RESEARCH ARTICLE

Key Points:
- The Taurides fold-thrust belt contains a minimum of 90.5-km shortening that occurred in Eocence and Mio-Pliocene phases
- The Antalya slab has been decoupled from the Cyprus slab and isolated in an upper plate position since Eocene times
- The Antalya slab consists mostly of continental lithosphere, which may have prevented it from sinking and detaching

Supporting Information:
- Supporting Information S1

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First Balanced Cross Section Across the Taurides Fold-Thrust Belt: Geological Constraints on the Subduction History of the Antalya Slab in Southern Anatolia

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Abstract Eastern Mediterranean subduction accommodated Africa-Eurasia convergence since Mesozoic time and produced multiple subducted slab fragments in the mantle below Anatolia. These included the north dipping Cyprus and ENE-dipping Antalya slabs, which are currently separated by an upper mantle slab gap. Segmentation of these slabs, and associated mantle flow, may have contributed to <8 Ma uplift of the Central Anatolian Plateau. The western Central Taurides fold-thrust belt in southern Turkey is in the upper plate above the Antalya slab and contains a geological record of its subduction. We present the first orogen-scale balanced cross section of the Taurides and find that it formed in two stages: (1) Cretaceous to middle Eocene thrusting resulted in a minimum of 73-km shortening, and (2) Mio-Pliocene thrusting resulted in a minimum of 17.5-km shortening. Eocene shortening accounts for only ~5 Myr of Africa-Eurasia plate convergence. It is unlikely that >400 km of post to middle Eocene plate convergence was accommodated between the Taurides and its Beydağları platform foreland and instead must have been accommodated south of Beydağları. The associated southward plate boundary jump separated the Antalya slab from the African plate and the Cyprus slab. The isolated Antalya slab was left in an intraplate setting and is probably still attached to Beydağları today. We suggest the continental composition of the Antalya slab may have prevented its detachment. Finally, the gap between the Antalya and Cyprus slabs existed since at least Eocene time; their decoupling likely did not contribute to late Neogene Central Anatolian Plateau uplift.

1. Introduction

Africa-Eurasia convergence in the eastern Mediterranean region has been ongoing since mid-Mesozoic time (e.g., Seton et al., 2012) and is presently accommodated by subduction at the Cyprus trench, south of Anatolia. Seismic tomography models of the upper mantle beneath Anatolia (Biryol et al., 2011; van der Meer et al., 2018) show two distinct high-velocity anomalies (Figure 1): A north dipping Cyprus slab that appears to be attached to the subducting African plate lithosphere, and an enigmatic ENE-dipping Antalya slab, which strikes NNW below the Gulf of Antalya. The two slabs are distinguishable in the upper ~300 km of the mantle. At deeper levels of the upper mantle, they either merge into one slab (Biryol et al., 2011) or are two separate but touching bodies (van der Meer et al., 2018). Given slow Cenozoic Africa-Eurasia convergence rates of 1–2 cm/year (Seton et al., 2012), these slabs must have formed during at least tens of millions of years of subduction of African Plate lithosphere.

The Cyprus and Antalya slabs may have played an important role in the recent uplift history of the nascent Central Anatolian Plateau. The Mut basin (Figure 2a) covers the south Central Taurides (Figure 3) and contains late Miocene marine sedimentary rocks that have been uplifted more than 2 km above sea level (Cosentino et al., 2012; Schildgen et al., 2012) with little deformation (Cosentino et al., 2012; Fernandez-Blanco, 2014). Lithospheric delamination (Bartol & Govers, 2014), segmentation of the Cyprus and Antalya slabs (Cosentino et al., 2012; Schildgen et al., 2012), and slab break-off (Schildgen et al., 2014; Öğretmen et al., 2018) have been invoked as mechanisms to explain this late Miocene and younger surface uplift. However, the geological record that may be interpreted to determine when these slabs formed, whether they were initially contiguous and if so when they separated, and that may be interpreted to determine if the composition of those slabs was continental or oceanic remains poorly constrained. Thus, the inferred late Mio-Pliocene history of the slabs has not been placed in the context of their long-term evolution.

Anatolia forms the upper plate above the Cyprus and Antalya slabs and contains the Taurides fold-thrust belt (Figure 2a), which formed during south (west) as well as north (east) verging thrusting in Late Cretaceous to
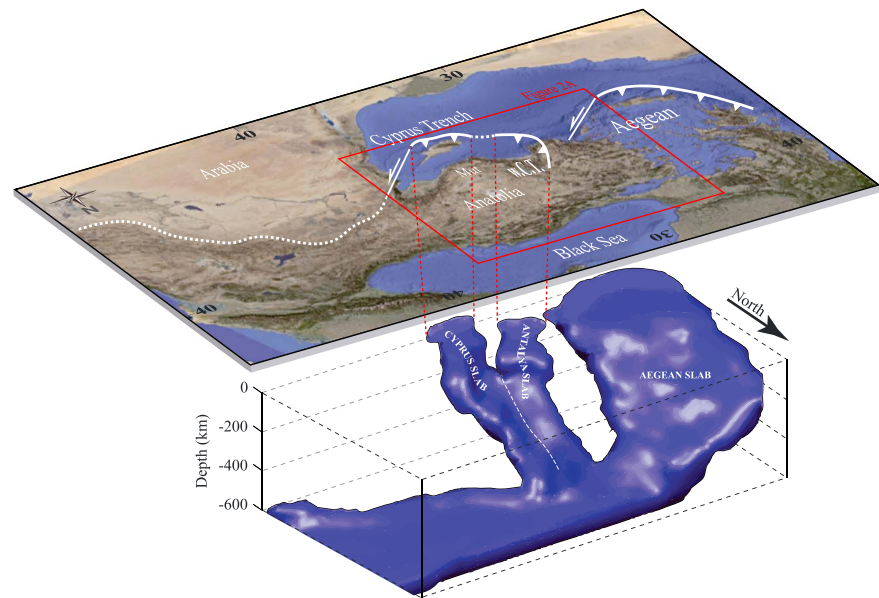
Figure 1. A 3-D model of subducted slabs in the mantle beneath the eastern Mediterranean region and modern plate contacts, modified from Koç, Kaymakci, et al. (2016) after Biryol et al. (2011). *w.C.T.* marks the location of the western Central Taurides. The slab geometry was extracted by Biryol et al. (2011) from their tomographic model of the eastern Mediterranean. The red box indicates the extent of the map in Figure 2a.

Eocene time (e.g., Gutnic et al., 1979; Özgül, 1984). This was followed by Mio-Pliocene thrusting of Miocene basins that unconformably covered the deformed western Central Taurides (Figure 2a; Ciner et al., 2008; Poisson et al., 2003). Koç, Kaymakci, et al. (2016) and Koç, van Hinsbergen, et al. (2016) suggested that renewed subduction of the Antalya slab may have been a driving factor in that Miocene deformation and that the slab may still be contiguous with the continental Beydağları foreland of the western Central Taurides (Figure 2a); however, how the Eocene and older history of the Taurides links to Miocene deformation is unknown.

In this paper, we aim to interpret the composition and subduction history of the Antalya slab and estimate the timing of its decoupling from the Cyprus slab by investigating the timing and magnitude of shortening during accretion of the western Central Taurides. To this end, we describe the structural style of the fold-thrust belt and interpret the subsurface structure of the belt. We present the first balanced cross section of the western Central Taurides composite fold-thrust belt from the Beydağları platform to the Central Taurides intramontane basins, over a distance of ~150 km (Figures 2a and 3). We investigate the minimum amount of subduction that must have occurred during the formation of the fold-thrust belt. We then evaluate the kinematic evolution of the Taurides in the context of Africa-Eurasia convergence and subduction.

2. Geological Setting

The Taurides are a fold-thrust belt that forms a mountain range along the southern margin of the Central Anatolian Plateau up to ~2.8 km high, with kilometer-scale relief. The fold-thrust belt predominantly consists of nonmetamorphic platform carbonate rocks, and minor deep-marine rocks. These are covered by an ophiolite-bearing nappe that forms the highest structural unit. The Taurides form the southernmost unit in a Late Cretaceous-Eocene accretionary orogen that makes up the Central Anatolian crust to the south of the Izmir-Ankara suture zone in northern Turkey (e.g., Sengör & Yilmaz, 1981). Units within that orogen may have originated as the eastern part of a microcontinental domain that occupied much of the Mediterranean region, known as the Adria-Turkey plate (Stampfli et al., 1991) or Greater Adria (Gaina et al., 2013). This microcontinental domain was separated from Eurasia in the north and Africa in the south by ocean basins.

All tectonic units in the Anatolian orogen are overlain by a Late Cretaceous (~95–90 Ma) ophiolite and ophiolitic melange (e.g., Dilek et al., 1999; Çelik et al., 2011; Parlak, 2016; van Hinsbergen et al., 2016, and references therein). The ophiolites originated in an intraoceanic subduction zone that formed in the Neotethys Ocean to the north of the Anatolian part of Greater Adria around ~100 Ma (Gürer et al., 2016;
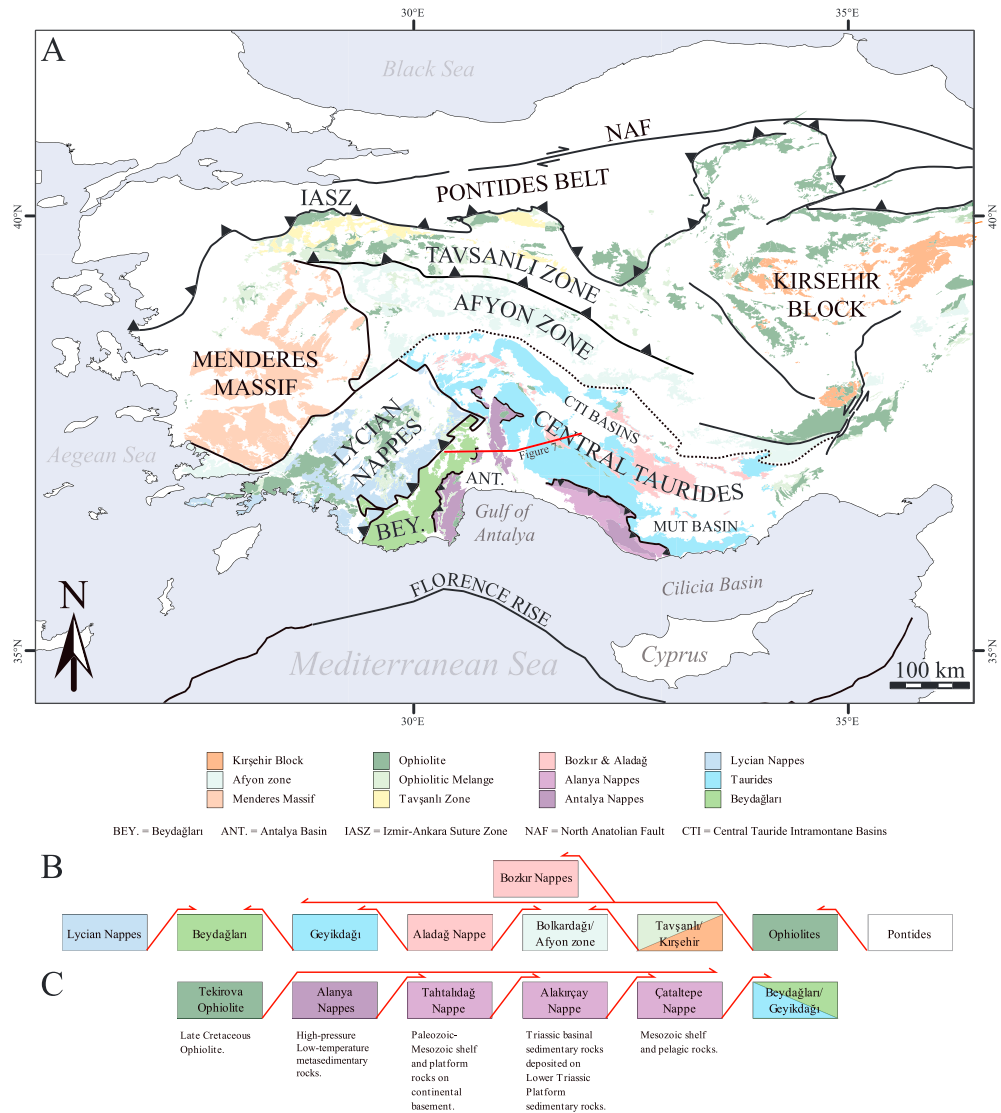
Figure 2. (a) A map of the major tectonic units of Anatolia. Polygons are based on the MTA 1:500,000 geological mapping series and are colored based on van Hinsbergen et al. (2016, and references therein). (b) Simplified tectonostratigraphic scheme of the major units of Central Anatolia based on van Hinsbergen et al. (2016, and references therein). The Antalya Nappes have been omitted for clarity. (c) Antalya Nappes tectonostratigraphy based on Yilmaz and Maxwell (1984), as used in the MTA 1:100,000 map series.

