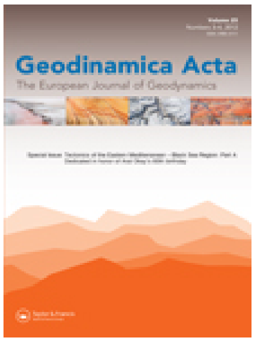

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Middle-Late Triassic radiolarian cherts from the Arkotdağ mélange in northern Turkey: implications for the life span of the northern Neotethyan branch

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Moderately to well-preserved, relatively diverse Middle and Late Triassic radiolarian assemblages have been obtained from the chert slide-blocks within the Late Cretaceous mélange of the IntraPontide Suture Zone at the Pelitören village to the NE of Kastamonu- Araç in northern Central Anatolia. In this locality, chert slide-blocks are tectonically overlain by metamorphic sole of the serpentinized peridotites belonging to the IntraPontide ophiolites. The oldest radiolarian assemblages, with the middle Late Anisian and late Early Ladinian ages, were found in green cherts in a pebbly mudstone. They are underlain by a larger slide-block composed of an alternation of radiolarian cherts and mudstones with late Early and early Late Carnian radiolarians. Another slide-block with cherts and mudstones between the sub-ophiolitic amphibolite and the Carnian cherts includes the late Early to early Middle Norian radiolarian assemblages. These new data reveal that the IntraPontide basin was already open during the Middle to Late Triassic time and deep enough for radiolarian cherts to deposit. Moreover, it suggests that the IntraPontide Ocean is contemporaneous with a number of inferred Paleo- and Neotethyan oceanic basins in SE Europe and NW Anatolia, which were proposed in copious tectonic models.

Keywords: IntraPontide Ocean; radiolarians; Middle-Late Triassic; N Turkey

1. Introduction

Disregarding the discussions on the locations, life span and subduction polarities of its branches, the presence of a multi-armed Neotethys in the Anatolian part of Eastern Mediterranean during the Mesozoic is frequently accepted (e.g. Göncüoğlu, Dirik, & Kozlu, 1997; Okay & Tüysüz, 1999; Robertson, 2002; Şengör, 1987). Information on the evolution of the southern (Amanos-Elazığ-Van-Zagros) and middle (İzmir-Ankara-Erzincan) branches of this oceanic system has been obtained by detailed geochemical work coupled with dating of crustal lithologies (for details see Göncüoğlu, Yalınız, & Tekin, 2006 for the middle, and Robertson et al., 2007 for the southern branch of Neotethys). The evolution of the northern oceanic basin, whose remnants were named as the IntraPontide Suture (IPS) zone by Şengör and Yılmaz (1981), on the other hand, is very little known. The IPS comprises a 400 km long, E-W trending belt of deformed and/or metamorphosed mélanges including ophiolite rocks derived from a Neotethyan oceanic basin (e.g. Göncüoğlu, Gürsu, Tekin, & Köksal, 2008; Göncüoğlu et al., 2012; Figure 1(a)). Paleogeographically, the IntraPontide Ocean (IPO) was presumed to be located between the Cimmerian Sakarya Terrane (e.g. Göncüoğlu et al., 2000) in the south and the Eurasian Istanbul terrane in the north. Its opening and closure age is a matter of debate (for details see Göncüoğlu et al., 2012). In NW Anatolia, the IPS is mainly obscured by the right-lateral North Anatolian Transform Fault. Moreover, the mélange complexes of the IPS are partly juxtaposed with ophiolites of the Triassic Palaeotethys (Küre Ophiolites) or oceanic assemblages of the Neotethyan İzmir-Ankara-Erzincan Suture, especially in northern Central Turkey (Figure 1(b)). This led some authors (e.g. Bozkurt, Winchester, & Satır, 2013; Elmas & Yiğitbaş, 2001; Moix et al., 2008) to refuse the existence of the IPS as the representative of a distinct oceanic branch.

One of the critical problems in discriminating the products of these coexisting oceanic branches is the lack of reliable data on the ages of the oceanic assemblages. The available age data from the İzmir-Ankara-Erzincan Suture suggest a Late Triassic to Late Cretaceous age for the oceanic sediments associated with the basaltic rocks derived from different tectonic settings (e.g. Göncüoğlu et al., 2006; Tekin & Göncüoğlu, 2007 Tekin, Göncüoğlu, & Turhan, 2002). Paleontological ages obtained from the Paleotethyan oceanic sediments, on the other hand, vary between the Late Permian (Göncüoğlu, Kuwahara, Tekin, & Turhan, 2004) and Middle (Kozur et al., 2000; Sayıt & Göncüoğlu, 2009, 2013) to Late (e.g. Sayıt, Tekin, & Göncüoğlu, 2011) Triassic. Regarding the age of the IntraPontide oceanic sediments, the findings are restricted to only three records (Göncüoğlu et al., 2008, 2012; Kaya & Kozur, 1987), which range between the Jurassic to Early Cretaceous. In order to have a better coverage of ages on the life span of the IPO, the authors sampled radiolarian cherts along a geotraverse across the IPS in central

