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Revised Late Campanian-Danian age of the melange-related turbiditic sequence in the Mersin area (Central Taurides, S. Turkey)

Hayati KOÇ*, Kemal TASLI, Erol ÖZER

Department of Geological Engineering, Faculty of Engineering, Mersin University, 33342 Çiftlikköy, Mersin, Turkey

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Abstract: A planktonic foraminiferal assemblage obtained from the Yavca stratigraphic section north of Mersin shows that the age of a melange-related turbiditic sequence extends to the Danian (Early Palaeocene). Previously, this turbiditic sequence, termed the Yavca Formation, was considered to be of Late Cretaceous or Campanian-Maastrichtian age. The formation is either depositionally overlain by the Fındıkpınarı ophiolite-related melange or tectonically by Mersin Ophiolite slices or Jurassic-Cretaceous platform carbonates. Clayey limestone and mudstone samples collected from the type area of the Yavca Formation yielded planktonic foraminiferal assemblages, which include *Parasubbotina pseudobulloides* (Plummer), *P. varianta* (Subbotina), *Praemurica pseudoinconstans* (Blow), *P. inconstans* (Subbotina), *Globanomalina compressa* (Plummer), *G. ehrenbergi* (Blow), *Subbotina triloculinoides* (Plummer), *S. triangularis* (White), *Morozovella praeangulata* (White), and *Eoglobigerina spiralis* (Bolli). These assemblages range from the late Danian P1c subzone to the basal P3a subzone. Basal red pelagic limestones are assigned here to the late Campanian-Maastrichtian, based on the presence of *Radotruncana* cf. *R. calcarata* (Cushman) and *Contusotruncana* cf. *C. walfischensis* (Todd). The age of the melange-related turbiditic sequence is revised to be late Campanian (Late Cretaceous) to Danian (Early Paleocene). This revised age provides a new insight into the evolution of the Central Taurides and helps refine palaeogeographical interpretation during this time. The timing of the ophiolite emplacement in the Central Taurides is interpreted as post-Danian to pre-Miocene (Late Palaeocene or Late Eocene).

Key Words: Early Palaeocene, planktonic foraminifera, ophiolite emplacement, Central Taurides, S Turkey

1. Introduction

Ophiolite-related rock assemblages overlying the Mesozoic Tauride Carbonate Platform are considered to be sutured remnants of the South Neotethys Ocean and have been widely used in regional tectonic reconstructions (Şengör & Yılmaz 1981; Robertson & Dixon 1984; Yılmaz 1993; Collins & Robertson 1997; Parlak & Robertson 2004; Robertson *et al.* 2009). Late Cretaceous melange-derived turbidites and associated ophiolitic melange in the Mersin area were originally studied by İlker (1975) under the name "Yavca Formation" from around Yavca village, 60 km northeast of Mersin (Figure 1). The name Yavca Formation has been subsequently restricted to the melange-related turbiditic sediments (Koç *et al.* 1997; Taslı & Eren 1999), by excluding one of the associated melange units (Fındıkpınarı Melange of Yaman 1991; Mersin Melange of Parlak & Robertson 2004). Comparable sediments were termed the Arslanköy Formation, assigned a Senonian age based on the presence of *Globotruncana stuarti*, *Globotruncana tricarinata* cf. *fornicata*, *Globotruncana rosetta*, *Orbitoides* sp., and *Siderolites* sp., and with a possible Danian age for its uppermost part containing ophiolitic olistostromes and olistoliths (Demirtaşlı *et al.* 1984). Ricou (1980) gave a stratigraphic section across the Cretaceous limestone massif and ophiolitic rocks in Kavaklıpınar village and differentiated 3 Maastrichtian rock assemblages. From base to top these are: (1) limestones containing rudist fragments, *Orbitoides media*, and *Siderolites calcitrapoides*; (2) a few metres of thick red limestones with *Globotruncana arca*, *G. calciformis*, and *G.* gr. *stuarti*; (3) 25-m-thick greenish sandstones. He suggested that the ophiolitic nappes in the Arslanköy and Namrun (Çamlıyayla) areas were emplaced onto the Taurus Limestone Axis during the Maastrichtian. The Yavca Formation can be correlated with the Maastrichtian "regular basal sequence" of ophiolitic melange in the Aladağ region, Eastern Taurides (Tekeli *et al.* 1984). Taslı and Eren (1999) dated the red limestones in the basal part of the Yavca Formation in the Aydıncık area as late Campanian, based on a planktonic foraminiferal assemblage comprising mainly *Globotruncanita calcarata*, *Gta. stuartiformis*, *Globotruncana arca*, and *Contusotruncana fornicata*, identified from thin sections.

