynamics of the eastern Mediterranean and eastern Turkey. Geophys. J. Int. 183 (3), 1165–1184.

Özgül, N., 1976. Toroslar'da bazı temel jeoloji özellikleri. Türk. Jeol. Kur. Bull. 19, 65–78.

Özgül, N., 1997. Stratigraphy of tectonostratigraphic units in the Bozkir–Hadim–Taskent around northern part of Central Taurus. Bull. Miner. Res. Explor. 119, 113–174.

Özkan, A.M., 1998. Konya Batisindaki Neojen Çökellerinin Stratigrafisi ve Sedimantolojisi. (PhD Thesis) S.Ü. Fen Bil. Enst, Konya, Türkey (208 pp.).

Özsayin, E., Dirik, K., 2011. The role of oroclinal bending in the structural evolution of the Central Anatolian Plateau: evidence of a regional changeover from shortening to extension. Geol. Carpath. 62 (4), 345–359.

Özsayın, E., Çiner, A., Rojay, B., Dirik, K., Melnick, D., Fernández-Blanco, D., Bertotti, G., Schildgen, T.F., Garcin, Y., Strecker, M.R., Sudo, M., 2013. Plio-Quaternary extensional tectonics of the Central Anatolian Plateau: a case study from the Tuz Gölü Basin, Turkey. Turk. J. Earth Sci. 22, 691–714.

Parlak, O., Robertson, A.H.F., 2004. The ophiolite-related Mersin Melange, southern Turkey: its role in the tectonic–sedimentary setting of the Tethys in the Eastern Mediterranean region. Geol. Mag. 141, 257–286.

Payne, A.S., Robertson, A.H.F., 2000. Structural evolution and regional significance of the Polis graben system, western Cyprus. In: Panayides, I., Xenophontos, C., Malpas, J. (Eds.), Proceedings of the Third International Conference on the Geology of the Eastern Mediterranean. Geological Survey Department, Republic of Cyprus, Nicosia, Cyprus (23–26 Sept: 45–59 pp.).

Pearce, J.A., Bender, J.F., De Long, S.E., Kidd, W.S.F., Low, P.J., Güner, Y., Şaroğlu, F., Yılmaz, Y., Moorbath, S., Mitchell, J.G., 1990. Genesis of collision volcanism in Eastern Anatolia, Turkey. J. Volcanol. Geotherm. Res. 44, 189–229.

Peyret, M., Masson, F., Yavasoglu, H., Ergintav, S., Reilinger, R., 2013. Present-day strain distribution across a segment of the central bend of the North Anatolian Fault Zone from a Persistent-Scatterers InSAR analysis of the ERS and Envisat archives. Geophys. J. Int. 192, 929–945.

Philip, H., Avagyan, A., Karakhanian, A., Ritz, J.-F., Rebai, S., 2001. Estimating slip rates and recurrence intervals for strong earthquakes along an intracontinental fault: example of the Pembak–Sevan–Sunik fault (Armenia). Tectonophysics 343, 205–232.

Piromallo, C., Morelli, A., 2003. P wave tomography of the mantle under the Alpine–Mediterranean area. J. Geophys. Res. 108 (B2), 2065. http://dx.doi.org/10.1029/2002JB001757.

Poisson, A., Orszag-Sperber, F., Temiz, H., Vrielynck, B., 2010. Stratigraphic and polyphased tectonic evolution of the Sivas basin (central Anatolia, Turkey). Darius Annual Report (48 pp.).

Poisson, A., Wernli, R., Lozouet, P., Poignant, A., Temiz, H., 1997. Nouvelles donnees stratigraphiques concernant les formations oligo-miocenes marines du bassin de Sivas. C. R. Acad. Sci. 325, 869–875.

Poisson, A., Wernli, R., Sağular, E.K., Temiz, H., 2003. New data concerning the age of the Aksu Thrust in the south of the Aksu valley, Isparta Angle (SW Turkey): consequences for the Antalya Basin and the Eastern Mediterranean. Geol. J. 38, 311–327.

Poisson, A., Orszag-Sperber, F., Kosun, E., Bassetti, M.-A., Müller, C., Wernli, R., Rouchy, J.-M., 2011. The Late Cenozoic evolution of the Aksu basin (Isparta Angle; SW Turkey). New insights. Bull. Soc. Geol. Fr. 182 (2), 133–148.

