Dynamics of episodic Late Cretaceous–Cenozoic magmatism across Central to Eastern Anatolia: New insights from an extensive geochronology compilation

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ABSTRACT

We compiled geochronology data from 87 published studies within the Anatolia orogen (32.5°E–44°E) to investigate the spatial and temporal patterns of continental magmatism during the final stages of Neotethys Ocean closure. The number and diversity of studies compiled here collectively provide a thorough characterization of magmatism (>700 ages) in the Anatolia orogen since the Late Cretaceous (ca. 100 Ma). Our new compilation reveals that magmatism was episodic and occurred in three distinct magmatic episodes punctuated by two orogen-wide magmatic lulls. We used regional-scale insights into the timing, location, composition, and evolution of magmatism revealed by our compilation to evaluate the tectonic and geodynamic processes responsible for each widespread magmatic lull, and to test and refine existing geodynamic models for Anatolia. We interpret the first orogen-wide magmatic lull (ca. 72–58 Ma) to have been the result of Maastrichtian to Paleocene collision of the Kırşehir and Anatolide-Tauride blocks with the Pontides arc along the Izmir-Ankara-Erzincan suture zone and synchronous collision of the Bitlis-Pütürge massif with the southern-margin of the Anatolide-Tauride blocks along the Bitlis suture zone. Migmatic quiescence during the second magmatic lull (ca. 40–20 Ma) was variably related to terminal subduction and Arabia slab break off along the Bitlis suture zone in the east, and Cyprus slab flattening due to postcollisional southward retreat of the Cyprus trench in the west, each triggered by middle to late Eocene Arabia collision. Postcollisional Neogene–Quaternary magmatism was most likely caused by lithospheric delamination and slab tearingrollback in the Eastern and Central Anatolia volcanic provinces, respectively.

INTRODUCTION

The spatial and temporal patterns of continental magmatism at convergent margins provide valuable clues about geodynamic processes in orogens. Convergence zone magmatism is fundamentally the result of flux melting of the mantle wedge above a subducting plate, but it is often influenced by a complex interplay of geodynamic processes, including slab break-off, slab tear or window development, lithospheric delamination, and variations in the style and geometry of upper-plate deformation (van Hunen and Miller, 2015). Compared to modern orogenic systems, where plate and mantle dynamics can be observed directly, deciphering the operative geodynamic processes in ancient orogens is much more challenging; many of the clues to the precollisional subduction/accretion history have been lost due to ocean closure and complete subduction of the lower plate. Thus, the record of magmatism, as well as magmatism, preserved on the upper plate provides fundamental insights into the tectonic and geodynamic evolution in ancient orogens.

The geologic records preserved at long-lived convergent margins reveal that magmatism is often episodic in both space and time, despite continuous relative plate convergence (e.g., Armstrong, 1988; Ducea, 2001; Gehrels et al., 2009; DeCelles et al., 2009; Klemetti et al., 2014). Periods of higher magma flux (magmatic episodes) are commonly separated by periods of much lower average magma addition rates (magmatic lulls), with the latter attributed to various internal and/or external tectonic forcing mechanisms (Paterson and Ducea, 2015). Internal forcing refers to cyclic processes within the magmatic arc that are driven by feedbacks between linked tectonic and magmatic processes like foreland shortening, crustal thickening, lithospheric delamination, magmatism, plateau uplift, and erosion (e.g., DeCelles et al., 2009; Paterson and Ducea, 2015; Cao et al., 2015). External forcing refers to processes or events that occur outside of the arc and their effects on slab geometry (e.g., Gutscher, 2002; Lallemand et al., 2005; Schellart et al., 2007), such as collision events (e.g., Gehrels et al., 2009), plate reconfigurations (e.g., Matthews et al., 2012), and changes in subduction parameters. Understanding the role of these various geodynamic forcing mechanisms at convergent margins requires extensive geochronologic data sets (i.e., >400 crystallization ages) that reveal the regional-scale spatial and temporal evolution of the magmatism (Paterson and Ducea, 2015).

The Anatolia orogen in Turkey represents a long-lived convergent margin with a complex history involving successive accretion and collision events during the closure of several intervening Neotethyan Ocean basins since the early Mesozoic (Fig. 1). Several key physical and temporal aspects of the Neotethyan evolution are debated and have not achieved consensus, including: (1) the number of, and relationships between, accreted microcontinental...
blocks; (2) the number of intervening ocean basins; (3) the polarity of subduction beneath the Pontides magmatic arc; (4) the timing of initial continental collision between Arabia and Eurasia; and (5) the tectonomagmatic setting for several episodes of magmatism during the closure of various ocean basins. Some competing geodynamic models for Anatolia may have arisen in part because of their focus on distinct local to subregional geologic provinces (e.g., Pearce et al., 1990; Platzman et al., 1998; Keskin, 2003; Altunkaynak and Dilek, 2013; Eyuboglu et al., 2017) rather than on regional-scale compilations of magmatism. Comparisons between the history of Anatolia and along-strike regions in the greater Alpine-Himalayan orogenic belt are also challenging without systematic and geographically extensive geochronology data sets. An abundance of geochronologic data in Anatolia makes a compilation of published radiometric igneous geochronology data a timely and important step toward unraveling the spatial and temporal pattern of magmatism and improving our understanding of the geodynamic and tectonic evolution of the Anatolia orogen.

In this paper, we present an extensive compilation of published radiometric geochronology data (702 dates) from continental igneous rocks spanning Central and Eastern Anatolia (32.5°E-44°E) since 100 Ma (Fig. 2). In addition to showing the spatial and temporal patterns of many well-documented magmatic provinces, our regional-scale synthesis reveals two distinct magmatic lulls throughout Central and Eastern Anatolia since the Late Cretaceous at ca. 72–58 Ma and ca. 40–20 Ma. We use these results to frame our discussion of the potential forcing mechanisms responsible for these pronounced magmatic lulls, as well as the implications of the identified magmatic episodes for existing geodynamic models. We do not attempt to reinterpret the cause of each magmatic episode or review the diversity of proposed geodynamic models in detail. Instead, we seek to reconcile key observations from our vast geochronology data compilation with the most widely accepted aspects of these models in order to refine and improve our understanding of the tectonic and geodynamic evolution of Anatolia.