Only one of numerous samples from the formation yielded a few recrystallised planktonic foraminifera, which

* Correspondence: hakoc@mersin.edu.tr

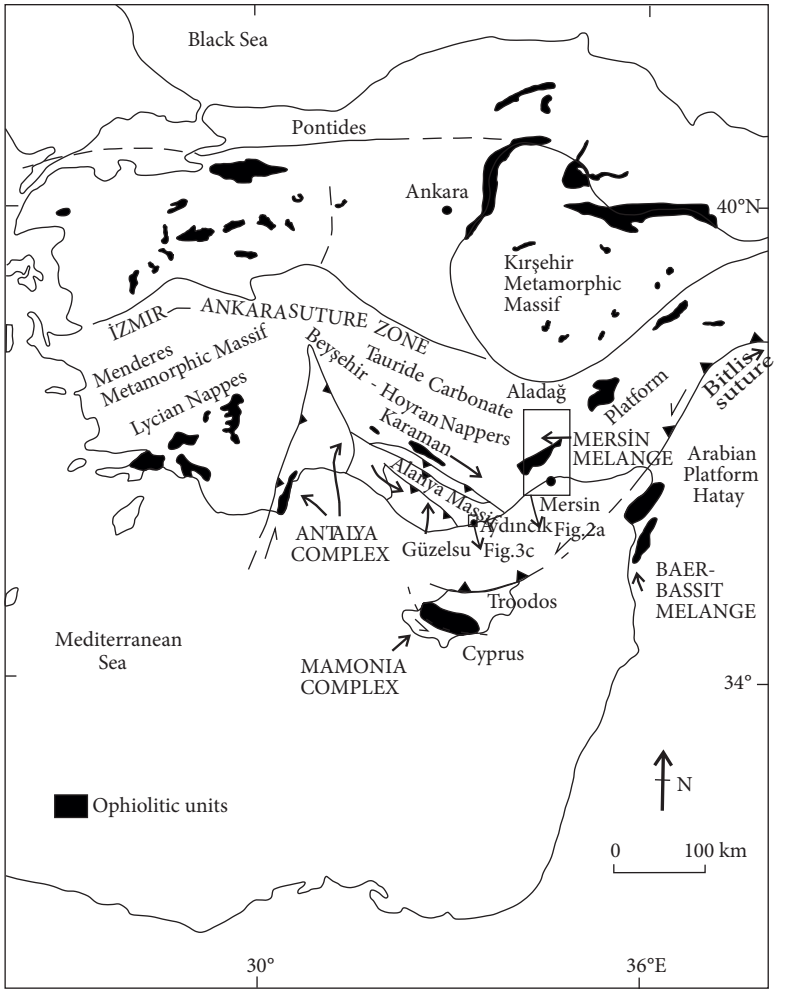

Figure 1. Tectonic map of Turkey (after Parlak & Robertson, 2004), showing ophiolite-related rock assemblages and the study areas.

were questionably assigned to *Parasubbotina* of Palaeocene age, during a recent study of the biostratigraphy and palaeoenvironmental setting of the Late Cretaceous sediments of the Central Taurides (Koç & Taslı 2010). Additional and more detailed sampling confirmed the occurrence of Palaeocene planktonic foraminifera within this formation. This study focuses on dating the melange-related turbiditic succession by means of its planktonic foraminiferal assemblages.