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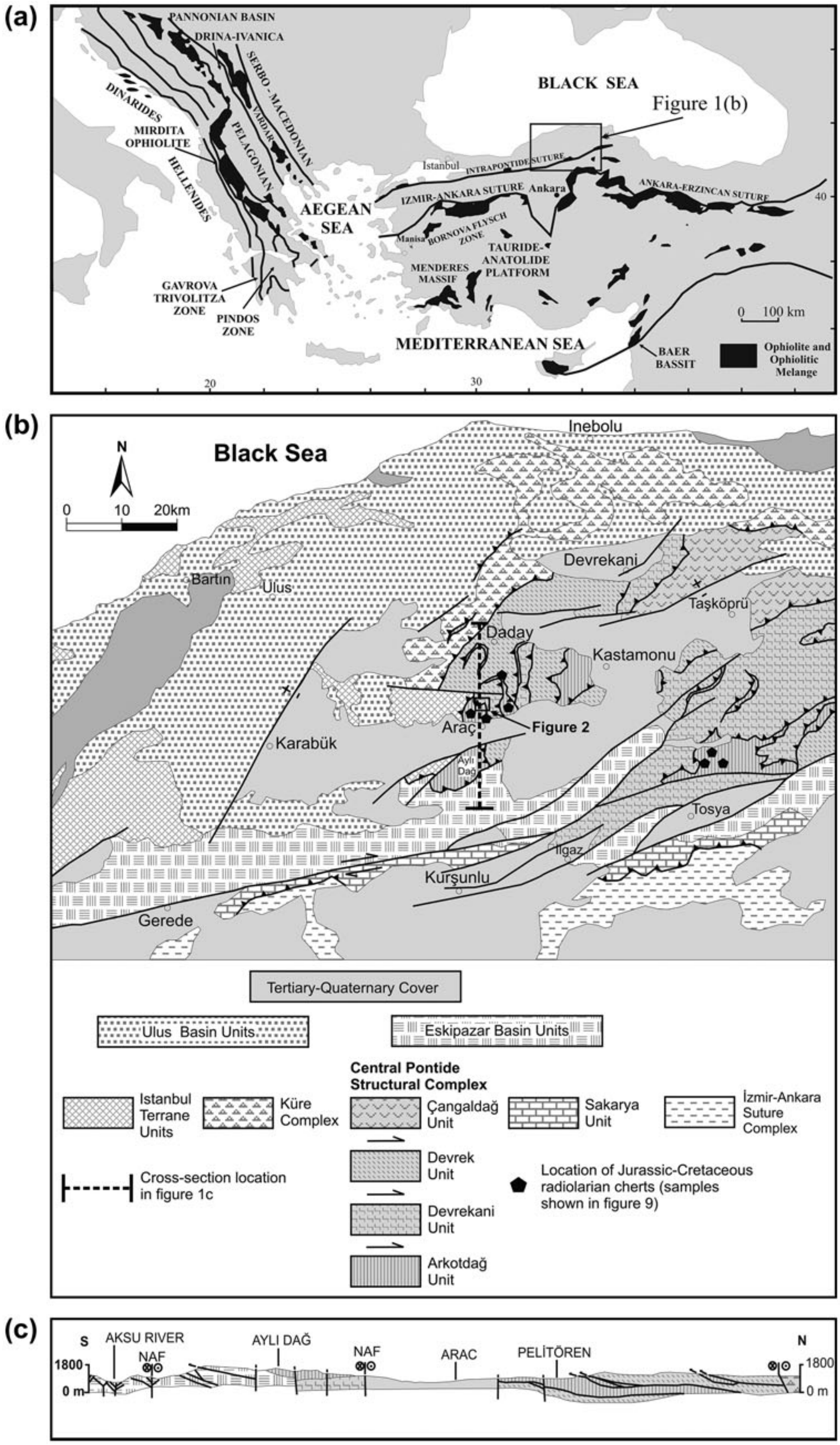

Figure 1. (a) The main tectonic units in NW Turkey and the location of the study area. (b) Simplified geological map showing the structural units in the study area and its surroundings (modified after MTA, 2012). (c) Simplified structural section with the main tectonic slices along the southern Daday–Araç geotraverse the study area. Explanations are the same as Figure 1(b).

northern Turkey (Marroni et al., in review) between Daday and Kurşunlu (Figure 1(a) and (b)). The most interesting finding of this campaign is the discovery of the Middle and Late Triassic radiolarian cherts, which will be described in detail in this paper. This is so far the first Triassic radiolarian finding from the IPS and has important constraints on the evolution of the IPO. By this, the geological meaning of these new data will be discussed within the framework of the evolution of the Neotethyan oceanic branches in the Balkan-N Anatolian realm.

2. Geological setting of the IPS units in the Daday–Kurşunlu geotraverse

Along the Daday–Kurşunlu geotraverse, the IPS zone consists of an imbricate stack of different tectonic units (Figure 1(b) and (c)). It includes slices of metamorphic and ophiolitic rocks separated by the slices of a sedimentary mélange, known as the Arkotdağ mélange (Tokay, 1973), within which Triassic radiolarian cherts have been discovered. To the south of Daday town in the northern part of the geotraverse, the Devrekani Unit is made of garnet-amphibolites, garnet-biotite gneisses and marbles with relict high-grade mineral assemblages imbricated with another metamorphic slice the Daday Unit, with greenschists, metaclastics and limestones, again with relict high-pressure minerals. The protolitic ages of these metamorphic units are not known. Recent Ar/Ar data (Okay, Sunal, & Sherlock, 2011; unpublished data of Marroni et al., in review) from the Devrekani amphibolites suggests metamorphism ages around 150 Ma (Late Jurassic). To the south of the studied geotraverse, these slices overthrust (Figure 1(b)) the Late Cretaceous-Middle Paleocene sedimentary cover of the Sakarya Terrane (Catanzariti et al., 2012). The thrust contacts among these units are covered by the early Eocene sediments and volcanic rocks.