**TECTONIC SETTING OF ANATOLIA**

The Anatolia orogen is situated along the westernmost segment of the Arabia-Eurasia collision zone (Fig. 1) and is composed of a mosaic of Neo-tethyan elements located between Eurasia and Gondwana since the terminal closure of the Paleotethys Ocean in the Triassic (Şengör, 1984; Stampfl and
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Borel, 2002; Berra and Angiolini, 2014). Tectonic blocks of the Anatolia collage originated as peri-Gondwanan platforms built on rifted continental lithosphere or magmatic arcs that are delineated by several distinct Neotethyan suture zones defined by ophiolitic belts. Successive accretion and collision events involving the closure of several Tethyan Ocean basins since the late Paleozoic, as well as consequent orogenic processes like delamination, slab steepening and break-off, crustal thickening, plateau uplift, and escape tectonics, have played a fundamental role in the geologic evolution of Anatolia and the timing, location, style, and intensity of magmatism within the orogen.

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The former location of the northern branch of the Neotethys Ocean is marked by the İzmir-Ankara-Erzincan suture zone, which separates the Pontides block to the north from the Kırşehir block, Anatolide-Tauride blocks, and Eastern Anatolia Plateau to the south (Fig. 1). The Pontides block consists of a Jurassic-Cretaceous magmatic arc constructed on a composite of metamorphic basement rocks and subduction-accretion complexes related to northward subduction of the northern Neotethys Ocean beneath the southern margin of Eurasia (Okay and Şahintürk, 1997; Yılmaz et al., 1997; Okay and Tüysüz, 1999; Topuz et al., 2010, 2013; Okay et al., 2013), though a model for southward subduction of Black Sea ocean lithosphere has also been proposed (Eyuboğlu et al., 2011, 2017). South of the İzmir-Ankara-Erzincan suture zone, the Anatolide-Tauride blocks are characterized by thick sequences of Paleozoic to early Cenozoic carbonatedominated strata with sporadic igneous rocks of various ages likely related to northward subduction of the southern Neotethys Ocean (MTA, 2002; Elnas and Yilmaz, 2003; Robertson et al., 2007; Okay, 2008; Robertson et al., 2012; Akinci et al., 2015; Nurul et al., 2016). Some workers consider the Kırşehir block to represent the metamorphosed northern margin of the Anatolide-Tauride blocks, based primarily on their similar Paleozoic–Mesozoic basement stratigraphy (e.g., Şengör and Yilmaz, 1981; Poisson et al., 1996; Yalınz et al., 2000; Hinsbergen et al., 2016). However, the Kırşehir block is distinguished from the Anatolide-Tauride blocks by widespread Late Cretaceous granitic magmatism (Whitney et al., 2003; Boztuğ et al., 2009c; Karamişan et al., 2016), leading others to consider the Kırşehir block as a discrete N-S-trending magmatic arc in the northern Neo-
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METHODS

We compiled radiometric dates of continental igneous rocks (n = 702) from 87 different studies of magmatic activity across Central and Eastern Anatolia (32.5°E–44°E) since the Late Cretaceous (ca. 100 Ma; Fig. 2; see Supplemental Compilation1). This regional geochronology database includes nearly all published dates and their 2σ analytical uncertainties for extrusive (n = 467) and intrusive (n = 235) igneous rocks in the study area. The compiled dates were obtained using K-Ar (291 dates), Ar/Ar (127 dates), and U-Pb (107 dates) methods, as well as zircon (U-Th)/He (13 dates) and obsidian fission-track (12 dates) analyses (Table 1; Fig. 3). The compilation is extensive but not exhaustive, and issues of methodological or sampling bias are inherent and unavoidable in a compilation of diverse compositions dated by a variety of techniques (e.g., Paterson and Ducea, 2015). However, the number and diversity of focused studies compiled here collectively provide a broad temporal and spatial characterization of Late Cretaceous–Cenozoic magmatism in the Anatolia orogen.

This new geochronology database also includes relevant information about the sample number, coordinate location (latitude/longitude), lithology, dating method, original publication, and notes regarding the accuracy and reliability of the data. General classifications are provided to differentiate the data by bulk composition (mafic, intermediate, felsic), rock type (intrusive vs. extrusive), and tectonic block (Table 1). In most cases (>70%), precise coordinate locations for dated samples were not provided in the original publications; locations for these samples were either approximated from figures and/or from detailed descriptions in the original publication, or they were inferred based on existing geologic maps and limited information in the text. Because of this, we also include an estimate of the maximum uncertainty for approximated and inferred sample locations in the database.

Dates from unpublished sources (e.g., graduate theses, dissertations, internal reports) and those dates from published sources that were interpreted by the original authors to represent processes unrelated to continental magmatic crystallization (e.g., metamorphism, hydrothermal alteration, ophiolite genesis, and obduction) were excluded from the database. This ensured that the data represent processes related to primary continental magmatism during the closure of the Neotethys Ocean and formation of Anatolia rather than other processes, such as the timing of deformation, alteration, or the generation of new oceanic crust, the latter of which is already well documented.

1Supplemental Compilation. Includes published radiometric dates (n = 702) of continental magmatic activity across Central and Eastern Anatolia since 100 Ma. Please visit https://doi.org/10.1130/GEOS164751 or access the full-text article on www.gsapubs.org to view the Supplemental Compilation.
(e.g., Parlak et al., 2013; van Hinsbergen et al., 2016). K-Ar and Ar/Ar dates from intrusive rocks (n = 160 dates) represent medium-temperature cooling ages (<500–300 °C; McDougall and Harrison, 1999) and are notably younger than crystallization ages (U-Pb), which may reflect either conductive heat loss or exhumation-related cooling after emplacement (Fig. 4). Thus, while included in the database, these K-Ar and Ar/Ar cooling ages were excluded from our interpretations of the timing of magmatic crystallization (Figs. 3 and 5).

### GEOCHRONOLOGY PATTERNS AND TRENDS SINCE 100 Ma

Our synthesis of geochronology data from Anatolia is summarized in Table 1, and as probability and kernel density plots in Figure 3 that compare analytical techniques (K-Ar, Ar/Ar, etc.), compositions (mafic, intermediate, felsic), and style of emplacement (intrusive, extrusive). These results illuminate several key aspects of the long-term pattern of magmatism across the study area, including: (1) the initiation and duration of three magmatic episodes; (2) the occurrence and durations of two distinct magmatic lulls; (3) the spatial distribution of magmatism through time; and (4) the compositional variability of the magmatic record in both space and time. We discuss each of these magmatic patterns in more detail in this section.