Polat, A., 1992. Structural and Geochemical Evolution of the Aladag Melange Complex and Greenschist Division of the Dynamothermal Metamorphic Sole Beneath the Pozanti–Karsanti Ophiolite, Eastern Taurides, Turkey. (M.Sc. Thesis) Univ. Houston, TX (298 pp.).

Popov, S.V., Rögl, F., Rozanov, A.Y., Steiniger, F.F., Shcherba, I.G., Dovac, M. (Eds.), 2004. Lithological-Paleogeographic maps of Paratethys: 10 maps of Late Eocene to Pliocene. Courier Forschungsinstitut Senckenberg (73 pp.).

Popov, S.V., Shcherba, I.G., Ilyina, L.B., Nevesskaya, L.A., Paramonova, N.P., Khondkarian, S.O., Magyar, I., 2006. Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean. Palaeogeogr. Palaeoclimatol. Palaeoecol. 238 (1–4), 91–106.

Pourteau, A., Candan, O., Oberhänsli, R., 2010. High-pressure metasediments in central Turkey: constraints on the Neotethyan closure history. Tectonics 29, TC5004. http://dx.doi.org/10.1029/2009TC002650.

Pourteau, A., Sudo, M., Candan, O., Lanari, P., Vidal, O., Oberhänsli, R., 2013. Neotethys closure history of Anatolia: insight from ^{40}Ar–^{39}Ar geochronology and *P–T* estimation in high-pressure metasediments. J. Metamorph. Geol. 31 (6), 585–606.

Reilinger, R.W., McClusky, S.C., Oral, M.B., King, R.W., Toksoz, M.N., Barka, A.A., Kinik, I., Lenk, O., Sanli, I., 1997. Global Positioning System measurements of present-day crustal movements in the Arabia-Africa-Eurasia plate collision zone. J. Geophys. Res. 102 (B5), 9983–9999.

Reilinger, R., McClusky, S., Vernant, P., Lawrence, S., Ergintav, S., Cakmak, R., Ozener, H., Kadirov, F., Guliuv, I., Stepanyan, R., Nadariya, M., Hahubia, G., Mahmoud, S., Sakr, K., ArRajehi, A., Paradissis, D., Al-Aydrus, A., Prilepin, M., Guseva, T., Evren, E., Dmitrotsa, A., Filikov, S.V., Gomez, F., Al-Ghazzi, R., Karam, G., 2006. GPS constraints on continental deformation in the Africa–Arabia–Eurasia continental collision zone and implications for the dynamics of plate interactions. J. Geophys. Res. 111, B05411. http://dx.doi.org/10.1029/2005JB004051.

Richardson, N.J., Densmore, A.L., Seward, D., Wipf, M., Yong, Li, 2010. Eocene incision of the Three Gorges and growth of the Yangtze River. Geology 38, 551–554.

Robertson, A.H.F., 1998. Tectonic significance of the Eratosthenes Seamount: a continental fragment in the process of collision with a subduction zone in the eastern Mediterranean (Ocean Drilling Program Leg 160). Tectonophysics 298 (1–3), 63–82.

Robertson, A.H.F., 2000. Tectonic evolution of Cyprus in its Easternmost Mediterranean setting. In: Panayides, I., Xenophontos, C., Malpas, J. (Eds.), Proceedings of the Third International Conference on the Geology of the Eastern Mediterranean. Republic of Cyprus, Geological Survey Department, pp. 11–44.

Robertson, A.H.F., Dixon, J.E., 1984. Introduction: aspects of the geological evolution of the Eastern Mediterranean. In: Dixon, J.E., Robertson, A.H.F. (Eds.), The Geological Evolution of the Eastern Mediterranean. Geological Society, London, Special Publications, 17, pp. 1–74.

Robertson, A.H.F., Woodcock, N.H., 1986. The role of the Kyrenia Range lineament, Cyprus, in the geological evolution of the eastern Mediterranean area. Philos. Trans. R. Soc. A 317, 141–177.

Robertson, A.H.F., Poisson, A., Akıncı, Ö., 2003. Developments in research concerning Mesozoic–Tertiary Tethys and neotectonics in the Isparta Angle, SW Turkey. Geol. J. 38, 195–234.