The Arkotdağ mélange is a block-in-matrix sedimentary mélange comprising several blocks of variable sizes. The blocks are originated from both continental (mainly metaclastics, metacarbonates and basaltic rocks) and oceanic crust and mantle (peridotites, gabbros, basalts and cherts). The blocks, making up about 70–75% of the mélange, are bounded by shear zones and/or primary sedimentary contacts with the sedimentary matrix. The matrix is represented by shales, coarse-grained sandstones and mudstones. The late Santonian nannofossils (e.g. *Aspitolithus* cf. *parcus;* Göncüoğlu et al., in press) were obtained from the marly sediments within the matrix. The cherts occur as pebbles and boulders as well as slide-blocks of several hectometers. They are green, gray, red and violet in color, well-bedded, with bed thicknesses of 5–20 cm. They may be massive or may alternate with mm–cm thick shales. The radiolarian assemblages were obtained from more than 30 individual chert samples, sometimes associated with basaltic pillow-basalts. Overall, the radiolarian ages obtained from the chert slide-blocks within the Arkotdağ mélange range from the Middle Triassic (late Anisian) to Late Cretaceous (early Turonian) with a gap in the Early Jurassic (Göncüoğlu et al., 2012). In this study, only the Triassic radiolarian fossils found in the Pelitören section of the Arkotdağ mélange to the NW of the Pelitören village will be reported and illustrated in detail.

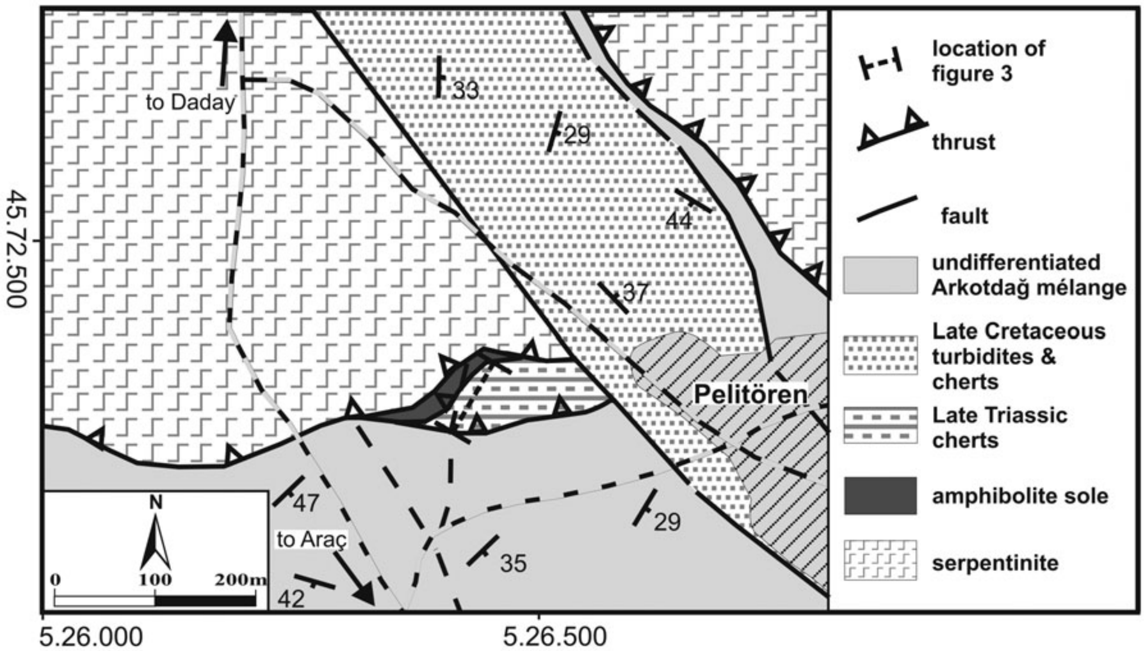

Figure 2. Local geological map of the Pelitören area with the location of the Middle and Late Triassic radiolarian chert block within the Arkotdağ mélange.

3. Lithological characteristics of the Pelitören Section

The Pelitören section (at F30b4 quadrangle sheet, between 45.72.362 N/5.26.406 E and 45.72.430 N/5.26.438 E UTM coordinates) is located to the north of Araç close to the Araç-Daday main road, 200 m to the NW of Pelitören road junction (Figure 2). The section is structurally underlying a thrust-sheet of serpentinized peridotites showing at its base a metamorphic sole consisting of banded amphibolites. It does not represent a stratigraphically coherent succession but comprises four different slide-blocks (Figure 3), which are thrust onto the blocky sediments of the Arkotdağ mélange. The basal part of the measured section is characterized by 25–30 meter thick, highly altered, yellow to brown colored basalts with deformed pillow structures. This part is overlain by 5-meter thick pelagic suite comprising the second interval (Figures 3 and 4(a)). The lower part of this second interval is represented by thin-bedded, mainly red, sometimes pale red colored chert – silicified mudstone – mudstone alternations (Figures 2, 3, and 4(b)). Two samples (12-TC-303A and 12-TC-303B) taken from this part yielded determinable radiolarians of the late Early to early Late Carnian ages.

