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Origin of the Upper Cretaceous–Tertiary sedimentary basins within the Tauride–Anatolide platform in Turkey

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Abstract – A number of sedimentary basins formed within the Tauride–Anatolide Platform of Anatolia during the Late Cretaceous–Tertiary period. Previous studies have proposed different tectonic and evolutionary models for each basin. Geological characteristics of the basins, however, suggest that all these basins are of the same origin and that they followed a similar evolutionary model to one another. Basin development within the Tauride–Anatolide Platform took place in a post-collisional environment following the northward subduction of the northern Neotethys ocean beneath the Pontides. The closure of the northern Neotethys ocean ended with collision of the Tauride–Anatolide Platform with the Pontide volcanic arc and resulted in large bodies of oceanic remnants thrust over the Tauride–Anatolide Platform as ophiolite nappes. Formation of the sedimentary basins followed the emplacement of the ophiolite nappes as they formed as piggy-back basins on top of the underlying thrust ophiolite basement.

1. Introduction

A number of sedimentary basins formed during the Late Cretaceous–Tertiary period in a variety of localities on the Tauride–Anatolide Platform (Fig. 1). The basins that are located at the central and eastern part of the platform were formed during the Late Cretaceous–Early Tertiary period (Şengör & Yılmaz, 1981; Görür *et al.* 1984; Cater *et al.* 1991; Gürer, 1996; Poisson *et al.* 1996; Erdoğan, Akay & Uğur, 1996), whereas those that are located at the western part of the platform were formed during the Late Tertiary (Şengör & Yılmaz, 1981; Şengör, Görür & Şaroğlu, 1985; Seyitoğlu and Scott, 1991; Yılmaz *et al.* 2000).

In recent years, a significant number of studies have been carried out to explain the formation of the basins and the relationships between the basin formation and the regional tectonic evolution. Several different models and tectonic environments have been proposed regarding the basin formation within the Tauride–Anatolide Platform (e.g. Haymana and Tuzgölü basins as fore-arc basins (Görür *et al.* 1984; Çiner, Deynoux & Koşun, 1996) or a remnant oceanic basin (Yılmaz *et al.* 1997); Çankırı basin as a collisional (Erdoğan, Akay & Uğur, 1996) or a piggy-back basin (Koçyiğit *et al.* 1995); Sivas basin as a piggy-back (Cater *et al.* 1991), an intra-continental (Poisson *et al.* 1996), a remnant oceanic basin (Yılmaz *et al.* 1997) or a post-collisional basin (Yılmaz, 1994); Hekimhan basin as a back-arc basin (Gürer, 1996); Maden basin as a back-arc basin (Şengör & Yılmaz, 1981) or a pull-apart basin (Aktaş & Robertson, 1984)).

The proposed models for the formation of the basins vary significantly because most of the previous studies have attempted to interpret the formation of the basins within the context of arc-related (or active continental margin) tectonic settings. These models are mostly based on the assumption that there was an oceanic area (the Inner Tauride Ocean: Şengör & Yılmaz, 1981; Görür *et al.* 1984) located between the northern and southern parts of the Tauride–Anatolide Platform. North-dipping subduction of this ocean during Late Cretaceous times is generally believed to have caused most of the geological events in the area, including the formation of the Late Cretaceous–Tertiary basins.

This work aims to reinterpret the geological data to contribute to the understanding of the formation of the basins within the framework of recent observations. We concentrate on the basins formed in the central and eastern parts of the Tauride–Anatolide Platform as most of the basins were formed in these areas.

2. Geological setting

The Anatolian plate is located in a collision zone between the Eurasian and Afro-Arabian plates and consists of a number of continental fragments, each of which is surrounded by the Palaeo- and Neotethys sutures. The oceanic and continental terranes of Anatolia underwent thickening related to closure of the northern branch of Neotethys and subsequent collision of the Tauride–Anatolide Platform with the Pontides during the Late Cretaceous–Early Tertiary period (Dixon & Robertson, 1984; Dewey *et al.* 1986). Following the emplacement of the ophiolite nappes onto the Tauride–Anatolide Platform in the Late