2. Materials and methods

Systematic sampling was carried out in the type area of the Yavca Formation, situated 1 km east of Yavca village (Figure 1). The type area is one of the best places to see the lower and upper depositional contacts of the formation, which are well preserved and easily accessible. Sampling was limited by the relative scarcity of suitable calcareous lithologies, compared to mainly sandy and silty lithologies. Another stratigraphic section further west, in which the lower and upper formation contacts are faulted, named the Bozkoyak stratigraphic section with 5 washing samples (Bo/15-19), was measured in the Aydıncık area. In total 36 samples, 21 of them washing samples while the others were thin-sectioned, were analysed. Muddy samples, each weighing approximately 1 kg, were crushed and then soaked in dilute hydrogen peroxide (10%) for 12 to 24 h. The residues were then washed through a 100-µm screen and dried out in an oven at less than 50 °C. About 250 specimens were picked and cleaned using ultrasonic agitation for intervals of 10 to 15 s. Determination of planktonic foraminifera were then made using an optical stereomicroscope with 40× and 100× magnifications. The free specimens of planktonic foraminifera were illustrated with field emission scanning electron microscope (FESEM) images in the Mersin University Advanced Technology, Education and Application Centre. Planktonic foraminiferal specimens are relatively well preserved although some are recrystallised and infilled

with iron oxide. The specimens are stored in the Geological Engineering Department collection, Mersin University, Mersin. Palaeocene taxa and biozones were identified according to the method of Olsson *et al.* (1999). The time scale used in this paper is that of Gradstein & Ogg (2004).

3. Geological setting

Ophiolite-related rock assemblages are widely distributed on the southern flank of the Bolkar Mountains, in the eastern part of the Central Taurides (Figures 2A and 2B). Demirtaşlı *et al.* (1984) recognised 3 tectono-stratigraphic units in the Bolkar Mountain area. The northern part of the Bolkar Mountains consists of metamorphosed Permian-Late Cretaceous carbonate rocks of the Bolkar Group, which are either tectonically overlain by late Senonian ophiolitic melange or unconformably overlain by late Maastrichtian-Tertiary volcano-sedimentary formations of the Niğde-Ulukışla Basin. The central portion of the Bolkar Mountain area contains slightly metamorphosed Permian-Late Cretaceous carbonate-dominated rocks with diabase intercalations that were thrust over the Late Cretaceous-Palaeocene formations of the Ereğli-Ulukışla Basin. The southern part of the Bolkar Mountain area, which is the equivalent of the Aladağ tectonic unit of Özgül (1976), comprises Permian limestones and sandstones (Öşün Formation), Triassic limestones, sandstones and shales with Permian limestone olistoliths (Karagedik Formation), Jurassic-lower Senonian carbonates (Cehennemdere Formation), and Senonian-Danian (?) flysch containing ophiolitic fragments (Arslanköy Formation), which structurally overlie the ophiolitic melange.

Two generalised N-S cross-sections (Figure 3) demonstrate that the Yavca Formation is sandwiched between several thrust sheets and that it structurally overlies a southward-dipping thrust sheet containing Mesozoic platform carbonate sediments or ophiolite slices (Figure 3A). This lithostratigraphical unit can be traced westwards into the Aydıncık area (Figure 3B and 3C) in discontinuous outcrops as a result of nappe cover erosion (Koç *et al.* 1997; Taslı & Eren 1999).

4. Lithology

The Bolkar Mountain inner platform carbonate deposition is represented by the Bajocian-Santonian Cehennemdere Formation (Taslı *et al.* 2006). It is overlain by late Campanian hemipelagic and pelagic grey limestones, which become siliceous and pinkish upwards, together with centimetric to decimetric-sized slump-folds. This unit was named the Kavaklıpınarı Limestone by Özer *et al.* (2002). Red pelagic limestones (2-6.5 m thick) or local carbonate breccia-conglomerates with a pelagic muddy matrix are recorded at the base of the overlying Yavca