This part is overlain by a 2-meter thick sequence of a pebbly mudstone with angular chert pebbles of different colors and origins, embedded in a clayey matrix. Two samples (12-TC-303D and 10-IPS-6) derived from these pebbles yielded relatively older radiolarian assemblages (middle Late Anisian and late Early Ladinian) compared with the radiolarians obtained from the basal part of this slice (Figures 2 and 4(c–d)). This pebbly mudstone is overlain by another block made of very thin-bedded, red to green colored chert – mudstone alternation without fossils.

The following two meters of the section is intensively soil-covered. The overlying part is characterized by approx. 10-meter thick, highly deformed, gray to green colored, thin to medium-bedded, chert-mudstone alternation comprising the third fossil-bearing succession (Figures 3 and 4(e)). From three samples collected from this interval, the late Early to early Middle Norian radiolarians have been obtained from the samples 12-TC-303G and 12-TC-303H. The contact with the tectonically overlying metamorphic sole is characterized by a 30-cm thick, extremely brecciated zone with angular chert fragments embedded in a matrix of finer chert grains cemented by cryptocrystalline quartz (Figures 3 and 4(f)).

4. Radiolarian assemblages from the Pelitören region

In the Pelitören section, the sample (12-TC-303A) taken from the basal part of the section yielded *Spongotortilispinus tortilis* (Kozur & Mostler) (Figure 5(a), *Pseudostylosphaera nazarovi* (Kozur & Mostler) (Figure 5(b)),

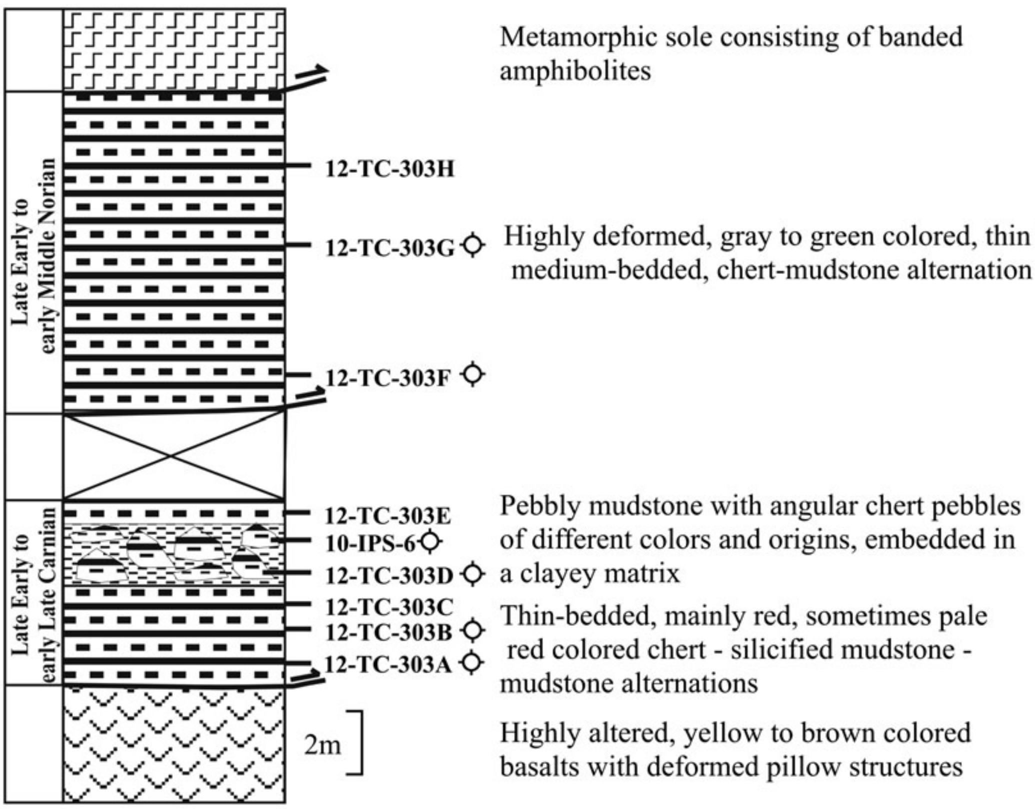

Figure 3. Log of the Pelitören section and sample locations.