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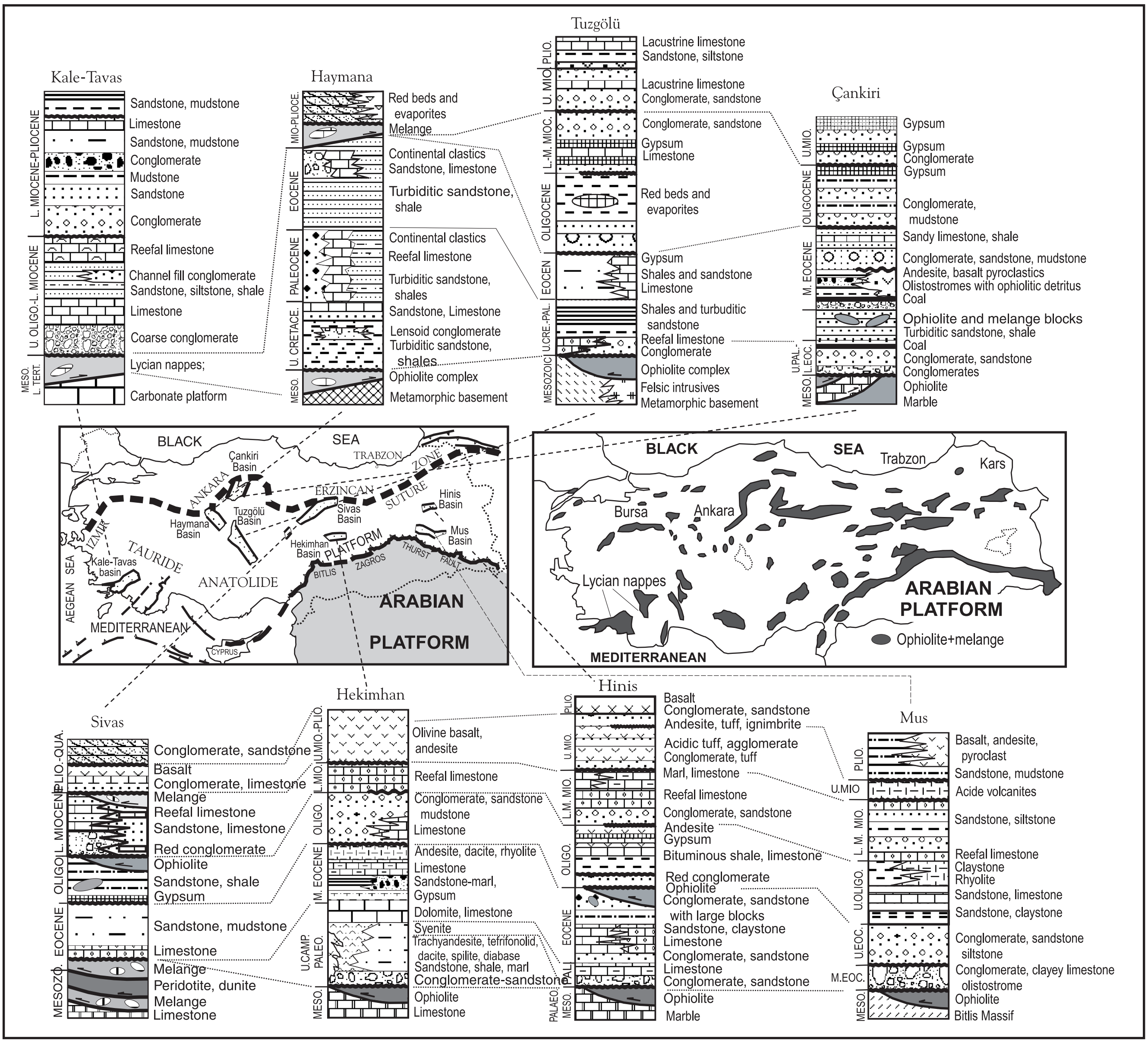

Figure 1. Map of Anatolia and its surroundings showing the localities of the Late Cretaceous–Tertiary sedimentary basins of the Tauride–Anatolide Platform and the distribution of ophiolite bodies. Schematic stratigraphic sections for the basins were prepared with data from Yılmaz *et al.* (2000) (for the Kale–Tavas basin); Görür *et al.* (1984) (for the Haymana and Tuzgölü basins); Tüysüz & Dellaloğlu (1992) (for the Çankırı basin); Gökten (1993) (for the Sivas basin); Gürer (1996) (for the Hekimhan basin); and Yılmaz (1994) (for the Hınıs and Muş basins).