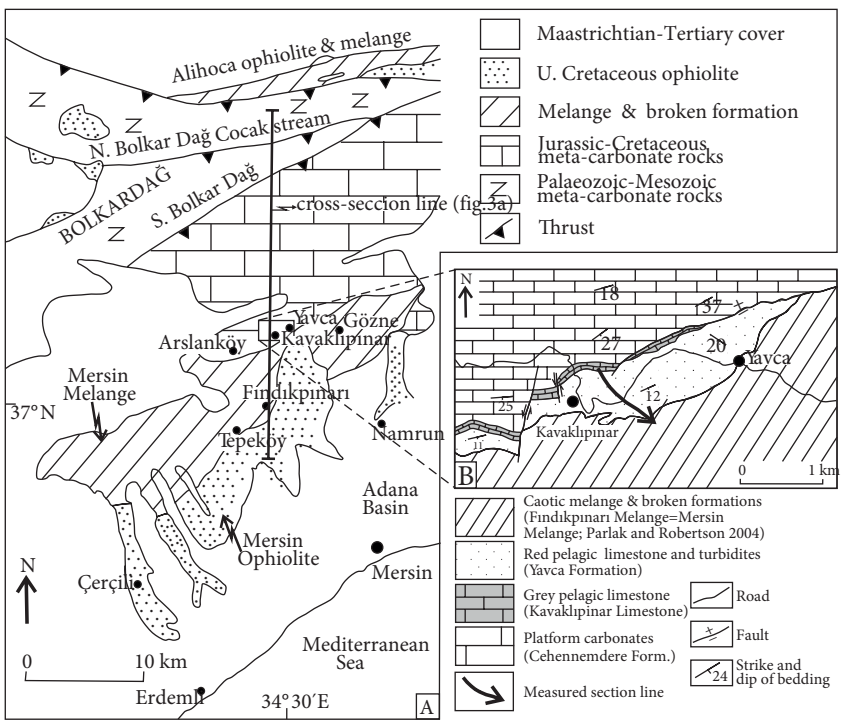

Figure 2. Simplified geological map of the Bolkar Mountains area (**2A**, after Parlak & Robertson 2004), and geological map of the Yavca area (**2B**, after Taslı *et al.* 2006) showing the section location.