van Hinsbergen et al., 2016). The northern margin of the Neotethys Ocean basin was bound by the Pontides, which have been part of Eurasia since Triassic times (Dokuz et al., 2017; Okay et al., 2006). A second subduction zone existed along the southern Pontides margin from Jurassic until latest Cretaceous to Paleogene time as shown by arc volcanism, accreted and metamorphosed rocks, and forearc basin evolution (e.g., Kaymakci et al., 2009; Okay et al., 2013, 2014; Topuz et al., 2014).

Closure of the Neotethys Ocean basin between the Pontides and the Anatolian part of Greater Adria was accommodated on two trenches, until the Pontides-Taurides collision in latest Cretaceous to Paleogene time. After that, subduction remained active on the southern (formerly the intraoceanic) trench (Gürer et al., 2016). The location of the former Neotethys Ocean is demarcated by the Izmir-Ankara suture zone (Sengör & Yilmaz, 1981; Figure 2a).

Three belts of metamorphic rocks are present north of the Taurides: the Tavşanlı zone in the northwest, the Kırşehir Block in the northeast, and the Afyon zone in the south. These are the northern parts of the Greater Adria microcontinental domain that were underthrusted and metamorphosed below the Anatolian
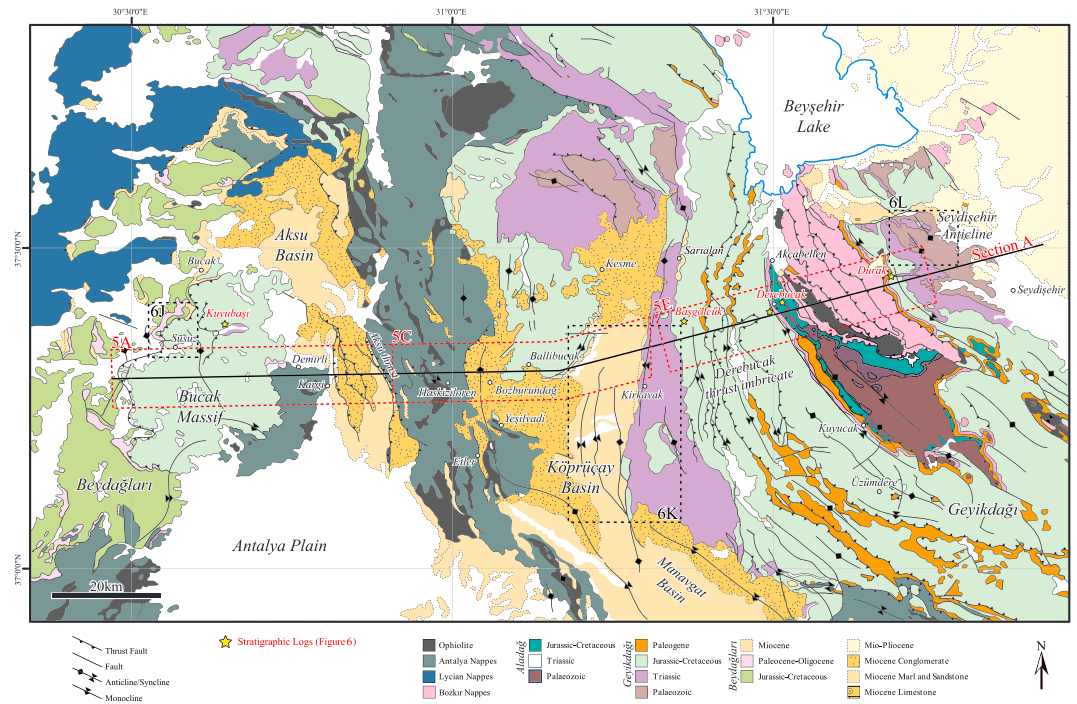
Figure 3. Large-scale structural map showing generalized stratigraphy and the location of our cross section (Section A; Figure 7). This map is based on the MTA 1:500,000 geological map series. The red dashed boxes around Section A indicate the extent of the strip maps shown in parts, in Figure 4. Black dashed boxes indicate the extent of maps in Figures 5j–5l.

ophiolites in Late Cretaceous time, with overall southward younging metamorphism and thrusting (e.g., Okay et al., 2001; Pourteau et al., 2010; van Hinsbergen, Kaymakci, et al., 2010; van Hinsbergen et al., 2016; Plunder et al., 2013, 2016; see Figure 2b). The metamorphic units in Anatolia were likely exhumed along extensional detachment faults in Late Cretaceous to early Eocene times (Gautier et al., 2002; Gautier et al., 2008, 2018; Lefebvre et al., 2011, 2015).

The Taurides are composed of a nonmetamorphic thrusted carbonate platform and slope-derived rocks (e.g., Gutnic et al., 1979; Özgül, 1984). These consist of the allochthonous Bolkardağı and Aladağ nappes, the para autochthonous Geyikdağı unit, and autochthonous Beydağları platform (Figure 2b). These units underlie an allochthonous nappe composed of ophiolites, ophiolitic mélange, and allochthonous Mesozoic carbonate blocks (e.g., Okay, 1984) collectively known as the Bozkır nappes (e.g., Andrew & Robertson, 2002; Özgül, 1976). The mélange matrix contains Late Cretaceous (Maastrichtian) planktonic foraminifera showing that it formed after that time (Özgül, 1997). Regionally, the Bozkır nappes were thrust over the coherent but internally deformed Bolkardağı and Aladağ nappes. The Bolkardağı nappe is the northernmost of these nappes and contains nonmetamorphosed sedimentary rocks Taurides in the southwestern Taurides. Toward the northeast, it was affected by an increasing grade of metamorphism where it becomes part of the Afyon zone (Candan et al., 2005; Okay, 1984). The Bolkardağı nappe accreted below the Bozkır nappes in Campanian-Maastrichtian times based on the age of the uppermost synorogenic sedimentary rocks in the nappe, the age of the overlying melange matrix (Mackintosh & Robertson, 2012), and 70–65 Ma ^{40}Ar/^{39}Ar cooling ages in the metamorphosed parts of the nappe (Özdamar et al., 2013; Pourteau et al., 2013). In the Derebucak area, the Bolkardağı nappe is not exposed; however, but it becomes a major unit of the internal nappe stack southward along the Central Taurides (Figure 3), where it consists of polymeta-morphic Precambrian basement and low-grade metamorphic Upper Paleozoic to Lower Paleocene sedimentary rocks (Demirtasli et al., 1984).

The Aladağ nappe forms the southern part of the allochthonous nappes (Özgül, 1976). In the southeast of the western Central Taurides near the town of Hadim, the Aladağ nappe was backthrust northeastward over the Bolkardağı nappe. Locally, the Aladağ nappe is covered by ophiolitic melange of the Bozkır nappes.

The Aladağ nappe contains an Upper Devonian to Maastrichtian sequence of shelf carbonate and clastic rocks (Özgül, 1976; Figure 4).

The allochthonous Bozkır, Bolkardağı, and Aladağ nappes were thrust over the Geyikdağı unit, which makes up the high elevation axis of the western Central Taurides (Figure 2b). In the northern part of the western Central Taurides, the Bozkır nappe is in direct contact with the Geyikdağı unit, and the Aladağ and Bolkardağı nappes are absent. In places, the Aladağ nappe is underlain by thin slivers of deep-marine sedimentary rocks, which are as young as Campanian-Maastrichtian age (Özgül, 1976; Mackintosh & Robertson, 2012). The structural and paleogeographic context of those rocks is enigmatic, but they may be derived from a deep basin, which has been referred to as the *Dipsiz Göl* basin that existed between the Aladağ nappe and the Geyikdağı unit platform.

The stratigraphy of the Geyikdağı unit varies regionally in terms of thickness and stratigraphic continuity but in its most complete form consists of Precambrian to Ordovician sedimentary rocks and an overlying sequence of Mesozoic to Paleogene carbonate rocks (e.g., Gutnic et al., 1979; Özgül, 1976; Figure 4). Within the study area, the Jurassic to Lower Cretaceous stratigraphy varies spatially (see Gutnic et al., 1979 for detailed descriptions). The Upper Cretaceous stratigraphy generally consists of shallow water to peritidal platform carbonates and rudist-bearing neritic limestones.

The top of the Geyikdağı unit stratigraphy is composed of marl and coarse sandstone with ophiolitic pebbles. Blocks derived from the allochthonous nappes become more common toward the hinterland (northeast). Gutnic et al. (1979) interpreted this as a foreland basin deposit deposited onto nummulitic limestone at the top of the carbonate sequence. The youngest reported foreland basin deposits are of late Lutetian age (~40 Ma), constraining the maximum age of thrusting in the Geyikdağı unit (Gutnic et al., 1979).

The Beydağları platform of southwest Turkey is the lowest structural unit in the Taurides. It forms the foreland of the western Central Taurides fold-thrust belt and is used as the regional pin line for our reconstruction. The Beydağları platform contains an exposed sequence of Mesozoic to Oligocene platform carbonate rocks (Özer et al., 2001). A 1-km-thick sequence of clastic sedimentary rocks was deposited onto the Beydağları platform in Miocene times, in response to the emplacement of the east-verging Lycian Nappes (Hayward, 1982). The emplacement of the Lycian Nappes may have been gravitationally driven and occurred during regional extension and exhumation in the Menderes region of western Turkey (van Hinsbergen, 2010), which was associated with Aegean extension to the west of the Taurides (e.g., Gessner et al., 2013; van Hinsbergen & Schmid, 2012).