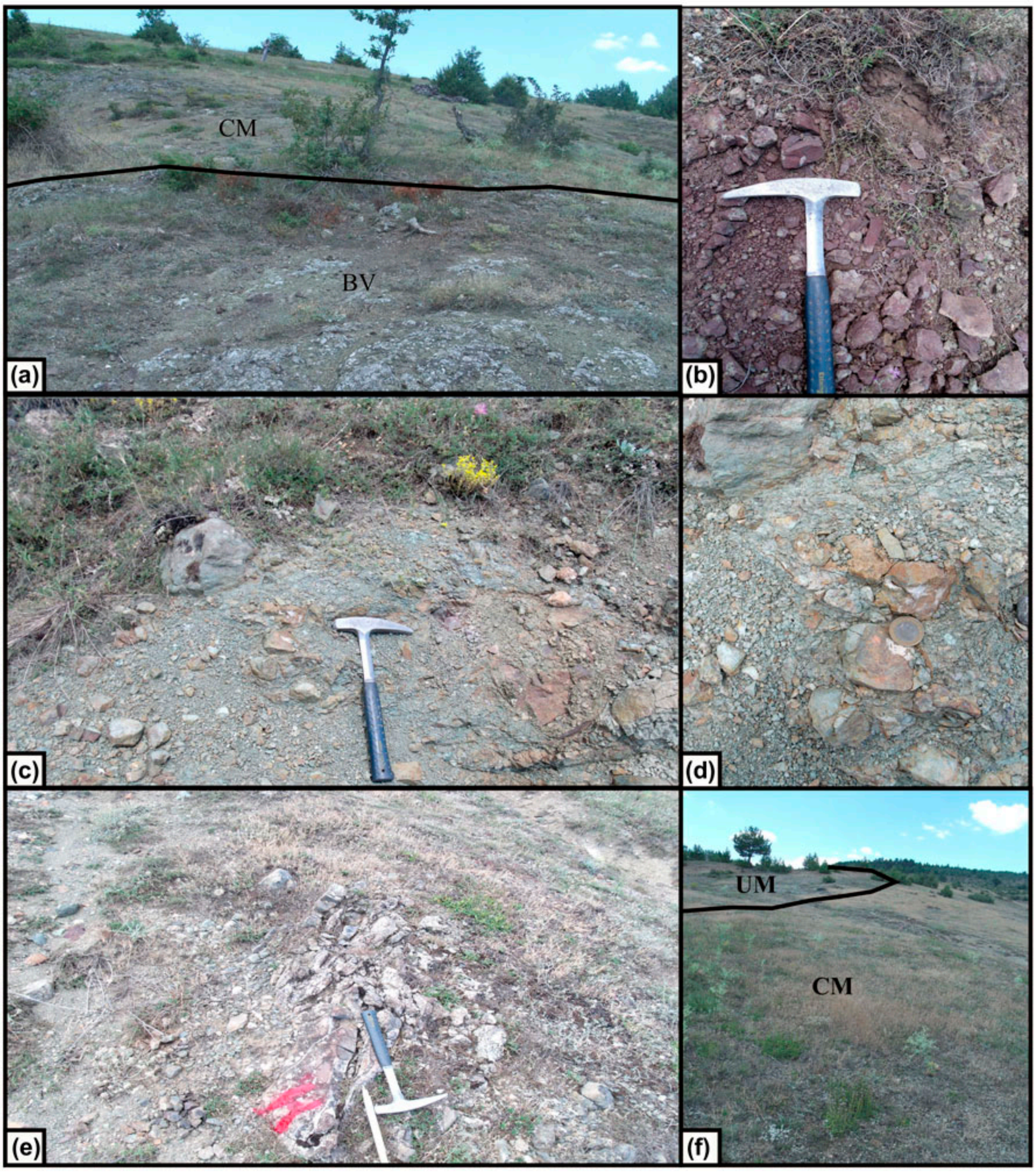

Figure 4. Field photographs from the Pelitören section: (a) Photographs showing the relation between first and second slices. Basic volcanics (BV) at the base of the section overlain by chert-mudstone alternations (CM) of the second slice with tectonic contact; (b) thin-bedded, red colored chert and silicified mudstone alternations where the sample 12-TC-303A was taken; (c–d) angular clasts derived from different lithologies (mainly chert) in clayey matrix, from where samples (12-TC-303D and 10-IPS-6) were collected; (e) photograph showing the locality of sample 12-TC-303H from highly deformed, gray to green colored, thin to medium-bedded, chert-mudstone (CM) alternations; and (f) tectonic relation between chert-mudstone alternations (CM) of late Early to early Middle Norian age and the overthrusting ophiolite body with an intervening amphibolite slice (UM) at the top of the section.

Nodotetrasphaera cive (Sugiyama) Figure 5(c)), *Annulotriassocampe baldii* Kozur (Figure 5(d), *A. sulovensis* (Kozur & Mock) (Figure 5(e)), *Canoptum cucurbita* (Sugiyama) (Figure 5(f)), *C. levis* Tekin (Figure 5(g)) and *C. inornatum* Tekin (Figure 5(h)). All of the taxa first appear in the Late Ladinian (Figure 6), some of them (*P. nazarovi, Nodotetrasphaera cive* and *Annulotriassocampe sulovensis*) disappear close to the end of middle Carnian based on the recent studies in SE Turkey (Dumitrica, Tekin, & Bedi, 2010, 2013a, 2013b; Tekin & Bedi, 2007a, 2007b). Three taxa (*Canoptum cucurbita*, *C. inornatum* and *C. levis*) are crucial to determine the upper limit of the age of the sample (Figure 6). According to Sugiyama (1997), *Canoptum cucurbita* first