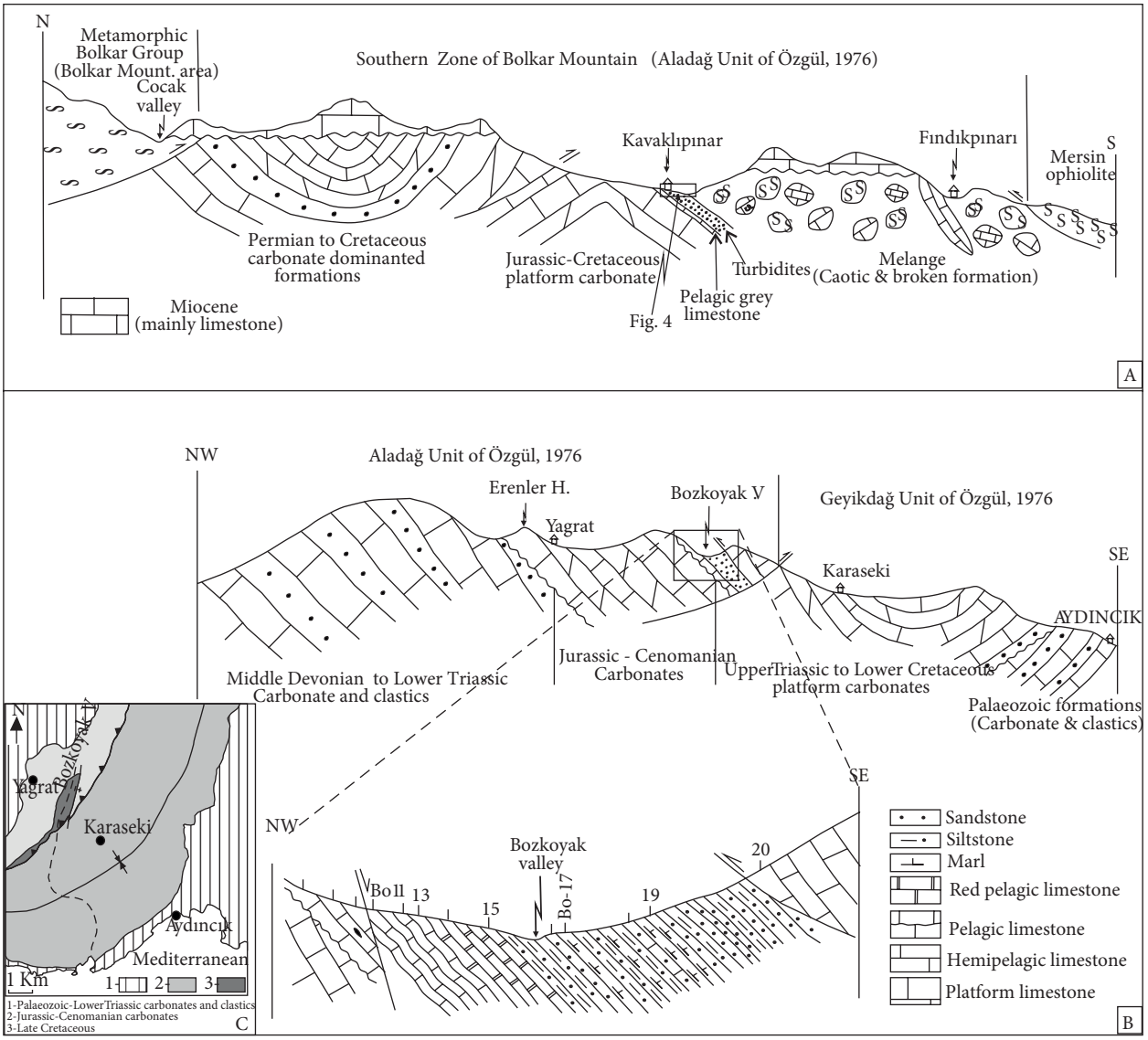

Figure 3. Generalised N-S cross-sections showing the regional geological setting and the measured sections: **A**) Mersin area, **B**) Aydıncık (Mersin) area, **C**) geological map of the Aydıncık area (Koç & Taslı 2010).

Formation. The depositional contact between the 2 units is uneven and affected by tectonic displacements in places. The Yavca Formation consists predominantly of thin- to medium-bedded, well-stratified, weakly graded, greenish sandstone-siltstone-mudstone alternations (Figure 4). The sandstones are dominated by chloritised basic extrusive clasts and subordinate polycrystalline quartz, radiolarian chert, pelagic carbonate, and biotite. Carbonate breccias and sandstones in the lower part of the succession consist of reworked rudist shells, pelagic grey wackestone, and neritic limestone in variable amounts. Massive clayey limestone and marl beds rarely occur throughout the succession. An upper horizon of red pelagic limestones, here dated as Early Palaeocene (sample Ya/10), in the mid-part of the succession overlies a 5-m-thick grey pelagic limestone with fragmentary small planktonic foraminifera, which is laterally discontinuous due to the channel filling and gravity sliding.

The upper contact of the Yavca Formation with the overlying ophiolitic melange is well preserved in the Kavaklıpınar area. A lenticular massive conglomerate (0-30 m thick), composed of well-rounded ophiolite-derived clasts (up to 3 cm across, mainly diabase, gabbro and subordinate limestone pebbles) and a dark muddy-sandy matrix, occurs between the 2 units.

5. Biostratigraphy

The Kavaklıpınarı Limestone, which underlies the Yavca Formation, contains *Globotruncana arca* (Cushman), *G. linneiana* (d'Orbigny), *Contusotruncana fornicata*