Robertson, A.H.F., Parlak, O., Ustaömer, T., 2012. Overview of the Palaeozoic–Neogene evolution of the Neotethys in the Eastern Mediterranean region (southern Turkey, Cyprus, Syria). Pet. Geosci. 18, 381–404.

Roe, G.H., Whipple, K.X., Fletcher, J.K., 2008. Feedbacks among climate, erosion, and tectonics in a critical wedge orogen. Am. J. Sci. 308 (7), 815–842.

Rojay, B., Karaka, A., 2008. Post-Miocene deformation in the south of the Galatean Volcanic Province, NW of Central Anatolia (Turkey). Turk. J. Earth Sci. 17 (4), 653–672.

Rowley, D.B., Currie, B.S., 2006. Palaeo-altimetry of the late Eocene to Miocene Lunpola basin, central Tibet. Nature 439 (7077), 677–681.

Royden, L.H., Papanikolaou, D.J., 2011. Slab segmentation and late Cenozoic disruption of the Hellenic arc. Geochem. Geophys. Geosyst. 12 (3), Q03010. http://dx.doi.org/10.1029/2010GC003280.

Şafak, Ü., Kelling, G., Gökçen, N.S., Gürbüz, K., 2005. The mid-Cenozoic succession and evolution of the Mut basin, southern Turkey, and its regional significance. Sediment. Geol. 173, 121–150.

Sagular, E.K., 2009. Fossil didemnid ascidian spicule records in the Plio-Quaternary marine clastics of the Antalya basin (Eastern Mediterranean) and their stratigraphic calibration to new nannofossil data. Geosci. J. 13 (2), 121–131.

Sagular, E.K., Çoban, H., 2009. Nannofossil-based chronostratigraphy of the tephra-interbedded marine clastics in Neogene Antalya basin. Yerbilimleri 30 (2), 145–167.

Salaün, G., Pedersen, H.A., Paul, A., Farra, V., Karabulut, H., Hatzfeld, D., Papazachos, C., Childs, D.M., Pequegnat, C., Team, S.I.M.B.A.A.D., 2012. High-resolution surface wave tomography beneath the Aegean–Anatolian region: constraints on upper-mantle structure. Geophys. J. Int. 190, 406–420.

Şaroğlu, F., Yılmaz, Y., 1987. Geological evolution and basin models during the neotectonic episode in eastern Anatolia. Bull. Miner. Res. Explor. Inst. Turk. 107, 61–83.

Schattner, U., 2010. What triggered the early-to-mid Pleistocene tectonic transition across the entire eastern Mediterranean? Earth Planet. Sci. Lett. 289, 539–548.

Schemmel, F., Mikes, T., Rojay, B., Mulch, A., 2013. The impact of topography on isotopes in precipitation across the Central Anatolian Plateau (Turkey). Am. J. Sci. 313 (2), 61–80.

Schildgen, T.F., Hodges, K.V., Whipple, K.X., Reiners, P.W., Pringle, M.S., 2007. Uplift of the western margin of the Andean plateau revealed from canyon incision history, southern Peru. Geology 35, 523–526.

Schildgen, T.F., Ehlers, T.A., Whipp, D.M., van Soest, M.C., Whipple, K.X., Hodges, K.V., 2009. Quantifying canyon incision and Andean Plateau surface uplift, southwest Peru: a thermochronometer and numerical modelling approach. J. Geophys. Res. Earth Surf. 114, F04014. http://dx.doi.org/10.1029/2009jf001305.

Schildgen, T.F., Balco, G., Schuster, G., 2010. Canyon incision and knickpoint propagation recorded by apatite $^4He/^3He$ thermochronometry. Earth Planet. Sci. Lett. 293, 377–387.

Schildgen, T.F., Cosentino, D., Bookhagen, B., Niedermann, S., Yıldırım, C., Echtler, H.P., Strecker, M.R., 2012a. Multi-phased uplift of the southern margin of the Central Anatolian plateau, Turkey: a record of tectonic and upper mantle processes. Earth Planet. Sci. Lett. 317–318, 85–95.

Schildgen, T.F., Cosentino, D., Caruso, A., Buchwaldt, R., Yıldırım, C., Bowring, S.A., Rojay, B., Echtler, H., Strecker, M.R., 2012b. Surface expression of Eastern Mediterranean slab dynamics: Neogene topographic and structural evolution of the SW margin of the Central Anatolian Plateau, Turkey. Tectonics 31, TC2005. http://dx.doi.org/10.1029/2011TC003021.