#### Magmatic Episodes

Our geochronology compilation reveals three prominent magmatic episodes in Central to Eastern Anatolia since the start of the Late Cretaceous ca. 100 Ma (Figs. 2 and 3). These magmatic episodes occurred during the Late Cretaceous (E1; 99–72 Ma, 47 dates), latest Paleocene to middle Eocene (E2; 58–40 Ma, 91 dates), and early Miocene to Quaternary (E3; 20–0 Ma, 387 dates). The timing and duration of each magmatic episode were determined by visual inspection of probability density plots and kernel density estimations (Vermeesch, 2012), the former of which incorporated the analytical precision of each date (top-right plot in Fig. 3). Constraining the duration of E2 was challenging because there are several (8) dates with significant errors between ca. 40 and 30 Ma (Fig. 2). Regardless, an uncertainty of ~1–2 m.y. can realistically be assumed for the bracketing ages of each magmatic episode.

The geochronology compilation here provides new, quantitative timing constraints for the magmatic record of Central and Eastern Anatolia, rather than the intensity and volume of the magmatic episodes. The timing of each magmatic episode is nevertheless consistent with the relative ages of igneous rock units that have elsewhere been inferred primarily from stratigraphic relationships (Fig. 5; MTA, 2002). Ar/Ar and K-Ar data from intrusive...
rocks are not included in the age ranges that delimit the magmatic episodes to ensure that interpretations are based on unequivocal crystallization ages rather than cooling events (Fig. 3). Exclusion of these data diminishes the distribution of E1 by >5 m.y., while the effects on E2 and E3 are negligible (Fig. 4), perhaps due to the scarcity of younger intrusive rocks exposed in the study area (Table 1).

Magmatic Lulls

An intriguing result from this regional compilation is the recognition that the three magmatic episodes (E1–E3) were each separated by distinct magmatic lulls (L1 and L2) with durations of >10 m.y. (Fig. 3). We emphasize that, rather than absolute amagmatism, these magmatic lulls should be considered periods when magma flux was much lower than average (Paterson and Ducea, 2015), determined in this case by the relative lack of dates for magmatism (L1 includes three dates; L2 includes 14 dates). The first magmatic lull (L1) occurred during the latest Cretaceous to latest Paleocene (72–58 Ma) and between magmatic episodes E1 and E2. The second magmatic lull (L2) occurred during the late Eocene to early Miocene (40–20 Ma) and between magmatic episodes E2 and E3 (Fig. 3).

It is important to note that the prominent gaps in the geochronology age distribution are consistent with an almost complete lack of mapped igneous rocks (e.g., MTA, 2002) during these time intervals (Fig. 5), which suggests that the magmatic lulls are not an artifact of undersampling or inadequate mapping. Furthermore, the sporadic, yet widespread occurrence of sedimentary rocks during the Paleocene and late Eocene–early Miocene suggests that the scarcity of crystallization dates during L1 and L2 reflects magmatic quiescence rather than sampling bias due to poor preservation of rocks of these ages (Fig. 5).
Spatial Observations and Patterns in Magmatic Migration

Evaluation of the regional distribution of geochronology data during each magmatic episode reveals spatial and temporal patterns of magmatic activity, most of which have not been previously identified or thoroughly documented (Figs. 6 and 7). The record of the Late Cretaceous magmatic episode (E1) is sporadic across Northern and Central Anatolia, particularly in the Pontides block, Kırşehir block, and eastern Anatolide-Tauride blocks. Magmatism in the eastern Anatolide-Tauride blocks and Kırşehir block may display a subtle northward age progression, whereas magmatism in the Pontides block shows no discernible spatial trend through time (Fig. 6A). Because data are sparse in these regions, additional dating of Late Cretaceous igneous rocks would help to corroborate this observation. The early to middle Eocene magmatic episode (E2) was much more localized in North-
ern Anatolia—primarily in the Pontides block (~80% of relevant dates)—and also shows no obvious spatial variation with age (Fig. 6B). The majority of the Neogene–Quaternary magmatic episode (E3) occurs in the Kirşehir block, eastern Anatolide-Tauride blocks, and Eastern Anatolia Plateau, along with scattered locations in the Pontides block and Arabia Platform (Fig. 7A). The earliest magmatism of E3 (20–13 Ma) occurred in the Anatolide-Tauride blocks and western Kirşehir block (38°N–39.5°N), whereas younger dates (generally younger than 13 Ma) are concentrated in the southern Kirşehir block (37°N–39°N) and Eastern Anatolia Plateau (Fig. 7). Magmatic activity in the Kirşehir block shows a general trend of expansion toward the southwest beginning at ca. 11 Ma; the older dates (ca. 11–5 Ma) are generally spatially confined between 38.5°N and 39°N, while the younger dates (ca. 4–0 Ma)
are more spatially erratic between 37°N and 39°N. Magmatism in the Eastern Anatolia Plateau shows a general progression and expansion of younger dates toward the southeast and east (Fig. 7A).

**Compositional Trends**

The compositions of samples in this database reveal general trends for each magmatic episode, and thus for the entire magmatic history of the Anatolia orogen. We emphasize that, rather than the cumulative volume of magma emplaced during each magmatic episode, these compositional trends only reflect the relative frequency of magmatism with different compositions based on the dated samples in the compilation. Out of the 702 igneous samples in this compilation, 30% are mafic, 16% are intermediate, and 54% are felsic (Table 1; Fig. 2). There is an apparent decrease in the frequency of felsic magmatism during each successive magmatic episode. More than 75% of felsic samples (106 dates) represent intrusive rocks, and they are mostly from E1 (126 dates), which is dominantly felsic (~85%) and intrusive (~70%). It is noteworthy that extrusive rocks from E1 (15 dates) are also dominantly felsic (Fig. 3). Episode 2 (129 dates) shows a more distributed range of compositions, though felsic samples (>50%) from intrusive rocks (>80%) still dominate. Extrusive samples (<50%) comprise an almost equal abundance of mafic, intermediate, and felsic rocks (Table 1). Samples from E3 (389 dates) are overwhelmingly from extrusive rocks (>99%) and are dominated by mafic (~45%) and felsic (~40%) samples. Differences in emplacement style (extrusive or intrusive) or sampling bias may affect the compositional, temporal, and spatial distributions, particularly because of the plethora of studies that have focused on Quaternary volcanism (e.g., Reid et al., 2017). However, when the abundance of published Quaternary ages (n = 189) from mostly mafic monogenetic volcanic fields are excluded, the compositional characteristics of E3 shift only slightly to being dominated by felsic samples (~50%).