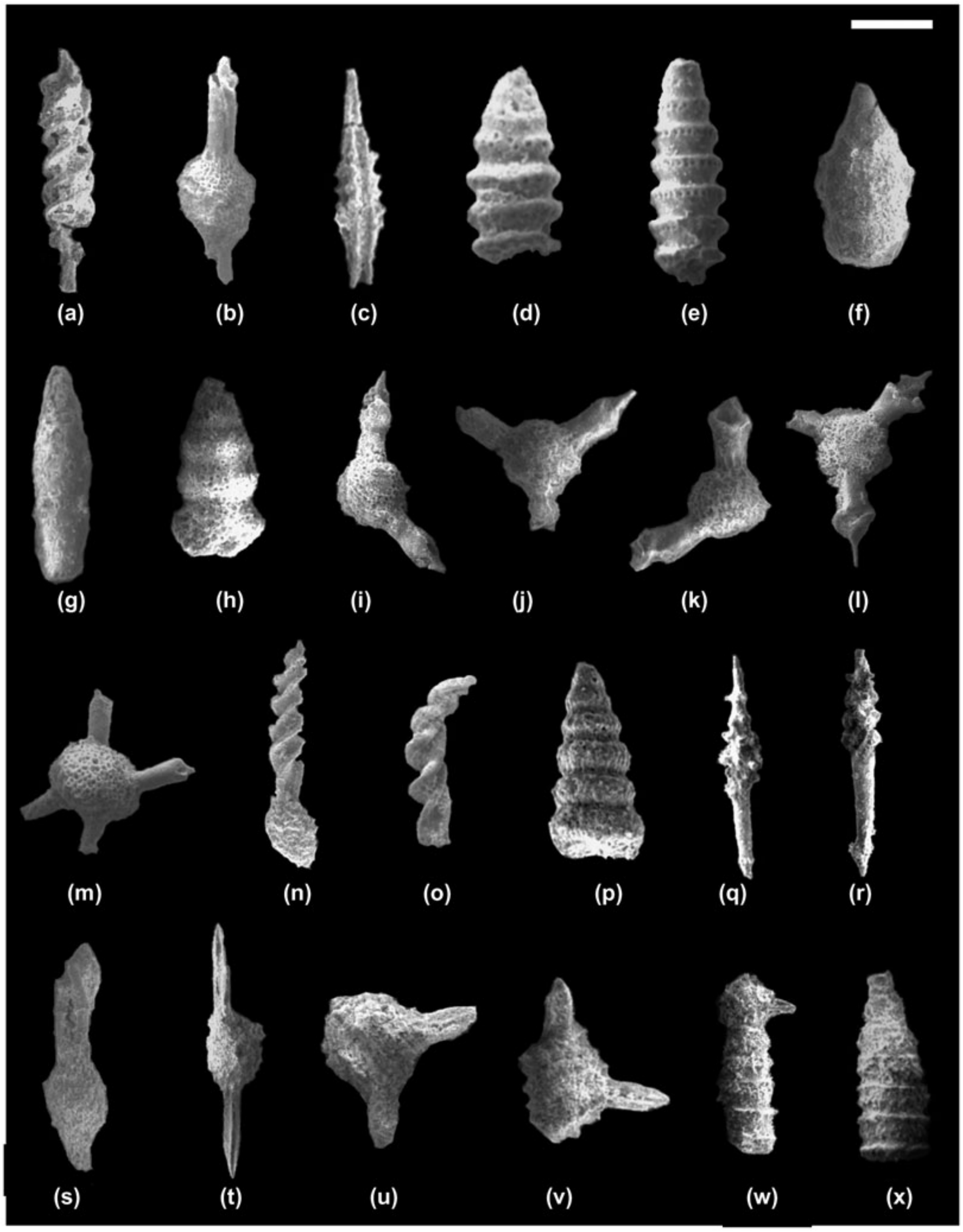

Figure 5. Scanning electron micrographs of the most critical Middle to Late Triassic radiolarians from the IntraPontide Suture Zone, northern Turkey. Scale number of microns for each figure: (a–h) Late Early to early Middle Carnian radiolarians from the sample 12-TC-303A in the Pelitören section: (a) *Spongotortilispinus tortilis* (Kozur & Mostler), scale bar- 100 µm; (b) *Pseudostylosphaera nazarovi* (Kozur and Mostler), scale bar- 125 µm; (c) *Nodotetrasphaera cive* (Sugiyama), scale bar- 100 µm; (d) *Annulotriassocampe baldii* Kozur, scale bar- 60 µm; (e) *Annulotriassocampe sulovensis* (Kozur & Mock), scale bar- 90 µm; (f) *Canoptum cucurbita* (Sugiyama), scale bar- 130 µm; (g) *Canoptum levis* Tekin, scale bar- 135 µm; (h) *Canoptum inornatum* Tekin, bar- 115 µm; (i–p) Early Late Carnian radiolarians from the sample 12-TC-303B in the Pelitören section: (i) *Capnuchosphaera crassa* Yeh, scale bar- 200 µm; (j) *Capnuchosphaera mostleri* Kozur, Moix & Ozsvart, scale bar- 150 µm; (k) *Capnuchosphaera theloides* De Wever, scale bar- 150 µm; (l) *Capnuchosphaera tortuospinosa* Kozur, Moix & Ozsvart, scale bar- 170 µm; (m) *Weverella tetrabrachiata* Kozur and Mostler, scale bar- 120 µm; (n) *Spongotortilispinus tortilis* (Kozur & Mostler), scale bar- 140 µm; (o) *Spongotortilispinus carnicus* (Kozur & Mostler), scale bar- 130 µm; (p) *Pachus multinodosus* Tekin, scale bar- 100 µm. (q–x) Late Early Ladinian radiolarians from the sample 12-TC-303D in the Pelitören section: (q–r) *Paroertlispongus daofuensis* Feng & Liang, scale bar for both specimens- 130 µm; (s) *Pseudostylosphaera inaequata* (Bragin), scale bar- 150 µm; (t) *Pseudostylosphaera longispinosa* Kozur & Mostler, scale bar- 275 µm; (u–v) *Muelleritortis firma* (Gorican), scale bar for both specimens- 125 µm; (w) *Bulbocyrtium* sp. scale bar- 115 µm; and (x) *Triassocampe scalaris* Dumitrica, Kozur & Mostler, scale bar- 100 µm.