Segev, A., Rybakov, M., Lyakhovsky, V., Hofstetter, A., Tibor, G., Goldschmidt, V., Ben-Avraham, Z., 2006. The structure, isostasy and gravity field of the Levant continental margin and the southeast Mediterranean area. Tectonophysics 425, 137–157.

Şen, P.A., Temel, A., Gourgaud, A., 2004. Petrogenetic modelling of Quaternary post-collisional volcanism: a case study of central and eastern Anatolia. Geol. Mag. 141 (1), 81–98.

Şengör, A.M.C., 1979. The North Anatolian transform fault: its age, offset and tectonic significance. J. Geol. Soc. Lond. 136, 269–282.

Şengör, A.M.C., 1995. The larger tectonic framework of the Zonguldak coal basin in Northern Turkey: an outsider's view. In: Yalçın, M.N., Gürdal, G. (Eds.), Zonguldak Basin Research Wells—I Kozlu-K20/G. Special Publication of TUBITAK, MAM, pp. 1–26.

Şengör, A.M.C., Kidd, W.S.F., 1979. The post-collisional tectonics of the Turkish–Iranian Plateau and a comparison with Tibet. Tectonophysics 55, 361–376.

Şengör, A.M.C., Natal'in, B.A., 1996. Palaeotectonics of Asia: fragments of a synthesis. In: Yin, A., Harrison, M.T. (Eds.), Tectonic Evolution of Asia. Cambridge Univ. Press, Rubey Colloq. Cambridge, pp. 486–640.

Şengör, A.M.C., Yılmaz, Y., 1981. Tethyan evolution of Turkey: a plate tectonic approach. Tectonophysics 75, 181–241.

Şengör, A.M.C., Görür, N., Saroglu, F., 1985. Strike–slip faulting and basin related formation in zones of tectonic escape: Turkey as a case study. In: Biddle, K.T., Christie-Blick, N. (Eds.), Strike–Slip Deformation, Basin Formation and Sedimentation. Society of Economic Paleontologists and Mineralogists Special Publication, 37 (227–440 pp.).

Şengör, A.M.C., Özeren, S., Genç, T., Zor, E., 2003. East Anatolian high plateau as a mantle-supported, north–south shortened domal structure. Geophys. Res. Lett. 30 (24), 8045. http://dx.doi.org/10.1029/2003GL017858.

Şengör, A.M.C., Tüysüz, O., İmren, C., Sakınç, M., Eyidoğan, H., Görür, N., Le Pichon, X., Rangin, C., 2005. The North Anatolian Fault: a new look. Annu. Rev. Earth Planet. Sci. 33, 37–112.

Şengör, A.M.C., Özeren, S., Keskin, M., Sakınç, M., Özbakır, A.D., Kayan, I., 2008. Eastern Turkish high plateau as a small Turkic-type orogen: implications for post-collisional crust-forming processes in Turkic-type orogens. Earth Sci. Rev. 90 (1–2), 1–48.

Seyrek, A., Demir, T., Pringle, M., Yurtman, S., Westaway, R., Bridgland, D., Beck, A., Rowbotham, G., 2008. Late Cenozoic uplift of the Amanos Mountains and incision of the Middle Ceyhan river gorge, southern Turkey; Ar–Ar dating of the Düziçi basalt. Geomorphology 97, 321–355.

Sobel, E.R., Hilley, G.E., Strecker, M.R., 2003. Formation of internally drained contractional basins by aridity-limited bedrock incision. J. Geophys. Res. 108 (B7), 2344. http://dx.doi.org/10.1029/2002JB001883.

Strecker, M.R., Alonso, R.N., Bookhagen, B., Carrapa, B., Hilley, G.E., Sobel, E.R., Trauth, M.H., 2007. Tectonics and climate of the southern Central Andes. Annu. Rev. Earth Planet. Sci. 35, 747–787.

Strecker, M.R., Alonso, R., Bookhagen, B., Carrapa, B., Coutand, I., Hain, M.P., Hilley, G.E., Mortimer, E., Schoenbohm, L., Sobel, E.R., 2009. Does the topographic distribution of the central Andean Puna Plateau result from climatic or geodynamic processes? Geology 37 (7), 643–646.