The Beydağları platform underwent a middle Miocene to Pliocene ~20° anticlockwise rotation in the eastern limb of the Aegean orocline (Kissel & Poisson, 1987; Morris & Robertson, 1993; van Hinsbergen, Dekkers, Bozkurt, & Koopman, 2010; van Hinsbergen, Dekkers, & Koç, 2010; van Hinsbergen & Schmid, 2012). Miocene sedimentary rocks of the Aksu basin did not rotate with the Beydağları platform (Koç, van Hinsbergen, et al., 2016), indicating that the Aksu basin and Beydağları platform were decoupled by major structures.

While the fold-thrust belt from the Bozkır nappes to the Beydağları platform was an overall southwest propagating thrust system, southwest Turkey contains another fold-thrust belt that already existed in Late Cretaceous to Paleocene time: the Alanya-Antalya Nappes. Those were thrust over the southern margin of the Geyikdağı-Beydağları platforms from south to north (Özgül, 1984) and therefore do not follow the general southwest-younging trend in ages of metamorphism and thrusting that is found in the rest of central and western Turkey. Paleocene marine sedimentary rocks seal frontal thrust contacts within the Antalya-Alanya Nappes near Alanya (Gutnic et al., 1979), indicating that accretion of the nappes was complete well before SW verging thrusting affected the Geyikdağı unit in Eocene time.

The Antalya Nappes are the lowermost structural unit and contain sedimentary and volcanic rocks interpreted as the folded and thrusted southern passive margin of the Geyikdağı-Beydağları platforms (Dumont et al., 1972; Robertson & Woodcock, 1984). We use the nomenclature and tectonostratigraphic subdivisions of Yilmaz and Maxwell (1984) as used in the 1:100,000 map series of the General Directorate of Mineral Research and Exploration Turkey (MTA); outlined in Figure 2b. The Alanya Nappes are structurally above the Antalya Nappes and consists of high-pressure low-temperature metamorphic rocks, which experienced peak metamorphism at ~85–80 Ma (Çetinkaplan et al., 2016; Okay & Özgül, 1984). The highest structural unit is a dismembered ~95–90 Ma ophiolite (Çelik et al., 2006), which is in direct contact with the Antalya Nappes on the eastern side of the Gulf of Antalya (Figures 2a and 2c). The ophiolites were emplaced northward onto the Taurides and are thought to be remnants of an oceanic upper plate below which oceanic lithosphere that

separated Greater Adria from the North African margin in Paleozoic and Mesozoic time subducted in Late Cretaceous time (Maffione et al., 2017; Moix et al., 2008). The Cyprus slab must contain this now subducted Cretaceous age upper plate oceanic lithosphere (e.g., Biryol et al., 2011; Maffione et al., 2017; Moix et al., 2008). The objective of our study is to reconstruct the relationship between the Antalya slab and the NW-SE trending western Central Taurides fold-thrust belt; the Antalya Nappes were formed above another older and separate subduction zone, and so in our reconstruction we treat them as a single composite unit.

Finally, in the central part of the composite fold-thrust belt, the Antalya Nappes and underlying Taurides are covered by the Miocene marine to marginal-marine Antalya basin, which includes the Aksu, Köprüçay, and Manavgat subbasins as well as the Gulf of Antalya (Figures 2 and 3). These subbasins contain a Burdigalian (~20–16 Ma) to lower Pliocene stratigraphy (~5–3 Ma; see Flecker et al., 2005; Çiner et al., 2008). The Antalya basin was deformed by thrust faults until at least early Pliocene time (Poisson et al., 2003). Koç et al. (2012, 2017) Koç, Kaymakci, et al. (2016) and Koç, van Hinsbergen, et al. (2016) demonstrated that Miocene thrusting was coeval with E-W extension in the Central Tauride intramontane basins (Figure 3) and accommodated westward convex oroclinal bending of the western Central Taurides.

3. Cross Section Construction

3.1. Methods

We constructed a balanced cross section of the western Central Taurides fold-thrust belt from the Beydağları platform, NE across the NW-SE trending belt, to assess the timing and style of deformation and minimum shortening. In the absence of subsurface data, we constructed the cross section using dip data, observations of field relationships, and lithostratigraphy. We interpreted thrust faults where there was structural repetition of the lithostratigraphy or footwall cutoff and hanging wall cutoff contacts. Faulting and folding on the scale of one hundred meters was not represented on our 144-km-long section, and so we collected dip measurements that were representative of the first-order structures. The shape of a thrust fault ramp exerts a first-order control on the style of deformation in the hanging wall above the fault (e.g., Berger & Johnson, 1980). We used surface constraints on hanging wall deformation to predict the position and shape of subsurface thrust faults. Thin-skinned fold-thrust belts evolve above a shallow dipping planar décollement (e.g., Dahlen, 1984; Davis et al., 1983). It was not possible to estimate the depth of the décollement using widely used area-depth calculation (e.g., Epard & Groshong, 1993), and we instead used the thickness of thrust sheets and predicted fault trajectories to estimate the depth of the décollement, which we explain further in section 3.3.

At each step in building the cross section, we assumed the simplest structural solution with the least shortening. Eroded hanging wall anticlines were reconstructed as close to the modern topographic surface as possible using the geometric model of Suppe (1983). We assumed that that area was conserved during deformation and that deformation was accommodated by layer-parallel shear. In the absence of evidence, we assumed negligible footwall deformation and assumed that thrust faults formed instantaneously, rather than by propagation. Section balancing assumes plane strain, which may be violated if the section is cross-cut by strongly oblique faults or strike-slip faults. Strike-slip faults and oblique faults have been interpreted in the western Central Taurides (Akay & Uysal, 1988; Glover & Robertson, 1998), although lateral offset has never been demonstrated on any of the high-angle faults within our cross section.

We balanced the section to test whether our structural interpretation was internally consistent and to calculate minimum shortening (e.g., Dahlstrom, 1969). A balanced cross section can be restored to its original, predeformation geometry with a near-perfect fit of all structural units in their predeformation order. We restored the section by unfolding each thrust sheet relative to a local pin line (i.e., within the thrust sheet). Parts of the section with an unknown stratigraphy were balanced using arbitrary template beds, and in Figure 7 those parts have been left as white spaces. We used the *flexural-slip unfolding* algorithm in Move 2016, which we benchmarked against the analytical method of Suppe (1983). Unfolding was imposed relative to a template horizon (i.e., the uppermost continuous stratigraphic horizon in the thrust sheet). The algorithm maintains area and also line length in lines that are parallel to the template horizon.

3.2. Field Observations

We found that the western Central Taurides developed as an overall west verging fold-thrust belt toward the Beydağları platform foreland. Our field observations are presented as a strip map and cross section in Figure 4. Descriptions of our main field observations are in Table 1, which is accompanied by photographs
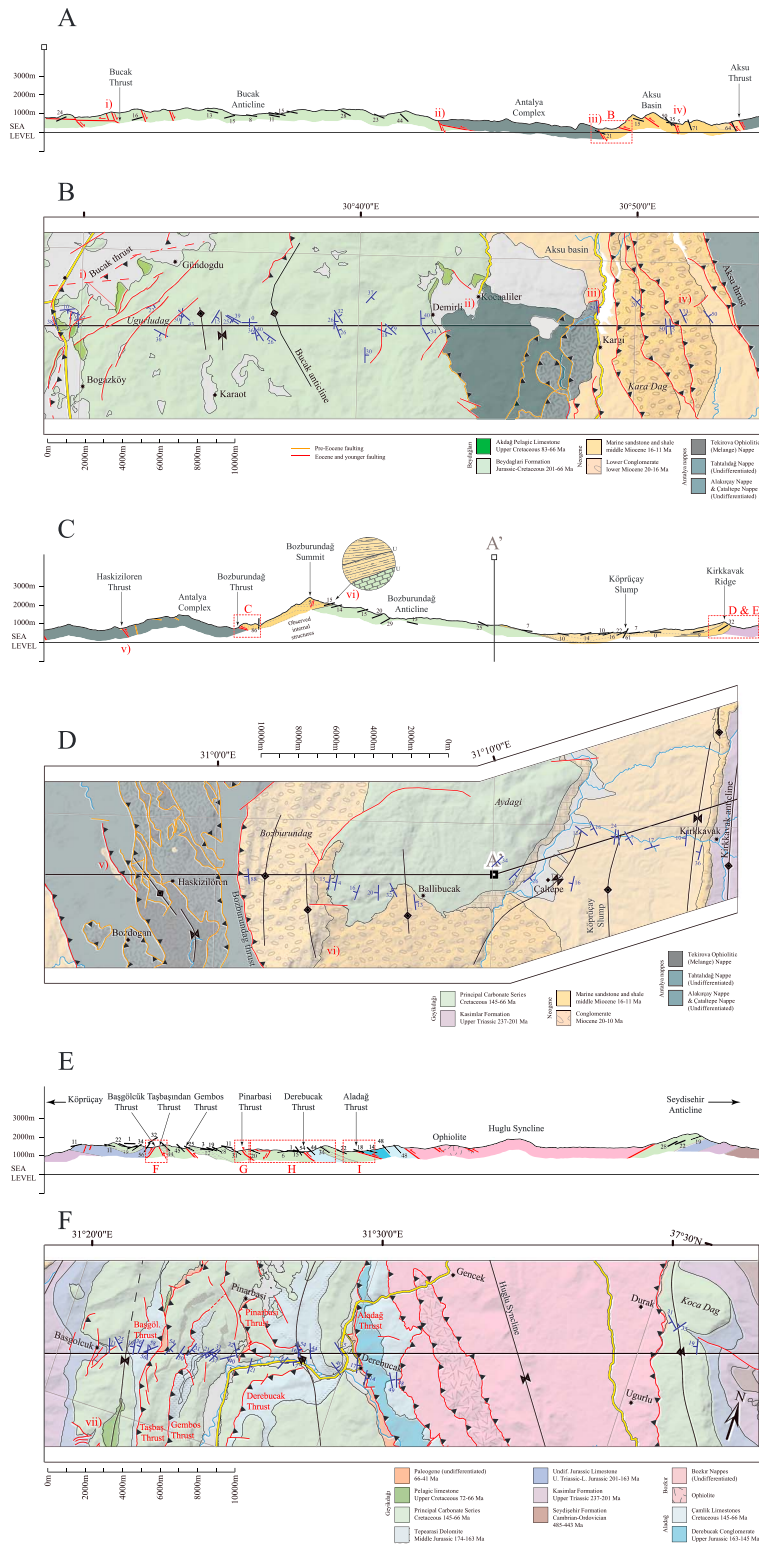
Figure 4. Strip maps containing the data we used to construct the cross section and the data projected to the cross section. Roman numerals refer to descriptions in Table 1. Capital letters refer to photos in Figure 5. The extent of each map is shown by red dashed boxes in Figure 3. A complete strip map is available in Figure S1 in the supporting information. Yellow lines are major roads (a and b) Beydağları to the Aksu thrust, including the Bucak anticline, and the Aksu thrust imbricate (c and d) Bozburundağ to Kirkkavak, showing the Bozburundağ thrust and the Köprüçay basin. (e and f) Kirkkavak to Tarasci, showing the Derebucak thrust imbricate and the Huğlu syncline.