Cretaceous, major imbrication of south-vergent thrusting occurred within the Tauride–Anatolide Platform.

Formation of the sedimentary basins within the Tauride–Anatolide Platform took place after the closure of the northern branch of Neotethys ocean along the Izmir–Ankara–Erzincan suture zone, resulting from north–south convergence between the Pontides and the Tauride–Anatolide Platform since Late Cretaceous times.

The northernmost part of the Tauride–Anatolide Platform is known as the Central Anatolian Crystalline Complex, a composite tectono-stratigraphic unit that consists of a number of basement metamorphic assemblages of Mesozoic age (e.g. the Kırşehir, Akdağ and Niğde massifs), together with ophiolite fragments and granitoid intrusions of Upper Cretaceous–Paleocene age. The massifs have similar metamorphic and sequential characteristics. The lower part of the Central Anatolian Crystalline Complex is an amphibolite-facies Mesozoic basement that consists dominantly of platform-derived marbles, while the upper part is composed of thrusts of younger fragmented Late Cretaceous ophiolite sequences. Numerous plutonic bodies that were formed in a post-collisional setting extensively intrude the ophiolites.

The Central Anatolian Crystalline Complex is bounded by carbonate platform sediments along its eastern and southern margins. This carbonate platform is known as the Tauride Carbonate Platform that was believed to have once been separated from the Central Anatolian Crystalline Complex by an ocean termed as the Inner Tauride Ocean (Şengör & Yılmaz, 1981). The closure of this ocean by a northward subduction beneath the Central Anatolian Crystalline Complex has been invoked by many researchers to explain much of the tectono-magmatic events that took place within the Tauride–Anatolide Platform. This includes (1) the regional magmatic activity within the Central Anatolian Crystalline Complex (mostly referred to as an arc magmatism; Görür *et al.* 1984; Gökten & Floyd, 1987; Erdoğan, Akay & Uğur, 1996); (2) the emplacements of ophiolites southward onto the Tauride Carbonate Platform (referred to as the oceanic remnants of the Inner Tauride Ocean: Görür *et al.* 1984; Dilek & Whitney, 1997; Whitney *et al.* 2001); and (3) the formation of the Cretaceous–Tertiary sedimentary basins within the Central Anatolian Crystalline Complex (mostly referred to as fore-arc or back-arc basins: Görür *et al.* 1984; Gökten, 1993, Gürer, 1996).

2.a. Regional magmatic activity

The magmatic activity on the Tauride–Anatolide Platform began during the Late Cretaceous period (Akıman *et al.* 1993). This activity concentrated around the Kırşehir Massif and produced common plutonic rock types of granodiorite, monzonite and syenite and volcanic rock types of andesite, dacite and trachyte. Both alkaline and calc-alkaline magmatic products are common in the area.

The granitoid plutons are distributed in three distinct localities within the Central Anatolian Crystalline Complex. These are: (1) the northern part of the Çankırı basin where a number of large intrusive bodies form a northwestern convex belt (the Sulakyurt granitoids: Kaymakçı, 2000); (2) the western margin of the Central Anatolian Crystalline Complex along which a set of plutonic bodies crop out (Baranadağ, Cefalık, Ağaçören and Elekçidağ granitoids); and (3) the Yozgat area which is represented by a large granitic emplacement (Yozgat Granitoid) (Akıman *et al.* 1993; Erler & Göncüoğlu, 1996; Erdoğan, Akay & Uğur, 1996).

The field relations and the radiometric data (K–Ar) from the granitoid plutons (e.g. Akıman *et al.* 1993; Ilbeyli & Pearce, 1997; Ilbeyli *et al.* 2001) indicate that the emplacement of the granitoid intrusion in the area lasted between about 95 and 66 Ma, during and after the main ophiolite obduction from the northern branch of the Neotethys ocean onto the Tauride–Anatolide Platform. Geochemical and petrographic characteristics indicate that some of these granitoid bodies are calc-alkaline, metaluminous and I-type with their collision-related affinities, while the others are alkaline, peralkaline, A-type and display within-plate geochemical signatures (Göncüoğlu & Türeli, 1993; Ilbeyli & Pearce, 1997).