Sumita, M., Schmincke, H.-U., 2013. Impact of volcanism on the evolution of Lake Van II: temporal evolution of explosive volcanism of Nemrut Volcano (eastern Anatolia) during the past ca. 0.4 Ma. J. Volcanol. Geotherm. Res. 253, 15–34.

Sunal, G., Tüysüz, O., 2002. Paleostress analysis of Tertiary post-collisional structures in the Western Pontides, northern Turkey. Geol. Mag. 139 (3), 343–359.

Tan, O., Tapırdamaz, C., Yörük, A., 2008. The earthquake catalogues for Turkey. Turk. J. Earth Sci. 17, 405–418.

Tanar, U., Gökçen, N., 1990. Mut-Ermenek Tersiyer istifinin stratigrafisi ve mikropaleontolojisi. Maden Tetkik ve Arama Genel Müdürlüğü (MTA) Dergisi 110, 175–180.

Tapponnier, P., Xu, Z.G., Roger, F., Meyer, B., Arnaud, N., Wittlinger, G., Yang, J.S., 2001. Oblique stepwise rise and growth of the Tibet plateau. Science 294 (5547), 1671–1677.

Tekeli, O., Aksay, A., Ürgün, B.M., Işik, A., 1984. Geology of the Aladağ Mountains. In: Tekeli, O., Göncüoğlu, M.C. (Eds.), Geology of the Taurus Belt. Proceedings of the International Tauride Symposium. Mineral Research and Exploration Institute of Turkey (MTA) Publications, pp. 143–158.

Temel, A., Gundogdu, M.N., Gourgaud, A., Le Pennec, J.L., 1998. Ignimbrites of Cappadocia (central Anatolia, Turkey): petrology and geochemistry. J. Volcanol. Geoth. Res. 85 (1–4), 447–471.

Tezel, T., Shibutani, T., Kaypak, B., 2013. Crustal thickness of Turkey determined by receiver function. J. Asian Earth Sci. 75, 36–45.

Toker, M., 2006. Van segmenti mikrodeprem potansiyelini kontrol eden neotektonik unsurlar. Toplantısı, Dokuz Eylül Üniversitesi, Jeoloji Mühendisliği Bölümü, Bildiri Özleri Kitabı, Buca, İzmir. ATAG-10 Aktif Tektonik Araştırma Grubu, 10, pp. 91–92.

Tunoğlu, C., 1991a. Orta Pontidler`de Devrekani Havzası`nın (Kastamonu kuzeyi) litostratigrafi Birimleri. Paper Presented at Suat Erk Jeoloji Sempozyumu, Bildiriler Kitabi.

Tunoğlu, C., 1991b. Orta Pontidler'de Devrekani Havzası'nın (Kastamonu kuzeyi) litostratigrafi birimleri. Suat Erk Jeoloji Sempozyumu, Bildiriler Kitabı, Ankara Üniversitesi, Fen Fakültesi, Ankara, pp. 183–191.

Turcott, D.L., Schubert, G., 2002. Geodynamics — 2nd Edition. Cambridge University Press, USA (456 pp.).

Türkelli, N., Sandvol, E., Zor, E., Gok, R., Bekler, T., Al-Lazki, A., Karabulut, H., Kuleli, S., Eken, T., Gurbuz, C., Bayraktutan, S., Seber, D., Barazangi, M., 2003. Seismogenic zones in Eastern Turkey. Geophys. Res. Lett. 30 (24), 8039. http://dx.doi.org/10.1029/2003GL018023.

Tüysüz, O., 1999. Geology of the Cretaceous sedimentary basins of the Western Pontides. Geol. J. 34 (1–2), 75–93.

Umhoefer, P.J., Whitney, D.L., Teyssier, C., Fayon, A.K., Casale, G., Heizler, M.T., 2007. Yo–yo tectonics in a wrench zone, Central Anatolian fault zone, Turkey. In: Roeske, S.M., Till, A.B., Sample, J.C. (Eds.), Exhumation Associated With Continental Strike–Slip Fault Systems. Geological Society of America Special Paper, 434 (35–55 pp.).

Ünay, E., de Bruijn, H., 1998. Plio-Pleistocene rodents and lagomorphs from Anatolia. Ned. Inst. Voor Toegepaste Geowet. TNO 60, 431–462.