Table 1
Descriptions of Key Field Relationships From West to East Along Section Line A

Observation	Description
Bucak thrust Figures 5a and 5j Figures 4a and 4b, point i)	At Susuz, Upper Cretaceous limestone is thrust over Paleogene and (locally) upper Miocene rocks of the Beydağları foreland. The overlying Upper Cretaceous rocks contain meter-scale bedded limestone that defines a west dipping monocline, which we interpret as a hanging wall anticline. The E-W trending valley at Susuz forms a reentrant in the thrust contact and exposes 1–3 km of Paleogene rocks in the footwall. South of Susuz (Figure 4a, point i), the Bucak thrust is downthrown on steep E-W trending faults and is covered by a thick layer of unconsolidated sediments. The west dipping hanging wall anticline, however, is continuous along strike to the line of the section. The hanging wall limestones dip ~20°W and are cut by a series of N-S trending normal faults that juxtapose massive and thickly bedded limestones with uppermost Cretaceous thinly bedded pelagic limestones.
East limb Bucak anticline Figures 4a and 4b, point ii)	Along the eastern limb of the Bucak anticline, Upper Cretaceous and local Paleogene limestones are covered on a flat-on-flat contact by a wide ridge of the Çataltepe nappe of the Antalya Nappes. The underlying rocks of the Bucak anticline are exposed to the north and south of the ridge, indicating that at least for the first few kilometers the underlying limestone dips shallowly east. The Çataltepe nappe is exposed for about 5 km and then dips below higher tectonostratigraphic units of the Antalya Nappes (Alakırçay nappe and Tahtalıdağ nappe).
Aksu basin margin Figures 4a and 4b, point iii) box B Figure 5b	Miocene sedimentary rocks are juxtaposed with the Antalya Nappes along 60–90°E dipping contact that we interpret as a normal fault. This locally forms the basin margin of the Miocene Aksu basin. Elsewhere, the Antalya Nappes are unconformably covered by gently folded (~10° dipping limbs) Miocene marine sedimentary rocks of the Aksu basin.
Aksu intrabasin thrusting Figures 4a and 4b, point iv) Figure 5b	On the strip map, the basin is dominated by a 600-m-high ridge of bedded lower Miocene conglomerate (Ciner et al., 2008) that has been thrust over upper Miocene sandstone and marl. Within the conglomerate ridge, the westernmost conglomerate unit dips ~20°E, followed by domains of ~50°E, then ~85°E on the eastern edge of the ridge. Between the 20°E and ~50°E dipping domains we found upper Miocene sandstone and marl on top of the conglomerate, which represents a thrust repetition. Between the ~50°and ~85°dipping domains we found a conspicuous footwall cutoff with local drag folding indicating a thrust fault.
Aksu thrust Figures 4a and 4b	The eastern margin of the Aksu basin is bound by a 60–80°E dipping Aksu thrust fault (e.g., Ciner et al., 2008), which juxtaposes the Çataltepe and Alakırçay nappes of Antalya Nappes with Miocene rocks.
Antalya Nappes Haskızılören thrust Figures 4c and 4d, point v)	The Antalya Nappes east of Aksu form high relief ranges of up to 2,000 m in elevation and include all tectonostratigraphic units of the Antalya nappes. The ophiolitic Tekirova Nappe is preserved within a N-S trending syncline, bound to the east and west by exposures of lower tectonostratigraphic units of the Antalya Nappes. The rocks within the Antalya Nappes are intensely deformed by faulting and folding. A large part of that deformation must be related to the accretion of the Antalya Nappes nappe stack in Cretaceous to Paleocene times. In some places, for example, near Haskızılören, Antalya Nappes rocks are thrust over outliers of lower Miocene rocks, which require that part of the internal deformation is post early Miocene in age.
Bozburundağ thrust Figure 3, Etler Figure 4c box C Figure 5c	At Haskızılören, the Alakırçay Nappe is overlain by vertically bedded upper Miocene conglomerates that dip onto a low-angle basal fault. This geometry is typical of a hanging wall cutoff but requires that younger rocks thrust over older ones. The internal structure of the Bozburundağ hanging wall was observed from a distance and has been imposed onto Section 4C. The conglomerates at Bozburundağ are the marginal facies of, and interfinger with, the marine sedimentary rocks of the Miocene Köprüçay basin to the east (Ciner et al., 2008; Deynoux et al., 2005). We consequently interpret this contact to be the result of inversion of an original basin-bounding normal fault that thrusted marginal basin fill over the footwall and the basin edge. At Etler, 10 km south along the Bozburundağ fault, a normal fault contact is preserved and Miocene conglomerates in the hanging wall are folded, suggesting that partial inversion affected the fault there.
Bozburundağ anticline Figure 3, Yeşilvadi Figure 4d, point vi) (see also Ciner et al., 2008)	Upper Miocene conglomerates of Bozburundağ contain an intraformational angular unconformity and thin toward the east, where the Cretaceous age Geyikdağı platform emerges in a west dipping sequence. An upward steepening of dips across the unconformities is consistent with our interpretation that the Bozburundağ conglomerates were deposited on the hanging wall of a growth fault. Locally, the Antalya Nappes are not present, presumably because of erosion. The flat-on-flat contact of Antalya Nappes rocks thrust over the underlying Geyikdağı unit is exposed to the south of our section at Yeşilvadi. Bedding in the conglomerates at Bozburundağ defines a strongly asymmetrical west verging fold. The east limb is shallow dipping and unconformably covers a N-S trending open fold in the Cretaceous limestone at Ballıbucak that was eroded prior to deposition of Miocene conglomerate.
Köprüçay basal unconformity Figure 3, Kesme Figure 4c box D Figures 5d and 5e	Miocene sedimentary rocks in the Köprüçay basin form an overall asymmetric syncline with a subvertical eastern flank, where conglomerates of the base of the stratigraphy define a high N-S trending ridge (Kirkavak ridge). Those conglomerates cover Triassic rocks on an angular unconformity that is spectacularly exposed at Kirkkavak in the south (Figure 5d) and on the mountain pass from Kesme to Dumanli (Figure 5e). Near the village of Kesme within the center of the Köprüçay valley (see Figure 3, Kesme), Miocene conglomerates cover an angular erosional unconformity and seal thrust faults that cut down into Triassic, Permian, and Precambrian rocks.

Table 1 (continued)

Observation	Description
Köprüçay Slump Figure 5k	In the south of the Köprüçay basin, middle and upper Miocene marl and sandstone form a major west verging anticline with a subvertical west limb that runs along the larger Köprüçay synclinal axis. This vertical limb can be traced N-S over ~20 km and gradually disappears north and southward. Interestingly, in the southern and eastern part of the synclinal axis, the eastern flat-lying limb abuts abruptly against subvertical basal conglomerates of the Köprüçay basin. This angular relationship suggests a normal fault contact, but this fault is located within the Miocene basin stratigraphy, between the competent basal conglomerates and the weak marl-rich marine deposits of the basin fill. We explain the major fold in the marl and sandstone within the topographically lowest part of the Köprüçay syncline as a mega slump that formed during folding of the underlying basement. We regard the formation of the slump to be evidence for timing of the uplift of the basin margin. The normal fault between these deposits with the basal conglomerates represents a slump scar that formed during the folding of the Köprüçay syncline. The subvertical eastern limb of the Köprüçay syncline is widely interpreted as a right-lateral *Kırkkavak strike-slip fault* (Dumont & Kerey, 1975) or a normal fault (Deynoux et al., 2005; Schildgen et al., 2012). The contact between the Miocene and Triassic stratigraphy is not a fault but an unconformity, and we found no evidence for the presence of a Kırkkavak fault other than the slump scar. Instead, this is the asymmetric Kırkkavak anticline adjacent to the Köprüçay syncline. There are surfaces within the Miocene conglomerate units that contain slickensides, which are likely a reflection of layer-parallel slip during folding. The vertical eastern margin of the syncline did not form the Miocene basin margin, as marine upper Miocene deposits are found at 1,500-m elevation east of the Kırkkavak anticlinal hinge at Sarıalan (Schildgen et al., 2012).
Cretaceous unconformity Figure 4f, point vii) Figure 6	East of the Kırkkavak anticline, the rocks are dominated by the Geyikdağı and higher structural units of the Taurides that contain a recognizable but laterally variable lithostratigraphy (Figure 6). The carbonates of the Geyikdağı unit are deformed by a thrust imbricate indicated by the repetition of the lithostratigraphy. The eastern limb of the Kırkkavak anticline contains Jurassic to Cretaceous platform carbonate rocks that create a syncline that preserves Upper Cretaceous rocks in the core toward the south. Toward the south of our strip map; uppermost Cretaceous limestone unconformably overlies the lower parts of the principal carbonate series, suggesting a phase of uplift and erosion sometime prior to latest Cretaceous time.
Başgölcűk thrust Figure 5f Figures 4e and 4f	The eastern limb of the syncline formed above an ~55°E dipping thrust fault at Başgölcűk that thrusted Lower Jurassic limestone over a narrow exposure of Paleogene rocks along a footwall cutoff. Paleogene rocks below the Başgölcűk thrust are overthrusted from the east by the ~65°W dipping Taşbaşından thrust along a footwall cutoff. This thrust also cross-cuts the Başgölcűk thrust. The overriding thrust sheet contains 100-m-scale thrust repetitions that locally steepened the overlying bedding.
Pinarbasi thrust Figures 4e and 4f Figure 5	Near Pınarbası, a well-exposed thrust fault dipping ~50°E separates deformed mudstone and sandstone of the Eocene *flysch* (Monod, 1977) that forms the highest stratigraphic unit of the Gembos thrust sheet from overlying fractured, Upper Cretaceous, well-bedded to massive limestone with minor dolomite beds of the Pinarbasi thrust sheet.
Derebucak thrust Figures 4e and 4f Figure 5h	The Cretaceous limestone and dolomite of the Pinarbasi thrust sheet is overthrusted by Lower Jurassic limestones of the Derebucak thrust sheet along a flat-on-flat thrust contact that is locally cross-cut by small-scale normal faults. Near the town of Derebucak, a conspicuous footwall cutoff between the underlying ~15°E dipping Upper Cretaceous limestones and ~45°E dipping Lower Jurassic limestones of the Derebucak thrust sheet is exposed in the valley side. At least 3.5 km of flat-on-flat overlap of the Lower Jurassic limestone on Upper Cretaceous limestone was mapped.
Derebucak H.W. anticline Figure 3, Üzümdere	The Derebucak thrust sheet extends 100 km southward along the range, and at Üzümdere, the hanging wall anticline of the thrust sheet is preserved, limiting shortening on the thrust to ~7 km.
Aladağ nappe Figure 3, Akçabellen	At Akçabellen, north of the section, the Aladağ nappe tapers out, and the ophiolite-bearing Bozkır Nappe lies directly on the Derebucak thrust sheet. The platform rocks of the Geyikdağı unit plunge below the allochthonous Aladağ and Bozkır nappes at Derebucak.
Aladağ H.W. anticline Figure 3, Kuyucak	South of Derebucak, the edge of the Aladağ nappe is marked by overturned Upper Triassic to Upper Cretaceous rocks, which we interpret as a hanging wall anticline.
Seydişehir anticline Figure 3	Geyikdağı unit rocks reemerge from below the Bozkır and Aladağ nappes in a 2,300-m-high ridge of west dipping Triassic to Eocene limestones. This ridge forms the eastern limb of the regional-scale Huğlu syncline and western limb of the regional-scale Seydişehir anticline. Cambrian-Ordovician shale and limestone are exposed in the Seydişehir valley below and form the core of the anticline. Tectonic windows through the internally deformed shale expose Triassic rocks and therefore demonstrate that there is duplexing of the Triassic and deeper stratigraphy in the anticline.
Central Tauride intramontane extensional basins Figure 2	East of Seydişehir, exposures of the Taurides become scarce owing to the overlying Mio-Pliocene fluviolacustrine sedimentary rocks and volcanic rocks of the Central Tauride intramontane Basins (e.g., Koç et al., 2012). Within these Mio-Pliocene basins, inliers of metamorphic rocks of the Afyon zone (Bolkardağı) and overlying ophiolite (e.g., Daşçı et al., 2015) are exposed, suggesting that the Taurides either underthrusted or are absent below higher tectonostratigraphic units.