**DISCUSSION**

Our extensive compilation of geochronology data from Central and Eastern Anatolia provides regional-scale insights into the timing, location, composition, and evolution of magmatism in the orogen since the Late Cretaceous. The most definitive and unambiguous result is the recognition that magmatism was episodic and punctuated by two long-lived magmatic lulls (~14 and 20 m.y. in duration) in Central and Eastern Anatolia during continuous plate convergence and closure of the Neotethys Ocean basin (McQuarrie et al., 2003; Seton et al., 2012). The spatial and episodic patterns of Late Cretaceous–Cenozoic magmatism in the Anatolia orogen have not been explicitly documented in previous work. These new observations also complement similar observations from modern and ancient convergent margins where episodic magmatic activity is well established, such as various segments of the North and South American Cordillera (e.g., Coast Mountains, British Columbia; Sierra Nevada; Central Andes), where magmatic lulls (most ~20–30 m.y. in duration) separate magmatic episodes lasting ~25–50 m.y. (e.g., Ducea, 2001; Gehrels et al., 2009; DeCelles et al., 2009; Klemetti et al., 2014; Paterson and Ducea, 2015).

In the following section, we discuss our new temporal constraints on the widespread magmatic lulls in Anatolia and their potential geodynamic explanations. Our discussion focuses primarily on the potential geodynamic mechanisms responsible for each lull because the prevalence of these distinct magmatic lulls has not been previously considered. In contrast, there are an extraordinary number of proposed models in the literature and considerable debate regarding the nature and causes of magmatism in the orogen (e.g., Innocenti et al., 1975; Notsu et al., 1995; Pearce et al., 1990; Keskin, 2003; Eyuboglu et al., 2017; Altunkaynak and Dilek, 2013). Rather than a thorough review of competing tectonomagmatic and geodynamic models for magmatism, which is beyond the scope of this paper, we use the new spatiotemporal constraints on the magmatic record revealed by our regional geochronology compilation to reevaluate and refine aspects of several proposed tectonomagmatic models. Ultimately, we produce a sequential geodynamic synthesis that explains the episodcity of magmatism in the Anatolia orogen since the Late Cretaceous by reconciling previously proposed geodynamic models for magmatism (Figs. 8A, 8C, and 8E) with our new hypotheses for the timing and mechanisms responsible for the two orogen-wide magmatic lulls (Figs. 8B and 8D).

**Possible Mechanisms Responsible for Magmatic Lulls**

Magmatic lulls at long-lived convergent margins have been attributed to feedbacks between linked tectonic and magmatic processes in the arc (Paterson and Ducea, 2015), specifically the underthrusting of hinterland lithosphere beneath the arc (DeCelles et al., 2009). The role of these internal forcing mechanisms is easier to assess at Cordilleran-type margins in the earlier stages of ocean closure, especially when external factors like collision and accretion and/or changes in subduction parameters (e.g., relative velocity, direction, slab dip) are negligible. At collisional margins such as Anatolia, however, the relative influence of internal factors can be difficult to evaluate due to the overwhelming effects of external forcing mechanisms, namely, collision events associated with the terminal stages of ocean closure.

External forcing mechanisms that may promote lulls in continental magmatic activity during continued plate convergence include: (1) flat slab subduction (van Hunen et al., 2002; Manea et al., 2012); (2) subduction hinge advance (Hall and Smyth, 2008); and (3) accretion, collision, or oblique convergence events (Paterson and Ducea, 2015; van Hunen and Miller, 2019). In addition to magmatic quiescence, these mechanisms often have profound systemwide effects on the reorganization of plate boundaries, changes in plate convergence rate, slab break-off and lateral tear propagation, the formation of back-arc basins, and slab window development (e.g., DeCelles et al., 2009; Matthews et al., 2012; van Hunen and Miller, 2019). Because each of these processes can have effects (often predictable) on the spatial and/or temporal patterns of magmatism, our new geochronology compilation provides a first-order test with which to evaluate their potential influences in Anatolia.
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Episode 1 (100–72 Ma)
- S. Neotethys
- ATB/EAP
- lithosphere
- delamination
- mantle upwelling
- toroidal flow?
- intra-oceanic subduction
- continental subduction
- extension
- collision

Lull 1 (72–58 Ma)
- S. Neotethys
- ATB/EAP
- SBZ
- collision
- soft collision
- slab break-off
- craton
- mantle upwelling
- rollback
- rollback
- slab flattening
- crustal thickening
- intra-oceanic subduction

Episode 2 (58–40 Ma)
- S. Neotethys
- Africa
- Arabia
- slab break-off
- trench retreat
- rollback
- rollback
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- rollback
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Slab flattening (i.e., a decrease in the angle of slab descent into the mantle) during subduction can cause magmatism to migrate inboard and away from the trench and eventually displace the mantle wedge to generate a magmatic lull. This process is often followed by slab steepening, break-off, and/or delamination of the upper plate’s mantle lithosphere and, often, the outboard migration of magmatism toward the margin (e.g., Coney and Reynolds, 1977; Dickinson and Snyder, 1978; Ramos and Folguera, 2009).

Magmatic quiescence during subduction has also been proposed to occur where a fixed or advancing subduction hinge causes the upper and lower plates to move in the same direction, which prevents replenishment of the depleted mantle wedge and thus inhibits melting (Hall and Smyth, 2008). A fixed hinge may result from either coupling between the upper and lower plates, or continental collision (Hall and Smyth, 2008). This mechanism for magmatic quiescence during subduction is not well understood or documented in the geologic record, perhaps because there are no obvious spatial trends in the magmatic record before or after the cessation of magmatism, or because this process is often obscured by the effects of collision (MacPherson and Hall, 1999; Hall and Smyth, 2008).

Finally, accretion, collision, or highly oblique convergence can lead to the reconfiguration or termination of subduction, the first two of which likely overwhelm other effects in Anatolia. Collision is typically accompanied by the cessation of arc magmatism (e.g., McKenzie, 1969; Cloos, 1993). However, other types of magmatism may take place for several million years after collision, depending on the dynamics of the mantle wedge. Collision often results in changes in the rate of plate convergence and/or trench migration, which can provoke a variety of mantle processes that affect the duration of magmatic quiescence and control the spatial and temporal distribution of subsequent magmatism. These mantle processes include slab break-off, the lateral propagation of slab tears, back-arc basin development, slab window formation, and delamination due to gravitational instabilities (van Hunen and Miller, 2015, and references therein). In the following discussion, we disregard the possibility of highly oblique convergence as a major contributor to magmatic quiescence in Anatolia based on evidence of orthogonal to moderately oblique plate convergence since the Late Cretaceous (McQuarrie et al., 2003; Seton et al., 2012).