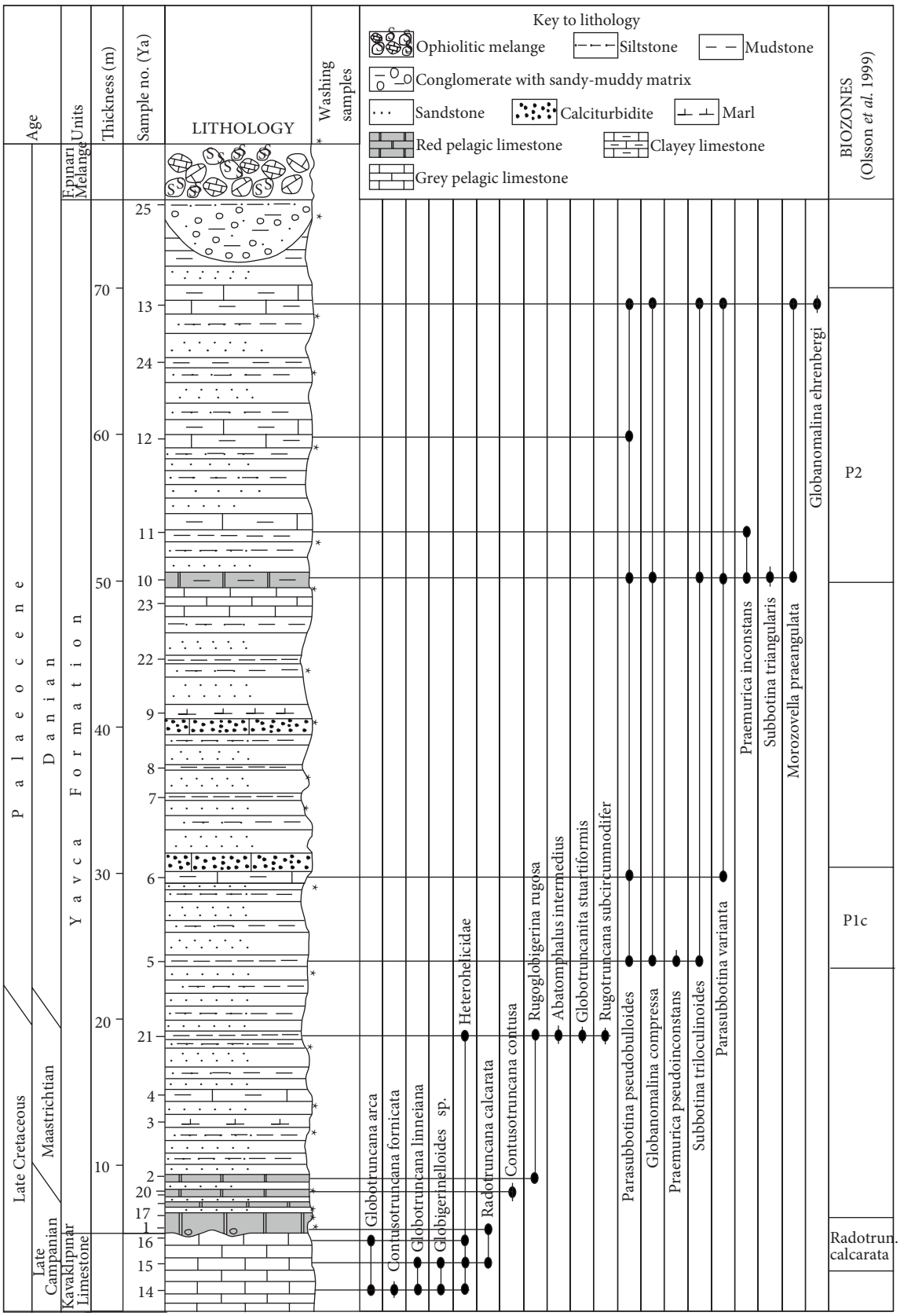

Figure 4. Local planktonic foraminiferal ranges and biostratigraphy of the Yavca stratigraphic section.