appears at the base of TR4A *M. cochleata* L-O. Z. further suggested by Tekin (1999) and disappears in the middle of TR5A *Capnuchosphaera* L-O. Z. corresponding to the basal part of *Tetraporobrachia haeckeli* zone by Kozur and Mostler (1994), Kozur (2003) of early Middle Carnian age (Figure 6). Based on the studies of Tekin (1999), Tekin and Göncüoğlu (2007) and Sayıt et al. (2011) also suggested that *Canoptum inornatum* and *C. levis* have ranges from Late Ladinian to early Middle Carnian as *C. cucurbita*. No specimens of

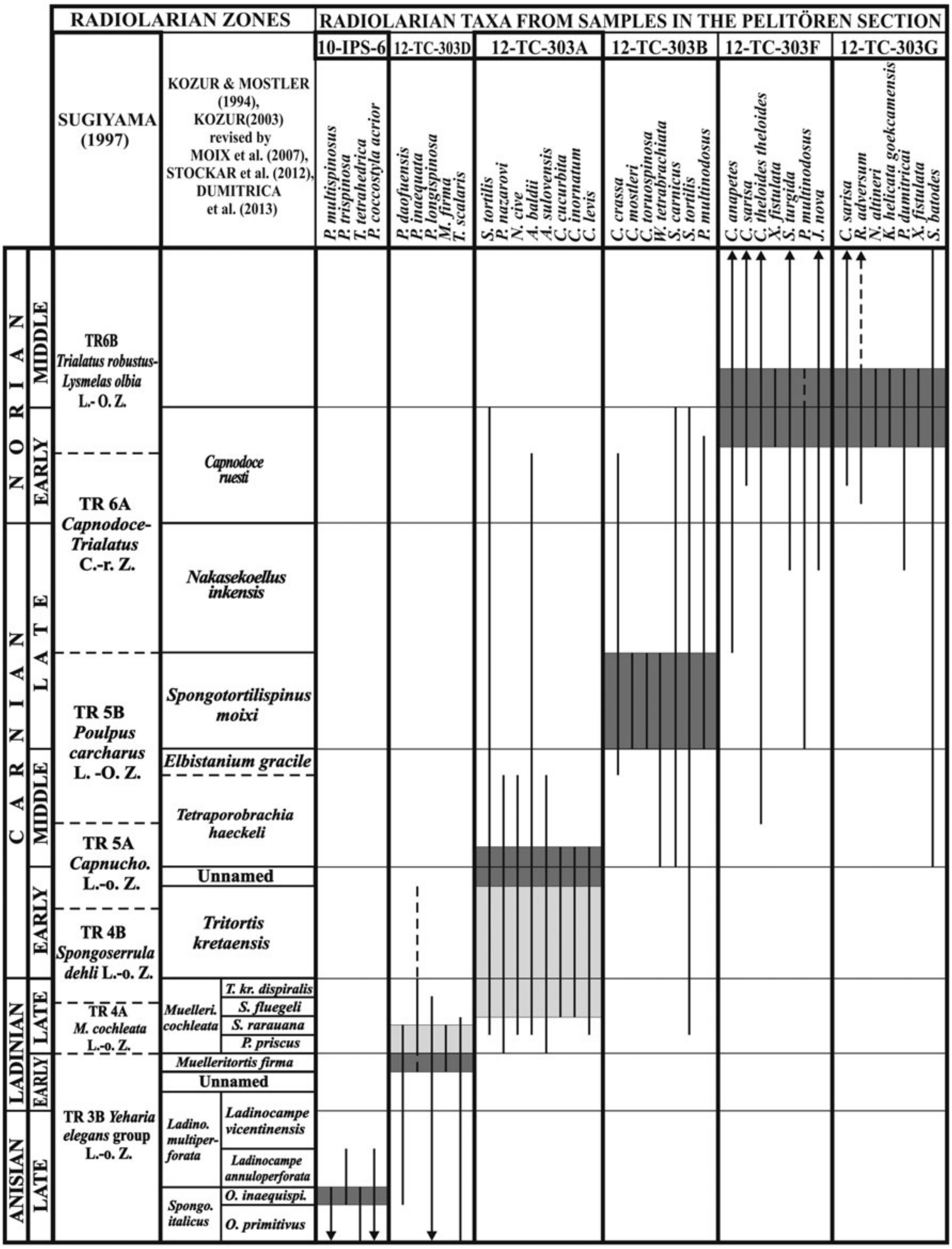

Figure 6. Stratigraphic ranges of the selected Triassic radiolarian taxa in the samples of the Pelitören section. Dark grey areas indicate the age of assemblages while light grey areas show the maximum ages of the assemblages.