Note. Numeral codes refer to points on the strip map and cross section (Figures 4a–4f). Letter codes refer to photographs in Figure 5.

and maps of key field relationships in Figure 5. In Figure 6, we provide five schematic logs that illustrate the various formations present across the fold-thrust belt, following the formation definitions of Monod (1977). The thicknesses portrayed are measured in continuous sections in the field or estimated from dip data. We found strong lateral variations in the presence, absence, and thickness of stratigraphic units compared to the composite stratigraphy of Monod (1977), which is in part the result of thrust tectonics and in part the result of erosional unconformities.

3.3. Cross Section Results

Our cross section successfully reconciles our field observations into a viable structural model and keeps structural relationships simple. The deformed and retrodeformed sections are shown in Figure 7, and a larger, more detailed version that shows lithostratigraphic constraints is available in the supporting information (Figure S2). Our section has a total length of 144 km, which becomes 234.5 km long when retrodeformed. This indicates a minimum of 90.5 km shortening since the onset of thrusting of the Aladağ and Bozkır nappes over the Geyikdağı unit in Eocene times. This total amount of shortening includes a minimum overlap of 55 km of the Aladağ and Bozkır nappes over the Geyikdağı unit. We measure a minimum of 18 km shortening in the Derebucak thrust imbricate and 17.5 km in basement-involved thrusting of the Bucak thrust and the thrusting that deformed the Antalya basin.

Our cross section starts in the Beydağları platform, which we describe as the foreland because it is the lowest structural unit (Figures 2a and 3), and is not deformed by thrust faults at the surface. We use dip data and the limited stratigraphic data to reconstruct the shape of the Bucak anticline. It is not possible to calculate the depth of the décollement using area-depth relationships, first because we have no independent constraint on displacement on the Bucak anticline (Figures 4a and 4b) for a simple area-depth calculation and second because there is no mappable lithostratigraphy to constrain the fold shape in the Bucak anticline for use in an area-depth plot (e.g., Epard & Groshong, 1993). We face the same problem in the Seydişehir anticline (Figure 3) in the eastern hinterland part of the section. We solve this problem by using the shape of the hanging wall deformation of the Bucak anticline to predict the shape of the underlying fault and find that a 10-km deep décollement recreates the wavelength of the anticline and gives a good fit for the shape of the fold while minimizing shortening. We interpret this as the basal décollement of the belt. Our reconstruction requires that below the Bucak anticline, the décollement dips at 2°E to fit the Taurides stratigraphy below the Antalya Nappes on the eastern side of the Bucak anticline. This is within 0.5° to 4° of typical décollement dips found in fold-thrust belts (e.g., Echavarria et al., 2003; McQuarrie, 2004; Mitra, 1988). We otherwise have no constraint on the depth and dip of the décollement, and so to the east of the Bucak anticline, we assume that it is subhorizontal to 1°E dipping, to minimize space above the décollement.

We interpret that the Aksu basin (Figures 4a and 4b, iii) filled a graben because the western basin margin is most simply interpreted as a normal fault. After restoring shortening within the Aksu basin, we predict that the subsurface extension of eastern basin-bounding normal fault is located to the east of the Aksu thrust, below the current position of the Antalya Nappes. We interpret a series of east dipping thrust faults within the Aksu basin based on lithostratigraphic repetition and footwall cutoffs. The thrust sheets become systematically steeper dipping toward the east, which we interpret as refolding caused by a foreland propagating thrust imbricate. The thrust imbricate incorporates a ~1-km thick stratigraphy and contains at least 15 km of shortening.