Valla, P., Herman, F., van der Beek, P., Braun, J., 2010. Inversion of thermochronological age-elevation profiles to extract independent estimates of denudation and relief history — I: theory and conceptual model. Earth Planet. Sci. Lett. 295 (3–4), 511–522.

van Hunen, J., Allen, M.B., 2011. Continental collision and slab break-off: a comparison of 3-D numerical models with observations. Earth Planet. Sci. Lett. 302, 27–37.

Vassilakis, E., Royden, L., Papanikolaou, D., 2011. Kinematic links between subduction along the Hellenic trench and extension in the Gulf of Corinth, Greece: a multidisciplinary analysis. Earth Planet. Sci. Lett. 303, 108–120.

Wdowinski, S., Ben-Avraham, Z., Arvidsson, R., Ekström, G., 2006. Seismotectonics of the Cyprian Arc. Geophys. J. Int. 164, 176–181.

Westaway, R., Pringle, M., Yurtmen, S., Demir, T., Bridgland, D., Rowbotham, G., Maddy, D., 2004. Pliocene and Quaternary regional uplift in western Turkey: the Gediz River terrace staircase and the volcanism at Kula. Tectonophysics 391, 121–169.

Yildirim, C., Schildgen, T.F., Echtler, H., Melnick, D., Strecker, M.R., 2011. Late Neogene orogenic uplift in the Central Pontides associated with the North Anatolian Fault — implications for the northern margin of the Central Anatolian Plateau, Turkey. Tectonics 30, TC5005. http://dx.doi.org/10.1029/2010TC002756.

Yıldırım, C., Melnick, D., Ballato, P., Schildgen, T.F., Echtler, H., Erginal, A.E., Kıyak, N.G., Strecker, M.R., 2013a. Differential uplift along the northern margin of the Central Anatolian Plateau: inferences from marine terraces. Quat. Sci. Rev. 81, 12–28.

Yıldırım, C., Schildgen, T.F., Echtler, H., Melnick, D., Bookhagen, B., Çiner, A., Niedermann, S., Merchel, S., Martschini, M., Steier, P., Strecker, M.R., 2013b. Tectonic and climatic implications of fluvial incision at the northern margin of the Central Anatolian Plateau based on multiple cosmogenic nuclides. Tectonics 32, 1–14.

Yıldız, A., Toker, V., Demircan, H., Sevim, S., 2003. Paleoenvironmental interpretation and findings of Pliocene–Pleistocene nannoplankton, planktic foraminifera, trace fossil in the Mut Basin. Yerbilimleri 28, 123–144.

Yılmaz, Y., 2007. Morphotectonic evolution of the Southern Black Sea Region and the Bosphorus Channel. In: Yanko-Hombach, V., Gilbert, A., Panin, N., Dolukhanov, P. (Eds.), The Black Sea Flood Question: Changes in the Coastline, Climate and Human Settlement. Springer, Dordrecht, pp. 537–569.

Yılmaz, Y., Tüysüz, O., Yiğitbaş, E., Genç, Ş.C., Şengör, A.M.C., 1997. Geology and tectonic evolution of the Pontides. In: Robertson, A.G. (Ed.), Regional and Petroleum Geology of the Black Sea and Surrounding Region. AAPG Memoir, 68, pp. 183–226.

Yılmaz, Y., Gökasan, E., Erbay, A.Y., 2010. Morphotectonic development of the Marmara Region. Tectonophysics 488 (1–4), 51–70.

Yuan, X., Sobolev, S.V., Kind, R., 2002. Moho topography in the central Andes and its geodynamic implications. Earth Planet. Sci. Lett. 199 (3–4), 389–402.

Zandt, G., Gilbert, H., Owens, T.J., Ducea, M., Saleeby, J., Jones, C.H., 2004. Active foundering of a continental arc root beneath the southern Sierra Nevada in California. Nature 431 (7004), 41–46.

Zor, E., Sandvol, E., Gürbüz, C., Türkelli, N., Seber, D., Barazangi, M., 2003. The crustal structure of the East Anatolian plateau (Turkey) from receiver functions. Geophys. Res. Lett. 30 (24), 8044. http://dx.doi.org/10.1029/2003GL018192.