The volcanic activity in the area began mostly simultaneously with the basin development as the volcanic products are generally intercalated with the basin in-fill deposits in all the basins. Geochemical characteristics and radiometric data suggest that the volcanic products were formed in association with the formation of the main intrusive bodies. Erdoğan, Akay & Uğur (1996) described an Early Paleocene magmatism that produced lavas of mainly calc-alkaline dacides in association with I-type granite plutons.

Most of the earlier studies interpreted this activity as being arc magmatism related to the closure of the Inner Tauride Ocean (Şengör & Yılmaz, 1981; Görür *et al.* 1984; Gökten & Floyd, 1987; Erdoğan, Akay & Uğur, 1996). Görür *et al.* (1984), for instance, interpreted the formation of a series of granite plutons (such as the Baranadağ Pluton) lying parallel to the southwestern margin of the Kırşehir Massif as the product of a N-dipping subduction of the Inner Tauride Ocean, however, there is no evidence supporting an arc-setting environment for these plutons.

More recent studies, however, showed that the regional magmatic activity began in a collisional environment and may have an intra-plate character. This is evident from the temporal evolution of the activity that changes from a syn-collisional episode (e.g. S-type, peraluminous granites) through a post-collisional, calc-alkaline episode (e.g. I-type, high-K, metaluminous granites) to a post-collisional, within-plate alkaline episode (e.g. A-type, peralkaline granites) (Göncüoğlu & Türeli, 1993; Ilbeyli & Pearce, 1997; Boztuğ, 2000).

2.b. Ophiolite obductions

The Tauride–Anatolide Platform (both the Central Anatolian Crystalline Complex and Tauride Carbonate Platform) contains the oceanic remnants derived from the northern branch of the Neotethys ocean. These Late Cretaceous fragmented ophiolites were emplaced onto the amphibolite-facies Mesozoic platform carbonates (marbles) and are exposed within distributed patches (Fig. 1). The ophiolites are made up of three distinct parts: (1) fragmented and stratiform ophiolite bodies; (2) tectonized ophiolite mélange; and (3) amphibolites that are concordant with the sub-ophiolitic metamorphic rocks (marbles) from the underlying carbonate platform. Parlak & Delaloye (1996) and Dilek *et al.* (1999) reported Ar–Ar ages of between 89.6 and 91.7 Ma for the mafic dykes of the ophiolite fragments. These ages pre-date the final emplacement of the nappes onto the Tauride–Anatolide Platform, since the dated mafic dykes intrude all structural levels