Thrusting within the Aksu basin must link into the basal décollement to be balanced and is likely linked along the Bozburundağ thrust (Figures 4c and 4d), because the uppermost unit of the Antalya Nappes is preserved above the Aksu thrust, indicating the absence of a large fault-bend-fold anticline associated with a major thrust ramp. Our interpretation requires that the décollement at the base of the Antalya Nappes was reactivated as a thrust flat connected to the Bozburundağ thrust and allowed the Antalya Nappes to bulldoze through the Aksu basin. We interpret that the Aksu fault was an in-sequence thrust relative to the Bozburundağ thrust, but out of sequence with respect to thrusting within the Aksu basin. We interpret that the Bozburundağ conglomerate (Figure 4c) was thrust over the Antalya Nappes along an inverted basin-bounding normal fault, which was folded by the underlying thrust fault. We reconstruct the shape of the thrust below Bozburundağ using the shape of the east dipping limb of the Bozburundağ anticline and the observation that to the west, the anticline remains buried below the Antalya Nappes that cover it.
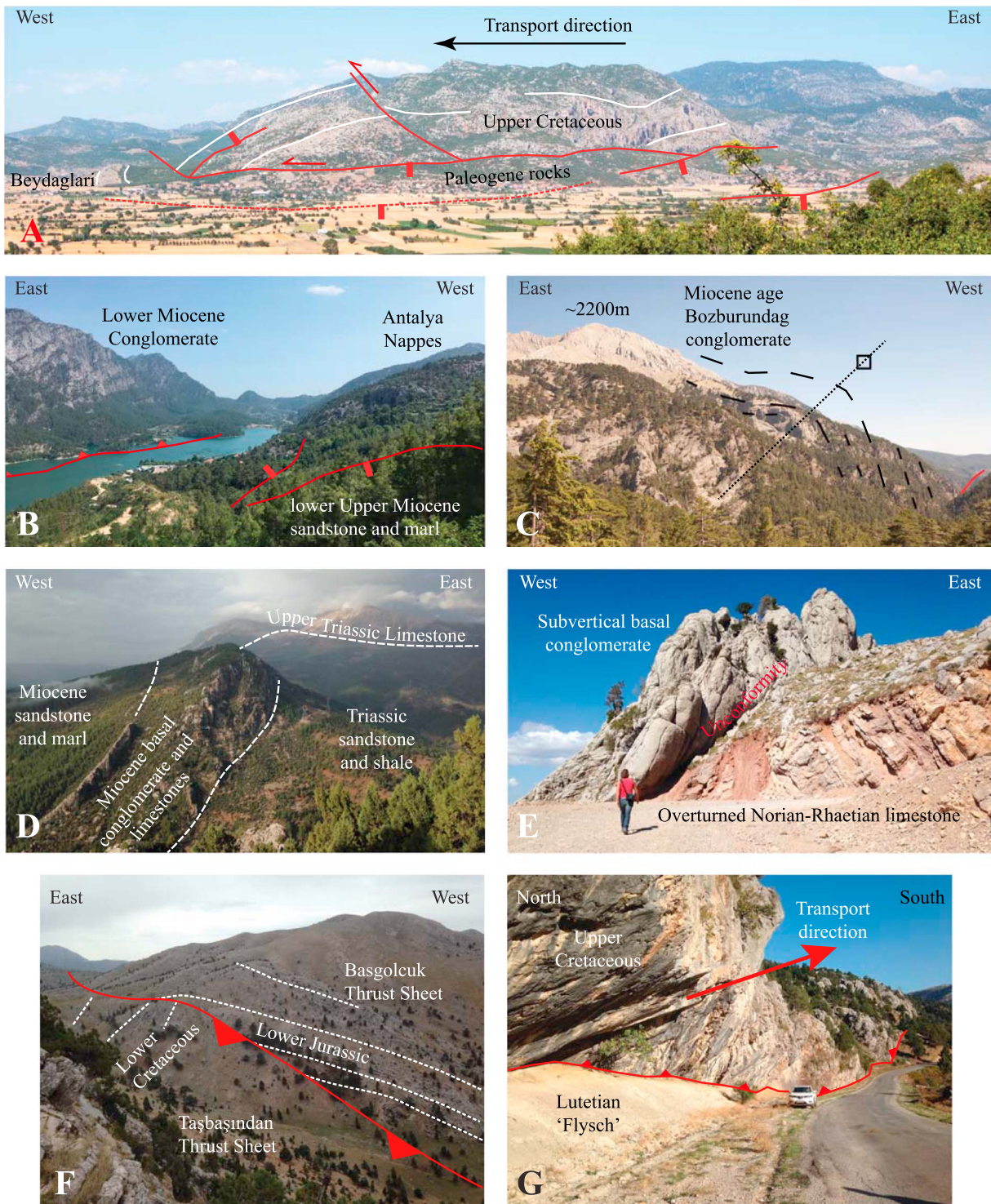
Figure 5. (a–i) Photos of key field relationships along Section A. The location of each photo and detailed descriptions of the contacts are in Table 1. (j) A geological map of the Bucak thrust contact at the village of Susuz, 3 km north of the strip map (map extent is shown in Figure 3). (k) A geological map showing the extent of the Köprüçay slump along the Köprüçay basin. East and west dipping domains are shown as dashed polygons. The extent of the Section A strip map is marked as a dashed box around the Section A line. Section X shows the internal structure of the Köprüçay slump. (l) Geological map of tectonic windows in the Seydişehir valley after Gutnic et al. (1979). The approximate northern edge of the Section A strip map is marked as a dashed black line.
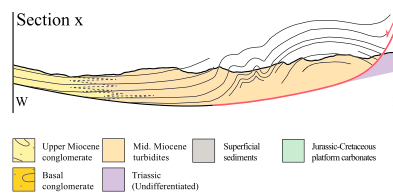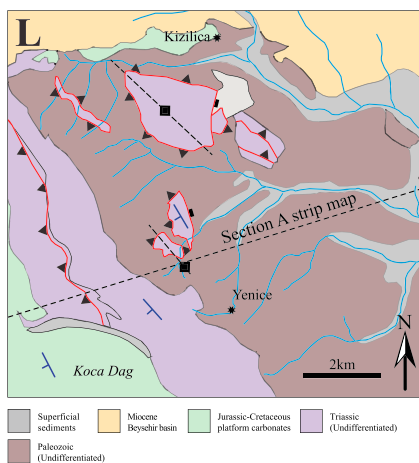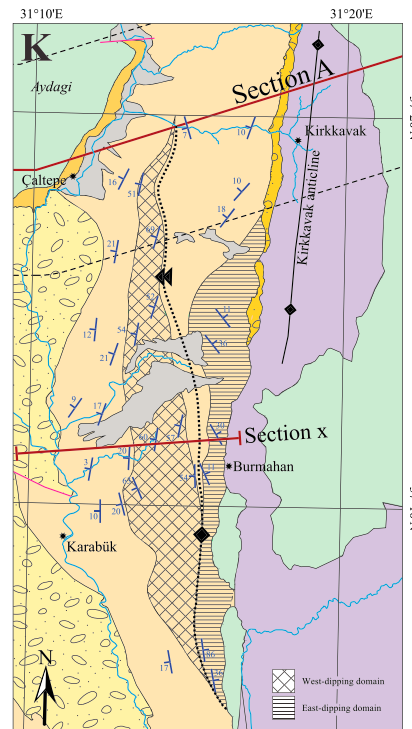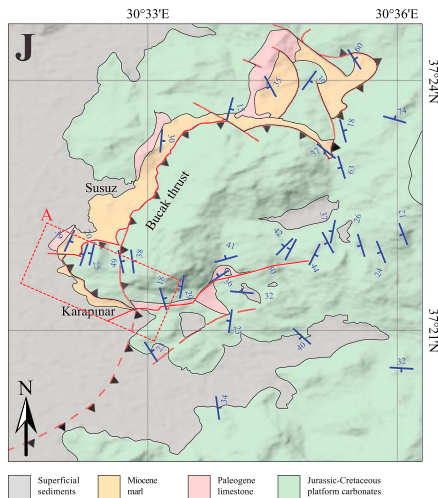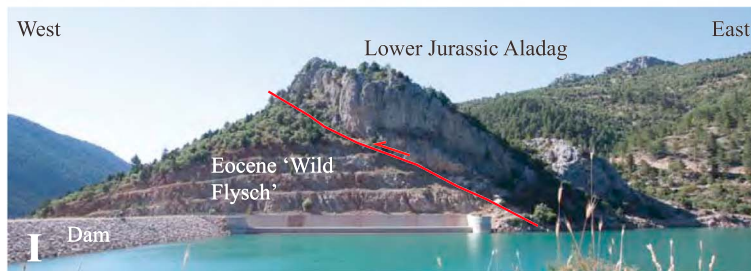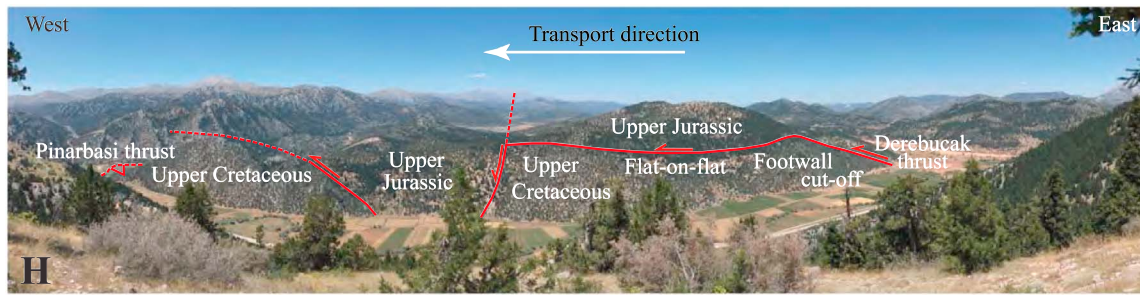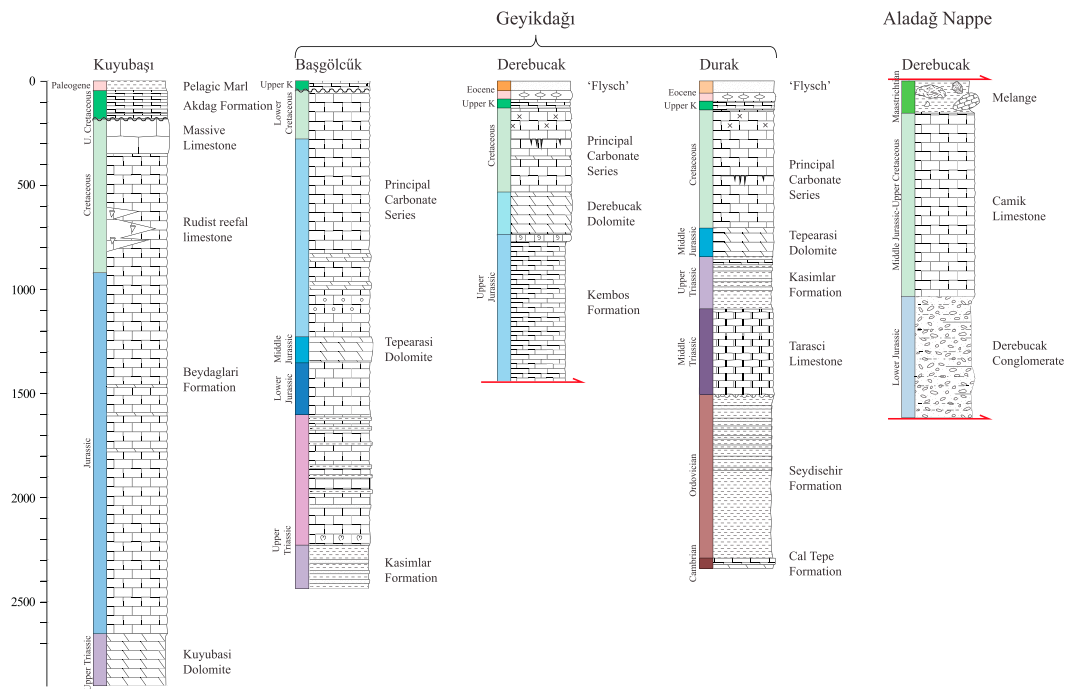
Figure 5. (continued)

Figure 6. Generalized stratigraphy along the line of the section. Stratigraphic ages and formation names of the Geyikdağı are based on Gutnic et al. (1979). The locations of these sections are indicated as yellow stars along Section A in Figure 3.

In the Köprüçay basin (Figure 5k), we assume based on the presence of angular unconformities exposed at both edges of the basin that the Miocene sedimentary rocks were deposited onto deeply incised and thrusted rocks that we saw near Kesme (Figure 3). We reconstruct the Kırkkavak anticline as an eroded and reactivated hanging wall anticline, which created steeply overturned Triassic rocks in the northern margin of the basin (Figure 7a). We attribute the tilt of the basin margin to folding in the hanging wall of thrust fault, which accommodated ~2 km of shortening by steepening of the fold limbs. We link the Kırkkavak thrust into the basal décollement to balance with thrusting to the west and to create uplift below the western edge of the Derebucak thrust imbricate. Uplift of the Kirkkavak anticline cannot be accounted for by Miocene deformation alone, suggesting that the anticline first formed by thrusting during Eocene times.

Thrust faults in the Derebucak area (Figure 3) form a thrust imbricate that does not include pre-Jurassic rocks as in the basement-involved thrust sheets to the west, and preserve the same structural level for ~20 km (Figures 4e, 4f, and 7a). We reconstruct the Derebucak thrust imbricate by assuming that the thrust faults sole into a single intermediate décollement at the base of the Jurassic platform carbonates. This is stratigraphically above the deep décollement we infer in thrusting to the west. We estimate an ~1.5-km-deep décollement using the stratigraphic thickness of the Derebucak thrust sheet (Figures 4e and 4f), as that thrust has a flat-on-flat relationship at its base. Mechanically, the Kasımlar formation mudstone at the base of the platform carbonates provided a glide surface (Figure 4), above which the thrust imbricate formed. The thrust fault shapes are reconstructed from dip data above footwall cutoffs and from the shapes of hanging wall anticlines. The resulting reconstruction is the simplest configuration.

The Bozkır nappes above the eastern edge of the Derebucak thrust imbricate are structurally complex and contain juxtaposed allochthonous units that change relative position along strike (Andrew & Robertson, 2002). We choose not to differentiate the internal structure of these nappes and instead measure the overlap of the Bozkır and Aladağ nappes over the Geyikdağı unit. No evidence for shortening exists in the underlying platform rocks or along strike of the Huğlu syncline (Figure 3), where the allochthonous nappes have been eroded and the underlying platform rocks are exposed.

Thrust repetition of Triassic and older rocks in tectonic windows in the core of the Seydişehir anticline indicate the presence of duplex thrusting (Figure 4l), which must be balanced by thrusting at the surface in
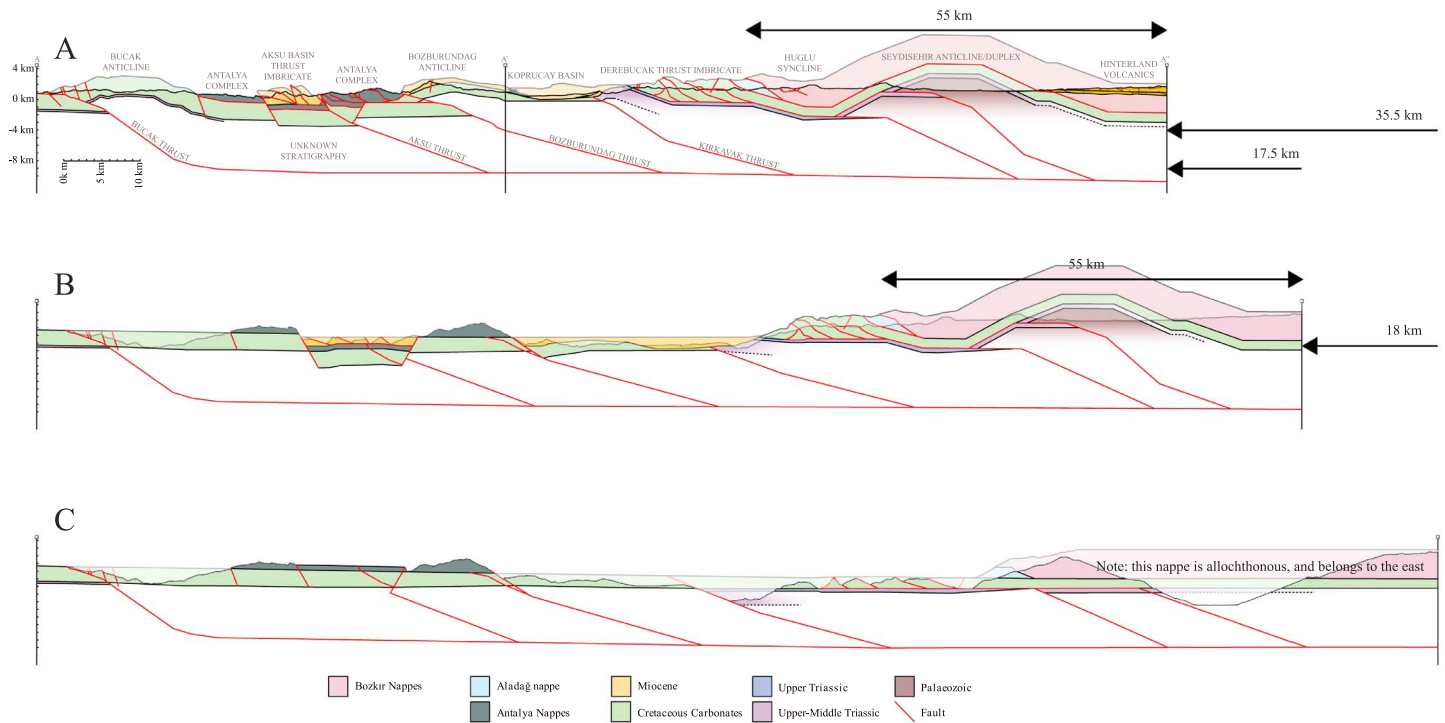
Figure 7. Section A from Bucak to Seydişehir. The Mesozoic stratigraphy has been generalized for clarity. A detailed large version of the section showing lithostratigraphic constraints is included in Figure S2 in the supporting information. White areas below the colored stratigraphic units were included in section balancing but contain an unknown stratigraphy. (a) The balanced cross section of Section A. (b) Retrodeformed Section A, restored to the pre-late phase of thrusting. (c) Retrodeformed Section A restored to the pre-Eocene phase of thrusting.