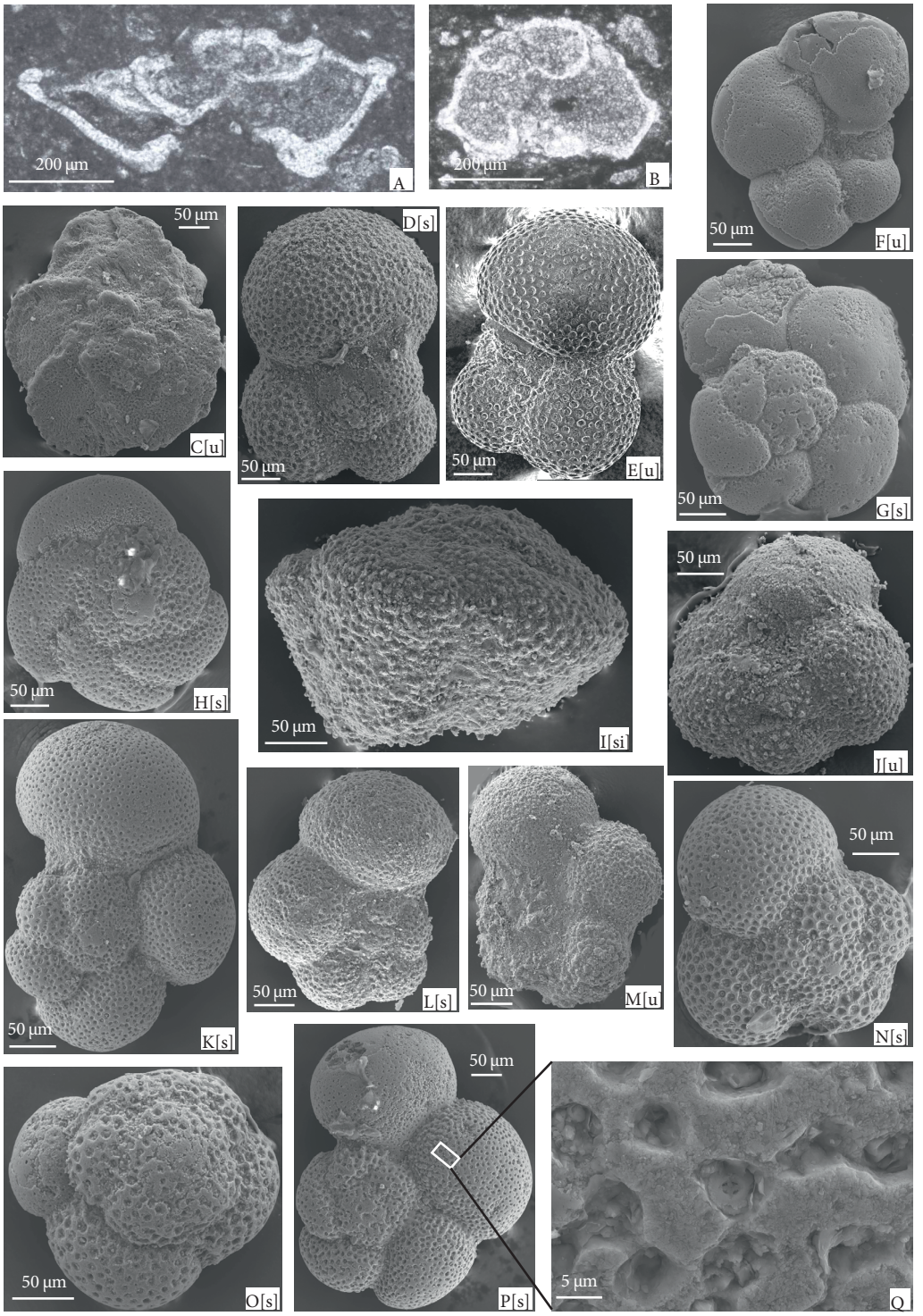

Figure 5. Optic images of planktonic foraminifera from the late Campanian-Maastrichtian red pelagic limestones (**A and B**) and SEM images of planktonic foraminifera from the Maastrichtian (**C**)-Danian (**D-R**) melange-derived turbiditic sequence in the Mersin area. **A**: *Radotruncana* cf. *R. calcarata*, sample Ya15, Kavaklıpınarı Limestone; **B**: *Contusotruncana* cf. *C. walfischensis*, sample Ya20, upper part of the basal red limestones of the Yavca Formation; **C**: *Globotruncana rosetta*, sample Ya21; **D and E**: *Subbotina triloculinoides*, sample Ya13; **F and G**: *Globanomalina compressa*, sample Ya10; **H-J**: *Morozovella praeangulata*, sample Ya10; **K-M**: *Parasubbotina pseudobulloides*, sample Ya13; **N**: *Parasubbotina varianta*, sample Ya10; **O**: *Eoglobigerina spiralis*, sample Ya10; **P**: *Praemurica inconstans*, sample Bo17; **Q:** Detail of praemuricate wall texture of *P. inconstans*. Note the presence of a coccolith in the pore. Codes following letters: [s], spiral view; [u]: umbilical view; [si]: side view.