**Maastrichtian–Paleocene Magmatic Lull (L1)**

The synchrony between incipient Anatolide-Tauride blocks–Pontides collision and the cessation of Late Cretaceous magmatism in the Pontides block, eastern Anatolide-Tauride blocks, and Kırşehir block at the onset of L1 strongly suggests a direct relationship between the two. Progressive closure and subduction of the northern branch of the Neotethys Ocean led to initial collision of the Kırşehir block and Anatolide-Tauride blocks with the Pontides block along the İzmir-Ankara-Erzincan suture zone as early as the Maastrichtian (ca. 72 Ma), according to structural, stratigraphic, paleontologic, and paleomagnetic studies (Yılmaz et al., 1997; Okay and Tüysüz, 1999; Kaymakci et al., 2008; Rolland et al., 2009, 2012; Rice et al., 2009; Meijers et al., 2010; Parlak et al., 2013). Uplift and exhumation associated with Kırşehir block–Anatolide-Tauride blocks–Pontides block collision during L1 are also suggested by a Maastrichtian–Paleocene unconformity throughout the central and eastern Pontides (Yılmaz et al., 1997; Okay and Şahintürk, 1997; Rice et al., 2006, 2009).

Thermochronologic data, including Ar/Ar, K-Ar (amphibole and biotite), and fission-track (apatite) cooling ages from numerous felsic plutons in the Pontides block, Kırşehir block, and eastern Anatolide-Tauride blocks, indicate rapid cooling at ca. 75–56 Ma (Boztuş and Harlavan, 2008; Boztuş et al., 2009a, 2009b, 2009c), synchronous with the first magmatic lull (L1; 72–58 Ma; Figs. 3–5). Shallow emplacement and condutive cooling can be ruled out based on geothermobarometric data that have been interpreted to indicate that many of these plutons were emplaced in the middle crust at depths of ~7–18 km (Libby, 2005; Boztuş et al., 2007a, 2007b). Rather, the ages and emplacement depths of early Late Cretaceous plutons suggest that rapid cooling was related to exhumation driven by Kırşehir block and Anatolide-Tauride blocks collision with the Pontides block (Boztuş et al., 2009c), and that the L1 event may have occurred because collision shut off arc magmatism.

South of the Pontides, magmatic quiescence throughout the Anatolide-Tauride blocks–Eastern Anatolia Plateau during L1 (Fig. 5) is much more difficult to explain, as the southern branch of Neotethys Ocean remained open before and after this time (e.g., Şengör and Yilmaz, 1981). Prior to L1, E1 magmatism along the southern margin of the Anatolide-Tauride blocks was the result of northward subduction of the southern Neotethys between ca. 93 Ma and 70 Ma, perhaps as an intra-oceanic arc (Fig. 8A; Elmas and Yilmaz, 2003; Robertson et al., 2007; Karaoğlan et al., 2013a; Akinci et al., 2015; Nurli et al., 2016). Late Cretaceous magmatism on the northern margin of the eastern Anatolide-Tauride blocks is more enigmatic, although speculative models invoking collision of an intra-oceanic arc and slab break-off in the northern Neotethys (Boztuş et al., 2007a) or extension caused by rollback of the southern Neotethys slab (Kuscu et al., 2010) have been proposed.

Regardless of the cause for E1 magmatism in the Anatolide-Tauride blocks, the apparent cessation of magmatism coeval with that of the Pontides block is puzzling. Campanian–Maastrichtian high-pressure metamorphic rocks and granitic magmatism along the Bitlis suture zone have been associated with collision of the Bitlis–Füprüge massif with the southern margin of the Anatolide-Tauride blocks–Eastern Anatolia Plateau (e.g., Rolland et al., 2012; Karaoğlan et al., 2013a), which may have caused a temporary lull in magmatism during reorganization of the subduction zone (Fig. 8B). Considering the other potential forcing mechanisms discussed herein, another speculative possibility is that L1 was related to flattening of the southern Neotethys slab beneath the Anatolide-Tauride blocks. This is supported by an apparent northward younging of magmatism in the Anatolide-Tauride blocks and southern portion of the Kırşehir block, as revealed by our geochronology compilation (Fig. 6A), though additional constraints on the timing and distribution of magmatism are needed to test this hypothesis. Alternatively, initial collision along the İzmir-Ankara-Erzincan suture zone to the north during the Maastrichtian may have led to stronger coupling between the Anatolide-Tauride blocks and...
the southern Neotethys oceanic lithosphere, and an effective decrease in the Anatolide-Tauride blocks–Arabia convergence rate, as proposed to explain magmatic quiescence in the Miocene Sunda arc in East Java during continuous subduction (MacPherson and Hall, 1999; Hall and Smyth, 2008). Clearly, more information regarding the subduction geometry and history of the southern Neotethys Ocean is needed in order to understand the mechanism responsible for magmatism in the Anatolide-Tauride blocks during L1.

**Geochemical and Spatiotemporal Characteristics of E2 Magmatism**

Some insights into the cause of L1 may be gathered from the geochemical characteristics and the spatiotemporal pattern of E2 (early to middle Eocene) magmatism that followed. Geochemical data from north of the Izmir-Ankara-Erzincan suture zone in the Pontides block show characteristics that transition from subduction-related to intraplate-related melting during the Eocene (Altun-kaynak and Dilek, 2013; Aydıncıkar and Şen, 2013; Arslan et al., 2013). This change in geochemical affinities is intended to reflect the transition from subduction of the northern Neotethys to postcollisional magmatism during widespread extension. Several studies document adakitic magmatism in parts of the region and propose a variety of interpretations for its origin, including melting of thickened or delaminated crust following collision (e.g., Dilek et al., 2010; Topuz et al., 2011) and melting during south-dipping subduction of a spreading ridge in the late Eocene (Eyuboglu et al., 2011, 2017). Pontides magmatism during E2 has also been attributed to postcollisional break-off of the northern Neotethys slab (e.g., Topuz et al., 2011). However, contrary to the idea that slab break-off results in widespread magmatism due to the influx of hot asthenosphere into the mantle wedge (Davies and von Blanckenburg, 1995), a compelling argument can be made that the volume of mantle displaced by slab break-off is relatively small, and thus there is limited “free space” in the overlying mantle wedge for asthenosphere to fill (Niu, 2017). A lack or limited amount of upward mantle flow thus eliminates decompression as a mechanism for widespread melting during slab break-off.