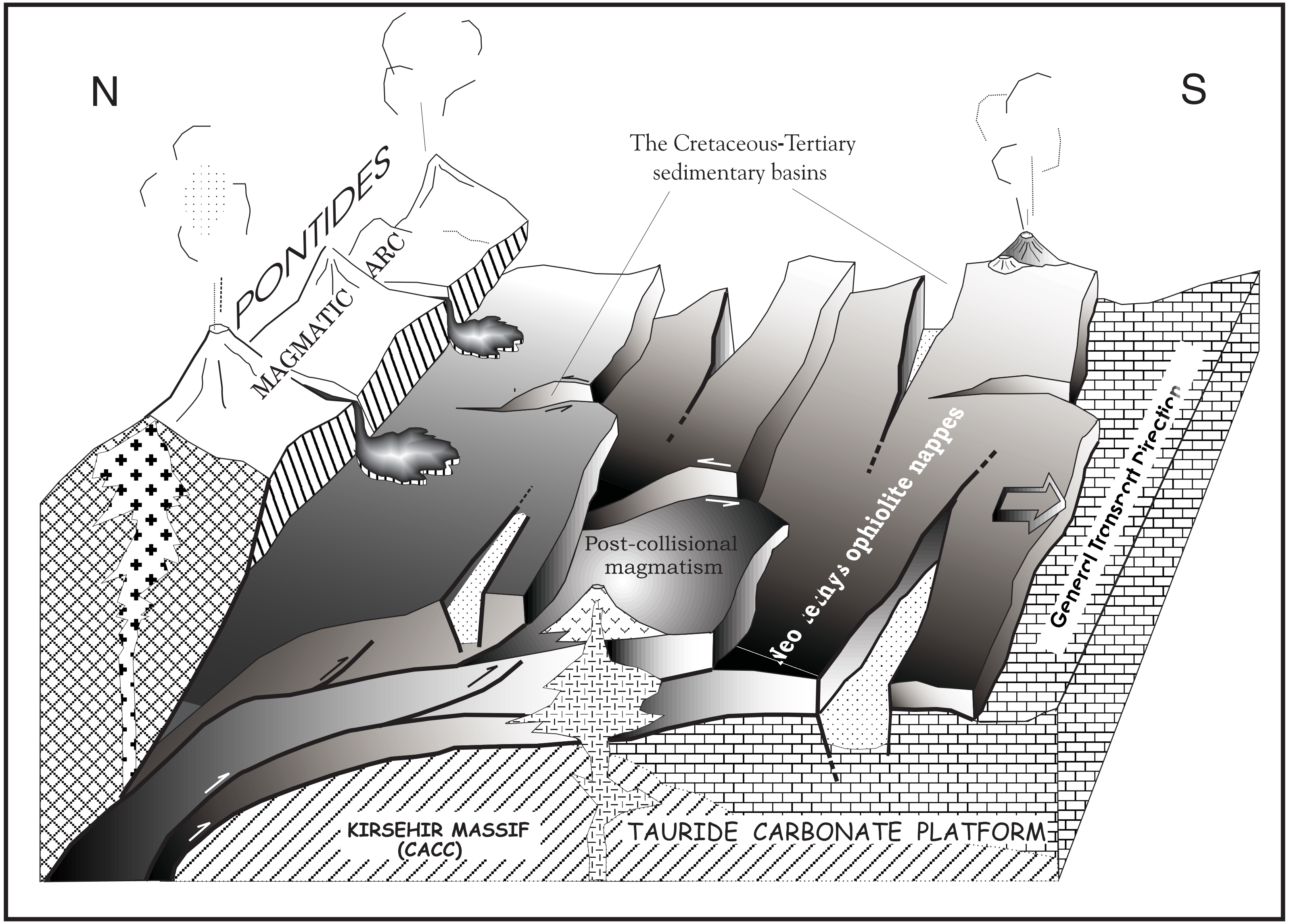

Figure 2. Block diagram showing the schematic representation of the formation of major basins on the Tauride–Anatolide Platform during Late Cretaceous–Tertiary times (CACC – Central Anatolian Crystalline Complex).

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of the ophiolites but not the underlying platform carbonates. The intrusion of the post-collisional Late Cretaceous granitoids, on the other hand, post-dates the ophiolite emplacements as seen from the intrusion of the plutonic bodies into both the basement assemblages and the overlying ophiolite nappes (Yalınız *et al.* 1999).

The ophiolites emplaced onto the Tauride Carbonate Platform are geochemically identical to those emplaced onto the Central Anatolian Crystalline Complex, indicating that they were generated from the same source (Yalınız, Floyd & Göncüoğlu, 1996; Parlak, Hock & Delaloye, 2000). Geochemical data mostly reveal a supra-subduction tectonic setting, related to the north-dipping subduction of the northern Neotethys ocean, for the origin of the Late Cretaceous ophiolite fragments obducted onto the Tauride Anatolide Platform (Parlak, Hock & Delaloye, 2000; Floyd *et al.* 2000; Yalınız, Floyd & Göncüoğlu, 2000).

2.c. Formation of the Cretaceous–Tertiary sedimentary basins

Figure 1 shows the distribution of the main sedimentary basins formed within the Tauride–Anatolide Platform, together with the generalized stratigraphic columns of each basin.

All basins shown in Figure 1 formed after the Late Cretaceous period, following the terminal closure of the northern Neotethys ocean. They formed on a basement composed of an ophiolitic complex. Sedimentary deposits and volcanic rocks that comprise sequences over 1000 m thick subsequently filled the basins.

The initial stage of sedimentation in these basins was characterized by terrestrial and shallow marine deposits that consist of both clastic and carbonate deposition. Formation of the red, clastic Maastrichtian deposits that are accompanied by rudist-bearing (*Hippurites sp.*) coral reef limestone may indicate a Maastrichtian transgressive deposition in all the basins during the early stage of basin formation. Deposition of olistostromal and turbiditic sequences followed the formation of the coral reefs, as the basins became deeper over time (Görür *et al.* 1984; Gürer, 1996).

During the Oligocene period, the region was uplifted to form a plateau. In the terrestrial areas, red clastics and evaporate deposition became predominant. This stage was followed by a new transgressive regime which led to the formation of shallow marine deposits and coral reefs in most of the basins during Early Miocene times.