the Derebucak thrust imbricate. We use the minimum shortening estimate obtained from the Derebucak thrust imbricate to reconstruct a hinterland-dipping thrust duplex that recreates the wavelength and amplitude of the Seydişehir anticline while balancing surface thrusting. Thick thrust sheets are required to fill space below the Seydişehir anticline while maintaining a balance with the Derebucak thrust imbricate. This suggests that the basal décollement below the Derebucak thrust imbricate steps down into the same basal décollement level that we reconstruct for the thrust faulting in the west, which also minimizes structural complexity.

4. Discussion

The aim of our paper is to determine the composition and subduction history of the Antalya slab and its relationship to the Cyprus slab through structural analysis of the Taurides fold-thrust belt. To this end, we develop the first orogen-scale cross section across the western Central Taurides. Below, we discuss the validity of our section and shortening estimates and then discuss the temporal evolution of the fold-thrust belt. We then use this reconstruction to interpret the long-term subduction history and discuss the role these slabs may have played during Miocene surface uplift in southern Anatolia.

4.1. Style of Deformation

The western belt from the Beydağları platform foreland to Köprüçay basin has long wavelength (~15 km) folding and thrusting that involves deep structural units, including Precambrian rocks found north of the Köprüçay basin. The eastern belt incorporates the Derebucak thrust imbricate, the Seydişehir duplex, and the Bozkır and Aladağ nappes.

In our structural model, we assum minimum shortening. Variation in the dip or depth of the décollement would influence our structural interpretation and the amount of shortening. For the basement-involved thrusting there is uncertainty in the subsurface structure because the full thickness of the thrust sheets is not present at the surface; we rely on the wavelength, amplitude, and shape of the fault related folding to

estimate the depth to décollement. It is plausible that some of the basement-involved thrusts are inverted normal faults that penetrate down to midcrustal depths as in a thick-skinned thrust belt, although we did not observe a change in stratigraphic thicknesses from the footwall to the hanging wall that would support this. At Bucak, we use the shape of the Bucak anticline to predict the shape of the underlying fault and find that a 10-km-deep décollement recreates the wavelength of the anticline and gives a good fit for the shape of the fold. A shallower décollement, however, would be associated with thinner thrust sheets and would require extra shortening to fill space beneath the Bucak anticline. We assume a subhorizontal dipping décollement to minimize space in the subsurface that needs to be filled by thrust repetition and hence shortening. For a steeper décollement of 3° to 4°, space above a décollement in the hinterland would likely need to be filled by underthrusting of an eastward continuation of the Beydağları platform below the Derebucak thrust imbricate, requiring ~40-km extra shortening and essentially making the Geyikdağı unit an internally deformed allochthonous nappe. The deep décollement and thick thrust sheets we reconstruct for the Seydişehir duplex are necessary to fill space beneath the Seydişehir anticline while balancing shortening in the Derebucak thrust imbricate.

In the Derebucak thrust imbricate, only the Mesozoic stratigraphy is incorporated in the thrust sheets along the entire belt, the thrusts are closely spaced, and numerous examples of flat-on-flat or footwall cutoff relationships demonstrate that the thrust sheets are only a few kilometers thick. Hanging wall and footwall cutoffs in the Derebucak thrust imbricate are preserved in most thrust slices and limit structural overlap, and so it is unlikely that thrusting there accommodated much more shortening than reconstructed. Our interpretation of the subsurface structure of the Derebucak thrust imbricate is subject to uncertainty. In the absence of seismic or drill-core constraints on the depth of the underlying intermediate décollement, a deeper or steeper décollement could accommodate more shortening, but would require a more complex structural model. Our reconstruction assumes the thrusts within the duplex in the Seydişehir anticline sole into the basal décollement to reduce complexity; the actual depth of the décollement that the duplex soles into is unknown.

Approximately 55 km of the 73 km of shortening in the belt east of Kirkkavak is demonstrated by the overlap of the Bozkır and Aladağ nappes preserved as klippen on top of the Geyikdağı unit (Figure 7). A hanging wall cutoff exists for the Aladağ nappe just south of our section, suggesting that only the Bozkır nappes may have extended farther west and were removed by erosion. Our shortening estimate does not include internal deformation within the Aladağ and Bozkır nappes, which may have accommodated a large but unknown amount of extra shortening.

The total amount of overlap of the Aladağ and Bozkır nappes over the Geyikdağı unit is unconstrained, and the thrust at the base of the Aladağ nappe may thus have accommodated a large amount of convergence before thrusting over the Geyikdağı nappe. Cretaceous deep-marine sedimentary rocks are reported at the base of the Aladağ nappes near the town of Hadim, 80 km to the southeast of Derebucak, and are interpreted as the remnants of a deep basin known as the *Dipsiz Göl* basin, which may have separated platforms that the Aladağ and Geyikdağı rocks originated from (Özgül, 1984; Mackintosh & Robertson, 2012). The consumption of the *Dipsiz Göl* basin may have accommodated a large amount of convergence with little or no accretionary record.

4.2. Timing of Deformation

The western Central Taurides formed in two main phases of thrusting. The early phase started with thrusting of the Bozkır Nappes over the Aladağ nappe in Late Cretaceous to Paleocene times, as constrained by uppermost Cretaceous (Maastrichtian) foreland basin deposits on top of the Aladağ nappe (Andrew & Robertson, 2002; Özgül, 1997). The formation of the Derebucak thrust imbricate at the expense of the Geyikdağı unit occurred after late Lutetian time (~40 Ma), based on the youngest stratigraphic unit incorporated in the thrusting (Gutnic et al., 1979).

Basement-involved thrusting to the west of the Derebucak thrust imbricate occurred largely in Neogene time but must have started prior to early Miocene deposition of the Köprüçay basin. This conclusion is required by the deep unconformity in the northern Köprüçay basin, the angular unconformity on the Kırkkavak anticline, and the reentrant in the Antalya Nappes exposed on Bozburundağ Mountain. The earliest stages of basement-involved thrusting between Kırkkavak and the Beydağları platform foreland must have predated deposition of Burdigalian sedimentary rocks (~20–16 Ma) that cover folds and thrusts beneath the

Köprüçay Basin. Those structures may therefore be part of the Eocene phase of thrusting. Folding in the Köprüçay basin and thrusting in the Aksu basin incorporate sedimentary rocks up to Tortonian age (~12–7 Ma), and the soft-sediment deformation and slope failure in the middle-upper Miocene of the Köprüçay basin dates the formation of the Kırkkavak fold. Minor thrusting affected Pliocene marine sedimentary rocks (Poisson et al., 2003), whereas widespread Pleistocene tufa deposits of the Antalya Plain (Figure 3) are undeformed (Glover, 1995). Thus, basement-involved thrusting between Kirkkavak and the Beydağları platform foreland started prior to the Burdigalian (~20 Ma) and continued until early Pliocene time. Whether there was a phase of tectonic quiescence between the late Eocene and early Miocene, or whether thrusting was continuous, is not known. The absence of upper Eocene or Oligocene sedimentary rocks throughout our section suggests that the thin-skinned thrusting of the Derebucak imbricate may have been confined to the middle Eocene and that the shortening occurred in two stages separated by a late Eocene to Oligocene period of tectonic quiescence.

4.3. Relationship of Taurides Deformation With Antalya Slab Subduction

Our cross section demonstrates that the western Central Taurides fold-thrust belt accommodated a minimum of 90.5 km of upper crustal shortening since the onset of middle Eocene thrusting of the Aladağ and Bozkır nappes over the Geyikdağı unit. Shortening in the fold-thrust belt must have led to northeastward displacement and deep underthrusting or subduction of the original crustal and mantle lithosphere underpinnings of nappes in the belt.

The carbonate platform sedimentary facies and the long stratigraphic range from Precambrian to Eocene of the Geyikdağı unit suggest that it must have been underlain by continental crust that supported a surface elevation around sea level. Such continental crust, similar to that of the Seychelles today, is typically ~30 km thick (Hammond et al., 2013). Our cross section shows a thin-skinned fold-thrust belt that formed above a basal décollement at ~10-km depth (Figure 7). The estimated total crustal thickness, however, is ~35–40 km (Di Luccio & Pasyanos, 2007; Tezel et al., 2013), suggesting that another 15–30 km of crust exists below the décollement. The crust below the décollement must be connected to the Beydağları platform foreland and may be underlain by its original mantle lithosphere.

The continental subduction and upper crustal accretion that formed the western Central Taurides occurred between the converging Africa and Eurasia plates. To assess how much time it would require in late Eocene and younger time to accommodate 90.5 km of continental subduction in southern Turkey, we compared our shortening record to the amount of convergence through time calculated from an Africa-Eurasia plate circuit reconstructed from the Atlantic Ocean. Using the Seton et al. (2012) plate circuit, we calculated an average Africa-Eurasia convergence rate of approximately 2 cm per year (20 km/Ma) during Eocene time. This is a minimum estimate of the subduction rate because it assumes that no extension occurred in the overriding Eurasian plate. This is, however, reasonable, because both the Black Sea and the extensional metamorphic complex of Central Anatolia in which the Kırşehir Block and Afyon zones exhumed are pre-late Eocene in age (e.g., Okay et al., 1994; Gautier et al., 2008; Lefebvre et al., 2011; van Hinsbergen et al., 2016; Gurer et al., 2018). In addition, there is no evidence for major Eocene to early Miocene shortening to the north or northeast of our section. Using the Africa-Eurasia convergence rate as an estimate for subduction rate, it is evident that the shortening associated with the underthrusting of the Geyikdağı unit below the Aladağ and Bozkır Nappes and its internal imbrication prior to basement-involved thrusting between Kirkkavak and the Beydağları platform foreland would require as little as ~5 Myr of late Eocene subduction and may well have occurred entirely within the Lutetian (~49–41 Ma, Gradstein, 2012).