Instead, evidence of early–middle Eocene extension, subsidence, and sporadic magmatism (e.g., Arslan et al., 2013) seems more compatible with a model involving lithospheric delamination and crustal collapse in response to collision and densification of the lower crust (Fig. 8C; e.g., Karsli et al., 2010; Kaygusuz and Öztürk, 2015). The ~14-m.y. delay between initial Kirşehir block–Anatolide-Tauride blocks–Pontides block (ca. 72 Ma) collision and initial magmatism of E2 (ca. 58 Ma) also seems more compatible with lithospheric delamination than slab break-off. Our geochronology compilation also reveals that there was no obvious spatial migration of magmatism in the Pontides block during E2, nor at any other time since the Late Cretaceous (Figs. 6 and 7). This observation is consistent with the expected pattern of magmatism caused by lithospheric delamination (proposed by Dilek et al., 2010; Topuz et al., 2011), which can lead to spatially and temporally isolated volcanism several millions of years after initial continental collision (Elkins-Tanton, 2005; Kaislaniemi and van Hunen, 2014). Lithospheric delamination may also explain the spatially confined, sporadic, and long-lived nature of E2 magmatism in the Pontides block (Figs. 5 and 6). The lack of any spatial migration of magmatism in the Pontides block during both E1 and E2 challenges models invoking subduction of the Black Sea spreading ridge to explain Eocene magmatism in the Pontides block, a hypothesis that is largely based on an apparent northward migration of magmatism there (Eyuboglu et al., 2011, 2017). Regardless of the geodynamic explanation for E2 magmatism in the Pontides block, there is an undeniable temporal relationship between the timing of Anatolide-Tauride blocks–Pontides block collision and the cessation of magmatism.

Following closure of northern Neotethys along the Izmir-Ankara-Erzincan suture zone, igneous rocks were emplaced along the southern margin of the Anatolide-Tauride blocks–Eastern Anatolia Plateau during E2 (Fig. 5; MTA, 2002). Geochemical, structural, and stratigraphic data have led some workers to suggest that magmatism was related to island-arc activity in the southern Neotethys Ocean (Elmas and Yilmaz, 2003; Nurlu et al., 2016). However, only sporadic geochronology data are available from the eastern Anatolide-Tauride blocks from 70 to 30 Ma (10 dates; Figs. 5 and 6), notably a small cluster of intrusive igneous ages at ca. 50 Ma (e.g., Parlak et al., 2013; Karaoğlan et al., 2013b). Magmatism along the southern Anatolide-Tauride blocks has often been assumed to have occurred during the middle Eocene, based on the inferred age of the Helete volcanic unit along the Bitlis suture zone (e.g., Yılmaz, 1993; Yığıtbuş and Yilmaz, 1996; Elmas and Yilmaz, 2003). However, U-Pb ages from crosscutting granites indicate a minimum age of ca. 83 Ma for the Helete volcanic unit, which is now interpreted as an intra-oceanic arc assemblage that was accreted to the southern margin of the Anatolide-Tauride blocks during the Late Cretaceous (Nurlu et al., 2016). Collectively, these observations provide some evidence of intra-oceanic and perhaps sporadic continental arc magmatism in the southern and central Anatolide-Tauride blocks during the Late Cretaceous (E1), but the nature, pattern, and tectonic setting of Maas-trichtian–Cenozoic magmatism remain poorly constrained along the southern margin of the Anatolide-Tauride blocks and Eastern Anatolia Plateau.

**Preferred Model for Magmatic Lull 1**

We support a model in which orogen-wide magmatic quiescence in Central and Eastern Anatolia during the Maastrichtian to Paleocene was fundamentally the result of incipient and progressive collision of the Kirşehir and Anatolide-Tauride blocks (including the Eastern Anatolia Plateau) with the Pontides, and collision of the Bitlis-Pütürge massif with the southern margin of the Anatolide-Tauride blocks–Eastern Anatolia Plateau (Fig. 8B). This model is favored based on the identical timing of magmatic quiescence documented in this study and exhumation of deeply emplaced plutons, subduction termination, and metamorphism along the Izmir-Ankara-Erzincan suture zone (Okay and Tüysüz, 1999; Kaymakci et al., 2009; Meijers et al., 2010; Rolland et al., 2012; Rolland, 2017) and the Bitlis suture zone (Rolland et al., 2012; Karaoğlan et al., 2013a). The spatially and temporally sporadic pattern of subsequent magmatism (E2) in the Pontides block (Fig. 6A), combined with evidence of an increased astheno-
spheric component of melting, supports models that attribute Eocene magmatism (E2) to lithospheric delamination and extensional collapse north of the İzmir-Ankara-Erzincan suture zone (Fig. 8C; Karsli et al., 2010; Altunkaynak and Dilek, 2013; Aydinçakır and Şengör, 2013; Kaygusuz and Öztürk, 2015). Although the cause of magmatic quiescence south of the İzmir-Ankara-Erzincan suture zone is more enigmatic, the apparent lull may reflect Late Cretaceous collision of the Bitlis-Pütürge massif (Fig. 8B), or it may simply be an artifact of insufficient data there. Additional geo chronological, geochemical, and structural constraints from Cretaceous to Eocene rocks along the Bitlis suture zone and within the Anato lide-Tauride blocks and Eastern Anatolia Plateau are needed to understand the duration, extent, mechanism, and evolution of magmatism there.

**Late Eocene–Early Miocene Magmatic Lull (L2)**

**Initial Arabia Collision as a Cause for L2**

Stratigraphic and structural evidence of crustal shortening along the Bitlis suture suggests that initial soft collision of the thinned Arabia margin with southeastern Anatolia (i.e., eastern Anatolide-Tauride blocks) occurred as early as the middle Eocene (Hempton, 1987; Yılmaz, 1993; Rolland et al., 2012), and just prior to the cessation of E2 magmatism at ca. 40 Ma. The conspicuous spatial and temporal coincidence of both distributed collisional strain and magmatic quiescence provides compelling evidence linking the cessation of magmatism in Anatolia during L2 to initial Arabia collision (Fig. 8D). This inference, combined with evidence of widespread contraction and exhumation across the entire width of the Arabia-Eurasia suture zone from the Bitlis suture to the Caucasus throughout the Oligocene and early Miocene (e.g., Moutheureau et al., 2012; Rolland, 2017), suggests that the effects of collision were widely distributed in both space and time for ~20 m.y. According to this hypothesis, the sudden termination of magmatism during the late Eocene may have been related to relatively early amagmatic break-off (Niu, 2017) of the Arabia slab during or very soon after initial collision. Although the timing of Arabia slab break-off is poorly constrained, the results of mantle tomography beneath the Eastern Anatolia Plateau are compatible with a model involving relatively early break-off ca. 45–40 Ma. A high-velocity anomaly interpreted as the remnant of the Arabia slab now resides near and beneath the mantle transition zone (≥660 km; Portner et al., 2018). Estimates of slab sinking rates vary widely (e.g., Billen, 2010; Schellart and Spakman, 2012), but a broken slab sinking at a globally averaged rate for the entire mantle of 13 ± 3 mm yr⁻¹ (Butterworth et al., 2014) since the late Eocene could have foun dered to depths of ~400–720 km, where the high-velocity anomalies are observed today (Portner et al., 2018).