During formation of the basins the ophiolite nappes were moving. This is evident from the ophiolite-bearing sequences within the basins and the movement of these sequences as tectonic slices within the ophiolite nappes. Movement of the ophiolite nappes took place in the Çankırı basin during Paleocene–Eocene times (Tüysüz & Dellaloğlu, 1992), in Haymana basin during the Pliocene (Görür *et al.* 1984), in the Tuzgölü basin during the Oligocene (Görür *et al.* 1984), in the Sivas basin during the Eocene–Oligocene (Gökten, 1993) and in the Hınıs basin during the Late Eocene (Yılmaz, 1994).

3. Discussion and conclusions

It is now well known that the northern branch of Neotethys (the Izmir–Ankara ocean) was consumed along a north-dipping subduction beneath the Pontides during Late Cretaceous times (Şengör & Yılmaz, 1981; Görür *et al.* 1984; Erdoğan, Akay & Uğur, 1996). This period was represented by the formation of abundant thrust faulting above the northern part of the Tauride–Anatolide Platform (the Central Anatolian Crystalline Complex), which was, in turn, buried and metamorphosed under the load of the nappe pile. During the same period, large-scale ophiolite emplacement was also reported to have occurred onto the southern part of the Tauride–Anatolide Platform (the northern margin of the Tauride Carbonate Platform) (Şengör & Yılmaz, 1981).

Recent studies suggest that the border between the Central Anatolian Crystalline Complex and the Tauride Platform contains no geological evidence for a northward subduction that was followed by the collision of these two adjacent blocks (e.g. a suture zone). There is, in fact, no evidence that may indicate that an ocean once separated these two blocks from one another. These two adjacent blocks seem to be the natural continuation of one another; the stratigraphic succession of the Central Anatolian Crystalline Complex is almost identical to that of the non-metamorphosed Tauride Carbonate Platform. The metamorphic nature of the northern part (the Central Anatolian Crystalline Complex) may, however, be attributed to its burial beneath the ophiolite nappes that originated from the closure of the northern Neotethys ocean. The Central Anatolian Crystalline Complex can thus be interpreted as the metamorphosed leading edge of the Tauride–Anatolide Carbonate Platform. The ophiolite nappes emplaced onto the northern margin of the Tauride Carbonate Platform are originally the same as those emplaced onto the Central Anatolian Crystalline Complex and are from the northern Neotethys ocean. The magmatic activity also seems to have taken place in a collisional environment rather than an arc setting. Thus, it is totally unnecessary to emplace an oceanic environment (the Inner Tauride Ocean) between the Tauride Carbonate Platform and Central Anatolian Crystalline Complex and relate the geological events to the closure of this ocean.

The Cretaceous–Tertiary basins of the Tauride–Anatolide Platform formed in a post-collisional environment, rather than in an arc setting, following the total consumption of the northern Neotethys ocean and south-vergent thrusting of the ophiolite nappes.

The common characteristics of the basins can be summarized as follows:

(1) The basins were formed on top of either ophiolite (and/or ophiolite mélange) nappes or (in some basins) a composite basement that consists of ophiolite + pre-existing basement assemblages of the Tauride–Anatolide Platform.

(2) The basin development in the area was restricted to the Late Cretaceous–Early Tertiary period, a time interval that post-dates the emplacement of the main ophiolite nappes.

(3) Small-scale ophiolite thrusting is also observed within or over the basin in-fill sequences in some of the basins (e.g. Haymana, Çankırı, Sivas and Hınıs) indicating thrust movement during the basin formation.

(4) Basal, terrestrial and shallow marine deposits that were followed by deeper turbiditic sequences of Paleocene–Eocene age marked the early stage of sedimentation in all basins. The Oligo-Miocene deposition is characterized by shallow marine, marine–deltaic, fluvial–lacustrine and deltaic–lacustrine deposits.

(5) Both alkaline and calc-alkaline, syn- to post-collisional volcanic products intercalated with the basin in-fills during various stages of basin development.

For describing the formation (or the major development stage) of the basins we use the term 'piggy-back', a concept derived from the fact that sediment accumulation takes place on top of a moving thrust fault (Ori & Friend, 1984). In the case of the Tauride–Anatolide Platform, these are the basins that are inferred to have been developed on top of the ophiolite nappes along with which they were carried long distances (Fig. 2).

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