This scenario poses the following question: Where was subduction accommodated before and after the accretion of the thin-skinned portion of the western Central Taurides? Several candidate structures exist that may have accommodated convergence prior to the underthrusting and internal imbrication of the Geyikdağı unit. First, we only constrain minimum shortening on the thrust fault below the Aladağ unit. The concentration of thrusting in the Derebucak thrust imbricate and the apparent lack of deformation in the platform rocks that were once covered by the Bozkır and Aladağ nappes suggest that the allochthonous nappes were first emplaced over the platform, and then in the latest stages of accretion, the thrust imbricate deformed ahead of the overriding allochthonous nappes. Wholesale underthrusting (i.e., convergence without shortening) of an eastern continuation of the Geyikdağı unit below the Aladağ nappe may be hidden if no window in Central Anatolia exposes the Geyikdağı unit—and no such window has been found. In the equivalent part of

the orogen in western Turkey, Miocene low angle normal faulting has exhumed a window that reveals stacked metasedimentary rocks of the Menderes Massif that may be the underthrusted northward continuation of the Beydağları platform, even though underthrusting there did not lead to major accretion at the thrust front in the Lycian Nappes (e.g., Collins & Robertson, 1998; Gessner et al., 2001; van Hinsbergen, 2010). Metasedimentary rocks with peak metamorphic ages as young as late Eocene (~35 Ma) are exposed as far as 200 km north of the Lycian thrust front (e.g., Lips et al., 2001; Bozkurt et al., 2011; Schmidt et al., 2015), and internal shortening within the Menderes Massif (e.g., Gessner et al., 2001) may have accommodated hundreds of kilometers of shortening equivalent to all ~55- to 35-Ma Africa-Eurasia convergence (van Hinsbergen, Kaymakci, et al., 2010). The underthrusting without major accretion that is recorded in western Turkey may be analogous to the fate of the missing Paleocene and early Eocene accretionary record in the western Central Taurides. Furthermore, the enigmatic deep-marine deposits of the *Dipsiz Göl* basin (Özgül, 1984) found below the Aladağ thrust (Mackintosh & Robertson, 2012) may be a remnant of a deep basin once separating the Aladağ nappe and Geyikdağı unit, which was consumed by underthrusting with almost no accretionary record. In even earlier times, before the accretion of the Aladağ and Bolkardağı nappe (Afyon zone) in the Maastrichtian to Paleocene (Özgül, 1997), convergence was accommodated by underthrusting below the ~95- to 90-Ma suprasubduction zone ophiolites and underlying mélange of the Bozkır nappes with no record of major accretion, but the development of a volcanic arc on the Kırşehir Block (van Hinsbergen et al., 2016, and references therein).

Where subduction happened after the late Eocene accretion of the western Central Taurides is more problematic. After Lutetian times (~40 Ma), a further 450 km of Africa-Eurasia convergence must have been accommodated according to the plate circuit. Our post-Lutetian estimate of the amount of shortening, probably confined to the Neogene, accounts for less than 5% of convergence, and uncertainties in the depth of décollement do not allow for more than a few tens of kilometers more shortening. In addition, we know of no candidate thrust west of the Derebucak imbricate that may have accommodated hundreds of kilometers of subduction without accretion. It is most likely that post-Lutetian Africa-Eurasia convergence was accommodated to the south of the Beydağları platform. This would require that by late Eocene time, the Beydağları platform foreland decoupled from the African plate and accreted to Anatolia.

A similar conclusion was drawn from a first-order structural transect of the Beydağları platform and Menderes Massif in western Anatolia. van Hinsbergen, Kaymakci, et al. (2010) argued that Africa-Eurasia convergence there was taken up by shortening in the Menderes Massif and Lycian Nappes until late Eocene time. No record of Oligocene thrusting exists in the Menderes massif, Lycian nappes, or its Beydağları platform foreland, during which time hundreds of kilometers of Africa-Eurasia convergence must have occurred. van Hinsbergen, Kaymakci, et al. (2010) suggested that in late Eocene time (~35 Ma), the entire crust of the Beydağları-Menderes platform accreted to the overriding Anatolian lithosphere. The Eocene and older plate boundary was hence kinked and had two roughly E-W trending segments along which the Aegean and Cyprus slabs subducted and a connecting N(W)-S(E) trending segment where the Antalya slab subducted. After the Aegean trench jumped to the south of the Beydağları platform in late Eocene time, the Aegean and Cyprus trenches were directly connected along the Florence Rise (Figure 2a). In that scenario, the Beydağları platform, which was connected to the Antalya slab, was isolated in an intraplate, upper-plate position, where it remains today. This explains why there is no shortening record to account for major post-Eocene plate convergence along the line of our section: The NW-SE trending western Central Taurides likely no longer accommodated Africa-Eurasia convergence after late Eocene time.

Did we constrain the subduction history and composition of the Antalya slab and its relation to the Cyprus slab? From the analysis above, it follows that the history of the western Central Taurides since Eocene time requires the consumption of at least 90.5 km of lower crust and lithosphere by underthrusting below the Anatolia. The Antalya slab is the straightforward candidate to contain this lithosphere. The length of the Antalya slab as suggested by seismic tomography (Biryol et al., 2011; van der Meer et al., 2018) is at least 300 km, at which point it becomes indistinguishable from the Cyprus slab in the tomography. The length of the slab requires that it contains not only the middle Eocene and younger lithosphere but also lithosphere that was consumed prior to underthrusting and accretion of the Geyikdağı unit, perhaps as far back as Late Cretaceous time. Subduction since Late Cretaceous time led to the accretion of continent-derived crustal units, and so the Antalya slab consists mostly of continental lithosphere. Presumably the net density of the slab was similar to that of the surrounding asthenospheric mantle, and so it did not break off shortly after

Eocene time. Moreover, our analysis suggests that the Antalya slab is continuous with the Beydağları platform and has not been connected to the African plate since late Eocene time. The Cyprus slab appears to be continuous with the African plate and must contain the oceanic lithosphere that separated Greater Adria from Africa, which according to plate reconstructions was 500 km wide and subducted after middle Eocene time (Maffione et al., 2017; Moix et al., 2008). The upper mantle portions of the slabs are of different composition, continental in the case of the Antalya slab and oceanic in the case of the Cyprus slab, and have been disconnected since middle Eocene time.

Our results call for a reassessment of the dynamics of the Miocene tectonic evolution and uplift history of the western Central Taurides. Segmentation of slabs below Anatolia may have played a role in uplift of the Central Anatolian Plateau in the last 8 Ma by allowing mantle upwelling between slab segments (Schildgen et al., 2012). The timing of uplift requires late Miocene segmentation of the slabs. Koç, van Hinsbergen, et al. (2016) and Koç, Kaymakci, et al. (2016) suggested that Miocene extensional deformation of the Central Tauride intramontane basins, westward convex western Central Taurides oroclinal bending, and Miocene E-W shortening in the western Central Taurides were collectively driven by westward rollback of the Antalya slab segment. Our analysis now shows that the Antalya slab has been decoupled from the Cyprus slab and evolved separately from the east Aegean slab for at least the last 35 Myr. We therefore conclude that slab segmentation did not trigger uplift. This does not necessarily mean that the previous hypotheses of Schildgen et al. (2012) and Koç, van Hinsbergen, et al. (2016); Koç, Kaymakci, et al. (2016) are falsified: slow westward rollback of the continental Antalya slab associated with early Miocene deformation may have opened a window between the slabs allowing asthenospheric inflow in late Miocene time. The detachment of the eastern Aegean slab below western Anatolia, which may have occurred around 15 Ma (Bocchini et al., 2018; van Hinsbergen, Kaymakci, et al., 2010) likely also influenced the dynamics of the Antalya and Cyprus slabs and promoted mantle flow. To advance our understanding of the role of these slabs in driving Anatolian crustal deformation and surface uplift, we foresee that further analysis is needed on the late Eocene to recent history of the Antalya slab, through map view restoration and denudation history of the western Central Taurides, to explain why these processes started only in Miocene time and to find the dynamic underpinnings of the enigmatic rise of the Central Anatolian Plateau.

5. Conclusions

In this paper, we study the history of shortening that led to the formation of the western Central Taurides to reconstruct the composition and subduction history of the Antalya slab in relation to the Cyprus slab underlying Central Anatolia. Our conclusions are summarized as follows:

- We present the first balanced, kinematically viable model of the structure of the western Central Taurides and find a minimum of 90.5 km of shortening in a thin-skinned fold-thrust belt. We identify and describe two décollement horizons and a two-stage evolution of the belt, associated with different structural styles.
- In an early deformation phase, shortening led to emplacement of the Bozkır and Aladağ nappes onto the Geyikdağı unit. Emplacement of these nappes was followed by formation of a thin-skinned fold-thrust belt from Kırkkavak to Seydişehir, east of which the décollement stepped down from ~1.5 km to ~10 km depth. The fold-thrust belt between Kırkkavak and Seydişehir formed until at least late Lutetian time (~40 Ma) and accommodated at least 73 km of Eocene shortening.
- The later deformation phase refolded the western part of the belt and created long (~15 km) wavelength folding and thrusting, caused by basement-involved thin-skinned thrusting that propagated the ~10 km décollement westward toward the Beydağları platform foreland. This later deformation phase must have been active since at least Burdigalian times (~20 Ma), until at least early Pliocene times, and accommodated a minimum of 17.5 km of shortening.
- Comparison of our shortening estimates with expected subduction rates calculated from a plate circuit model shows that even with the uncertainties associated with our model, there are hundreds of kilometers of Africa-Eurasia convergence that left no accretionary record in the western Central Taurides. Pre-Eocene convergence left a highly incomplete shortening record.
- After Eocene times, Africa-Eurasia convergence in this segment of the plate boundary must have been accommodated to the south of the Beydağları platform foreland, indicating that after late Eocene times,

the Beydağları platform was decoupled from Africa and amalgamated to the overriding plate. The Antalya slab underlying the Beydağları platform may still be attached to the Beydağları lithosphere and has remained almost stagnant since Eocene times. The Miocene shortening phase was likely dynamically driven by the Antalya slab, but how remains enigmatic

- We suggest that the Antalya slab consists largely of continental lithosphere, in contrast to the Cyprus slab, which must consist largely of oceanic lithosphere. These two slabs were segmented since Eocene times, and so the process of segmentation was thus not a driver of Central Anatolian Plateau rise.

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