**Other Explanations for L2**

An alternative explanation for L2—either explicit or implicit in various models—is that subduction of southern Neotethys continued during L2, and Arabia collision was delayed until the Miocene (e.g., Şengör and Yılmaz, 1981; Robertson, 2000; Okay et al., 2010; Bartol and Govers, 2014; Cavazza et al., 2017). In this case, L2 may have been driven by other external forcing mechanisms related to changes in subduction parameters. Plate-kinematic models that show no significant changes in subduction obliquity or relative convergence rates since the late Eocene (McQuarrie et al., 2003; Seton et al., 2012) effectively rule them out as mechanisms responsible for the lull.

Magmatic lulls documented along multiple segments of the North and South American Cordillera during the Cenozoic (e.g., Kay and Mpodozis, 2002; Ramos and Folguera, 2009) are commonly attributed to a decrease in the angle (i.e., flattening) of subduction. Slab flattening can be triggered by enhanced positive buoyancy due to abnormally thick or hot crust (van Hunen et al., 2002; Gutscher, 2002) or negative pressure in the mantle wedge (Manea et al., 2012; O’Driscoll et al., 2012). Nevertheless, the potential influence of these flat-slab mechanisms is poorly constrained and speculative in Anatolia.

Some workers have proposed that horizontal underthrusting of the Arabia slab led to wholesale lithospheric delamination beneath Eastern and Central Anatolia (Bartol and Govers, 2014; Delph et al., 2017). According to this model, the southern Neotethys oceanic lithosphere subducted shallowly beneath the Anatolian (Anatolide-Tauride blocks-Eastern Anatolia Plateau) continental crust by displacing the subcontinental mantle lithosphere, which was followed by delamination and asthenospheric melting that generated magmatism during the Miocene (E3). This model is consistent with widespread amagmatic activity in the upper plate during the Oligocene and explains the thermal structure and pattern of subsequent uplift across Central and Eastern Anatolia by a shared mechanism (Bartol and Govers, 2014). However, there are some problems with the tectonic implications of this model, particularly in relation to key differences in the magmatic and geodynamic evolution of Eastern and Central Anatolia, which we discuss in more detail in the following section.

Testing the possible role and duration of flat-slab subduction will require additional geochronologic data from post-middle Eocene igneous rocks within the Anatolide-Tauride blocks and Eastern Anatolia Plateau. Diagnostic stratigraphic evidence such as basin-scale unconformities and abnormally thick sedimentation linked to dynamic subsidence may also support such a model (e.g., Heine et al., 2008; Smith et al., 2014). Subduction hinge advance and mantle stagnation may have also played a role in L2, although direct evidence of this process is lacking. Advanced plate-circuit models that can constrain both absolute and relative plate motion may also shed light on these and other hypotheses.

**Geochemical and Spatiotemporal Characteristics of E3 Magmatism**

Proposed tectonomagmatic models for Neogene–Quaternary magmatism in Anatolia (E3) assume a syn- or postcollisional tectonic setting for magmatism and are generally informed by evidence of regional plate uplift, extensional structures, the presence of high-velocity anomalies in the mantle, and a variety of geochemical characteristics from igneous rocks (e.g., Pearce et al., 1990; Keskin, 2003; Şengör et al., 2003; Angus et al., 2006). As tradi-
ationally defined, the Central Anatolia volcanic province and Eastern Anatolia volcanic province are spatially separated by more than 300 km, located within different tectonic blocks (Kırşehir block and Eastern Anatolia Plateau, respectively), and characterized by different styles of volcanism and geochemistry. Previous geochemical studies have identified a distinctive subduction component in most Neogene magmatism in Central and Eastern Anatolia, variably modified by influences from asthenosphere-derived components (e.g., Pearce et al., 1990; Notsu et al., 1995; Keskin et al., 1998; Şen et al., 2004; Reid et al., 2017). Most authors attribute these characteristics to extension-related melting and mixing of variable amounts of asthenosphere and metasomatized lithosphere sources. McNab et al. (2018) noted several geochemical similarities between the Central Anatolia volcanic province and Eastern Anatolia volcanic province basalts that they attributed to melting of upwelling asthenosphere across the entire region. However, recent orogen-scale investigations of mafic Neogene volcanic rocks have drawn different conclusions about the similarity of tectonomagmatic mechanisms responsible for the Central Anatolia volcanic province and Eastern Anatolia volcanic province, and whether there are key differences associated with the dynamics of the subducting African plate and colliding Arabian plate, respectively. Reid et al. (2017) identified a greater subduction-modified source contribution to the Central Anatolia volcanic province basalts compared to the Eastern Anatolia volcanic province ones, derived from either mantle lithosphere or residual arc mantle still largely shielded from upwelling asthenosphere by the Cyprean slab.

New observations from the spatiotemporal magmatic record provide additional insights into variations between Eastern and Central Anatolia tectonics during L2. The initiation of E3 magmatism occurred in the eastern Anatolide-Tauride blocks and northwestern Kırşehir block at ca. 20 Ma (Fig. 7), which is much earlier than the ca. 13–11 Ma inception of postcollisional magmatism inferred elsewhere in the Central Anatolia volcanic province and Eastern Anatolia volcanic province (e.g., Besang et al., 1977; Keskin et al., 1998). This early to middle Miocene magmatism does not exhibit any obvious variation in spatial or temporal trends (Fig. 7) and no obvious compositional differences from the younger volcanic provinces (e.g., Kürüm et al., 2008; Asan and Kurt, 2011), which we discuss below.

The results of this study show a shift in the locus of Central Anatolia volcanic province volcanic centers toward the southwest from ca. 11 Ma to the present (Fig. 7), with a greater concentration of Pliocene- and Quaternary-aged volcanism in the southwestern end of the Central Anatolia volcanic province, perhaps associated with slab steepening/rollback in the same direction following flat subduction (Fig. 8E; e.g., Biryol et al., 2011; Schildgen et al., 2012; Delph et al., 2017; Abgarmi et al., 2017; Portner et al., 2018). Flat subduction of the Cyprean slab (Africa plate) may have been an expected consequence of Anatolide-Tauride blocks–Arabia collision farther east. Numerical modeling studies suggest that indenter-style collision causes a reduction in plate convergence at the collision zone and rapid retreat of the adjacent trench, where subduction continues (Moresi et al., 2014; Sternal et al., 2014). Rapid trench retreat leads to both extension and trenchward absolute motion of the overriding plate, which typically causes slab flattening as the slab is overridden by the upper plate (Figs. 8D–8E; van Hunen et al., 2002; Menea et al., 2012).