(Plummer), and *Radotruncana* cf. *R. calcarata* (Cushman) (Figure 5A). The last mentioned species, which is the index for the early late Campanian (Robazsynski & Caron 1995) or late Campanian (Patterson *et al.* 2004), also occurs in the basal part of the red pelagic limestones that are included in the Yavca Formation. The upper part of the red pelagic limestones, which is intercalated with sandstones, yielded *Contusotruncana* cf. *C. walfischensis* (Todd) (Figure 5B) of mid to late Maastrichtian age. Only 4 of 18 mudstone samples taken from the upper turbiditic part of the Yavca section yielded well-preserved planktonic foraminifera, whereas the others are barren or contain only scarce poorly preserved planktonic foraminifera. A planktonic foraminiferal assemblage comprising mainly *Abatomphalus intermedius* (Bolli), *Globotruncana rosetta* (Carsey) (Figure 5C), *Rugoglobigerina hexacamerata* Brönnimann, *Globotruncanita stuartiformis* (Dalbiez), and Heterohelicidae, which is found 10 m above the red pelagic limestones, indicates a late Maastrichtian age.

Sample Ya/5, taken from 25 m above the base of the Yavca section, contains *Parasubbotina pseudobulloides* (Plummer) (Figures 5K, 5L and 5M), *Subbotina triloculinoides* (Plummer) (Figures 5D and 5E), *Globanomalina compressa* (Plummer) (Figure 5F and 5G), and *Praemurica pseudoinconstans* (Blow). Above (in samples Ya/6, 10, & 13), *Parasubbotina varianta* (Subbotina) (Figure 5N), *Morozovella praeangulata* (White) (Figure 5H, 5I and 5J), *Praemurica inconstans* (Subbotina) (Figure 5P), and *Subbotina triangularis* (White) are added to this assemblage. In the Bozkoyak section (Figure 3B), only one sample (Bo-17) yielded *Morozovella praeangulata* (White), *Praemurica inconstans* (Subbotina), *Parasubbotina pseudobulloides* (Plummer), *P. varianta* (Subbotina), and *Subbotina triloculinoides* (Plummer). The species in these assemblages broadly range through the P1c *Globanomalina compressa*/*Praemurica inconstans-Praemurica uncinata* Interval Subzone, the P2 *Praemurica uncinata-Morozovella angulata* Zone, and the basal P3a *Morozovella angulata-Igorina albeari* Interval Subzone, which can be assigned to the late Danian and the early Selandian. In the absence of *M. angulata*, the P3a subzone may be absent. However, although some discussion of the stratigraphic ranges of Palaeocene planktonic foraminiferal species persists, the assemblages that we identified are restricted to the Early Palaeocene (Toumarkine & Luterbacher 1985; Olsson *et al.* 1999; Berggren *et al.* 2000; Patterson *et al.* 2004).

6. Discussion and Conclusion

The melange-related turbiditic sequence in the Mersin area, representing an early stage in the ophiolite emplacement, is here dated as late Campanian-Danian based on the newly collected planktonic foraminifera. The timing of emplacement of the Mersin Ophiolite, until now considered to be latest Cretaceous, can now be revised as post-Danian. In the Çamlıyayla (Namrun) area, further northeast, the ophiolitic melange is overlain by transgressive Early to Mid-Eocene conglomerates and nummulitic limestones (Başalan *et al.* 2007). The Melange can be dated as Late Palaeocene, based on its stratigraphic position overlying the Early Palaeocene turbiditic sequence, but there is no relation between the tectonically overlying ophiolite beneath Miocene cover sediments in the south and the transgressively overlying Eocene formations in the north, as seen in the work of Parlak & Robertson (2004, Fig. 3). Hence, 2 hypotheses for the timing of final ophiolite emplacement can be proposed. The emplacement took place either in latest Palaeocene time, immediately after formation of the melange; or it took place in Late Eocene time before the Miocene cover sediments were deposited.

Additional reliable age data for the ophiolite-related rocks in other areas are still needed for a more complete palaeogeographic and tectonic reconstruction of the Taurides. The main difficulties are the often incomplete stratigraphic record caused by tectonic truncation of the sedimentary sequences, unstable palaeoenvironmental conditions (e.g., gravity sliding, slumping, and debris flow), and the paucity of fossiliferous intervals in predominantly clastic sediments.

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