Previous geochronological work in the Eastern Anatolia volcanic province has been used to suggest that magmatism roughly migrated southward, based on the timing of volcanic inception (e.g., Keskin et al., 1998; Keskin, 2003). This interpretation of Eastern Anatolia volcanic province geochronology is roughly consistent with the results of our compilation, but our results only show a broad and patchy southeastward (and eastward) expansion of all magmatic activity since ca. 11 Ma (Fig. 7A). Competing models propose that middle to late Miocene magmatism in the Eastern Anatolia volcanic province was caused by (1) rollback and break-off of the Arabia slab (Keskin, 2003) or (2) delamination of subduction-modified mantle lithosphere due to Raleigh-Taylor instabilities following Arabia collision and crustal thickening (Pearce et al., 1990; Kaislaniemi and van Hunen, 2014; Kocaarslan and Ersoy, 2018). Several high-velocity anomalies have been imaged in the upper mantle beneath the Eastern Anatolia Plateau and are interpreted as slab fragments related entirely to slab break-off (Portner et al., 2018), although we suggest that these may instead be fragments of lithosphere that were delaminated due to postcollisional crustal thickening in the Anatolide-Tauride blocks and Eastern Anatolia Plateau; this inference supports previous models (Figs. 8E; Pearce et al., 1990; Kaislaniemi et al., 2014; Kocaarslan and Ersoy, 2018). Thus, the range of depths of high-velocity seismic anomalies above and below the mantle transition zone (i.e., 300 to >660 km depth) under Eastern Anatolia (Portner et al., 2018) may be related to early amagmatic break-off during collision (ca. 45–40 Ma) and subsequent lithospheric delamination or “drips” beginning as early as ca. 20 Ma, considering average slab sinking rates (Butterworth et al., 2014). In this scenario, the broad southward and eastward progression in the Eastern Anatolia volcanic province and generally sporadic nature of magmatism across the entire collision zone (Fig. 7A) likely reflect localized lithospheric delamination driven by sublithospheric small-scale convection that roughly propagated southeastward (Kaislaniemi et al., 2014). According to this hypothesis, magmatic quiescence during L1 and subsequent magmatism (E3) in the eastern Anatolide-Tauride blocks and Eastern Anatolia Plateau were inherently related to lithospheric thickening during Arabia-Eurasia collision.

These observations and inferences from the magmatic record and regional geophysical data sets (e.g., Ates et al., 1999; Portner et al., 2018) are consistent with the idea that the eastern margin of the Kırşehir block is a major lithosphere-scale tectonic boundary, with subduction of the Cyprean slab to the west and Arabia collision to the east (Figs. 8D–8E). Recent tomography models show various distinct high-velocity anomalies at different depths and with different geometries across this boundary (Portner et al., 2018). Beneath the Central Taurides and southwest of the Central Anatolia volcanic province, a vertical and horizontally torn slab imaged at ~150–200 km depth (Portner et al., 2018) could be the remnants of the Cyprean slab following middle–late Miocene steepening and break-off (Fig. 8E; e.g., Biryol et al., 2011; Schildgen et al., 2012; Reid et al., 2017; Delph et al., 2017). Farther east, high-velocity anomalies
are present at greater depths (>300 km) beneath the eastern Anatolide-Tauride blocks and Eastern Anatolia Plateau, the presence of which suggests that break-off and delamination occurred much earlier beneath the Eastern Anatolia volcanic province (Portner et al., 2018).

**Preferred Model for Magmatic Lull 2 and E3 Magmatism**

We suggest that the late Eocene to early Miocene orogen-wide magmatic lull (L2) in Central and Eastern Anatolia was largely the result of incipient and progressive collision of the Arabia plate (Fig. 8D). Initial soft collision of Arabia by ca. 45–40 Ma involved crustal thickening and slab steepening. Subsequent amagmatic break-off of the Arabia slab in the east is supported by the orogen-wide magmatic lull beginning ca. 40 Ma. Farther west, L2 provides support for syn- to postcollisional retreat of the Cyprus Trench, causing the Anatolide-Tauride blocks to rapidly advance southward over the subducting African plate oceanic lithosphere (Cyprean slab), effectively causing flat-slab subduction (Fig. 8D). As a result, E3 magmatism likely resulted from localized lithospheric delamination due to sublithospheric small-scale convection in the eastern Anatolide-Tauride blocks and Eastern Anatolia Plateau, and by steepening and rollback of the Cyprean slab beneath the Kirşehir block and central Anatolide-Tauride blocks in the west (Fig. 8E).

**CONCLUSIONS**

Our regional-scale synthesis of geochronology data provides valuable new insights into the tectonomagmatic evolution of Central and Eastern Anatolia, and the closure of the Neotethys Ocean since the Late Cretaceous. The basic observation from the geochronology compilation is that magmatism was episodic and included two major magmatic lulls at ca. 72–58 Ma and ca. 40–20 Ma. Based on our analysis of the space-time patterns of magmatism and our consideration of potential mechanisms for amagmatism, we propose the following hypotheses for the two distinct and widespread magmatic lulls documented herein. The first magmatic lull (L1; ca. 72–58 Ma) was the result of initial collision and subduction termination along the Izmır-Ankara-Erzincan suture zone. Although the mechanism responsible for L1 (as well as E1 and E2) south of the Izmır-Ankara-Erzincan suture zone is enigmatic, it was probably related to contemporaneous collision of the Bitlis-Pütürge massif along the southern margin of the Anatolide-Tauride blocks–Eastern Anatolia Plateau. The second widespread magmatic lull (L2; ca. 40–20 Ma) was fundamentally driven by Arabia collision, although by different mechanisms in the Arabia collision zone to the east and in the Cyprus subduction zone to the west. In the east, L2 was related to initial soft collision of the Arabian passive margin with the Anatolide-Tauride blocks–Eastern Anatolia Plateau by ca. 40 Ma. In the west, L2 was the result of syn- and postcollisional retreat of the Cyprus Trench and attendant flattening of the Cyprean slab beneath the central Anatolide-Tauride blocks and Kirşehir block. This model implies that postcollisional magmatism since the early Miocene (E3) was caused by lithospheric delamination related to crustal thickening and small-scale mantle convection in the east beneath the Eastern Anatolia volcanic province, and slab tearing and rollback in the west beneath the Central Anatolia volcanic province. Our preferred geodynamic model suggests that external forcing, namely, collision events, had a profound influence on the episodicity of magmatism in the Anatolia orogen.

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