Tritortis kretaensis (Kozur & Krahl), which is very characteristic for the latest Ladinian to middle Early Carnian (Bragin, 1991; Kozur, 1988; Kozur & Krahl, 1984; Sugiyama, 1997; Tekin, 1999; Tekin & Göncüoğlu, 2007) have been encountered in the sample 12-TC-303A. Based on this fact, it could be possible to estimate the age of the sample 12-TC-303A as late Early Carnian – early Middle Carnian corresponding to "unnamed" and basal part of the "*Tetraporobrachia haeckeli* Zone" by Kozur and Mostler (1994) and Kozur (2003) and to the middle part of the "*Capnuchosphera* Lowest-Occurrence Zone" by Sugiyama (1997) (Figure 6).

Sample 12-TC-303B contains rich radiolarian fauna including *Capnuchosphaera crassa* Yeh (Figure 5(i)), *C. mostleri* Kozur, Moix & Ozsvart (Figure 5(j)), *C. theloides* De Wever (Figure 5(k)), *C. tortuospinosa* Kozur, Moix & Ozsvart (Figure 5(l)), *Weverella tetrabrachiata* Kozur & Mostler (Figure 5(m)), *Spongotortilispinus tortilis* (Kozur & Mostler) (Figure 5(n)), *S. carnicus* (Kozur & Mostler) (Figure 5(o)) and *Pachus multinodosus* Tekin (Figure 5(p)). Two of the taxa *(Capnuchosphaera mostleri* and *C. tortuospinosa*) have only been determined previously from the early Late Carnian layers (Kozur, Moix, & Ozsvart, 2009) in the Mersin mélange, southern Turkey. While *Pachus multinodosus* appears for the first time at the base of late Carnian (Bragin, 2007; Tekin, 1999)*, Weverella tetrabrachiata* disappears at the end of *Spongotortilispinus moixi* Zone according to Kozur et al. (2009). Thus, radiolarian fauna of sample 12-TC-303B is well correlative to the fauna obtained from the Mersin mélange (Kozur, Moix, & Ozsvart, 2007a, 2007b, 2007c, 2009; Moix et al., 2007) corresponding to *Spongotortilispinus moixi* Zone indicating the early Late Carnian age (Figure 6). Although Kozur et al. (2009) defined the *Elbistanium gracile* Zone for the earliest Late Carnian, subsequently Dumitrica et al. (2013b) suggested that the age of the *Elbistanium gracile* Zone is latest Middle Carnian based on the conodont data (Figure 6). Based on these facts, the age of the sample 12-TC-303B should correspond to the early Late Carnian including its earliest part.

Rich radiolarian fauna *(Paroertlispongus daofuensis* Feng & Liang (Figure 5(q–r)), *Pseudostylosphaera inaequata* (Bragin) (Figure 5(s)), *P. longispinosa* Kozur & Mostler (Figure 5(t)), *Muelleritortis firma* (Gorican) (Figure 5(u–v)), *Bulbocyrtium* sp. (Figure 5(w)) and *Triassocampe scalaris* Dumitrica, Kozur & Mostler (Figure 5(x)) have been obtained from the pebbles in clayey matrix with sample No.12-TC-303D. Although many of the taxa have long ranges (e.g. *Paroertlispongus daofuensis, Pseudostylosphaera longispinosa* and *Triassocampe scalaris*) (Feng & Liang, 2003; Gorican & Buser, 1990; Kozur & Mostler, 1994; Sugiyama, 1997; Tekin, 1999; Tekin & Sönmez, 2010), presence of *Muelleritortis firma* is very crucial to define the age of this assemblage in correspondence to the *Muelleritortis firma* Zone by Kozur and Mostler (1994) and Kozur (2003) (Figure 6). According to the recent study of Tekin and Sönmez (2010), *Muelleritortis firma* co-occur with *Muelleritortis cochleata* until the middle Late Ladinian (to the middle of *Spongoserrula rarauana* subzone of *M. cochleata* Zone) with gradual decrease in amount of *Muelleritortis firma* and gradual increase in amount of *Muelleritortis cochleata.* Because of absence of *Muelleritortis cochleata* in the radiolarian assemblage of sample 12-TC-303D, it can be suggested that the age of the sample is the late Early Ladinian (Figure 6) based on the new zonal scheme of Stockar, Dumitrica, and Baumgartner (2012).

The radiolarian assemblage (*Paroertlispongus multispinosus* Kozur & Mostler shown in Figure 7(a–b), *Paurinella trispinosa* (Lahm) shown in Figure 7(c), *Tetrapaurinella tetrahedrica* Kozur & Mostler shown in Figure 7(d) and *Pseudostylosphaera coccostyla acrior* (Bragin) shown in Figure 7(e)) derived from another pebble (sample 10-IPS-6) in the same pebbly mudstone indicates older ages than the radiolarian assemblages from the other pebbles do. Based on previous studies (e.g. Kozur & Mostler, 1994, 1996; Kozur & Reti, 1986), while *Paurinella trispinosa* first appears at the base of *Oertlispongus inaequispinosus* subzone of *Spongosilicarmiger italicus* zone, *Paroertlispongus multispinosus* and *Tetrapaurinella tetrahedrica* last appear at the end of *O. inaequispinosus* subzone of *S. italicus* zone (Figure 6). Thus, this assemblage clearly reveals the *O. inaequispinosus* subzone of *S. italicus* zone (Figure 6). Previously, this zone corresponded to the late Early Fassanian (early Ladinian) based on the zonal scheme of Kozur and Mostler (1994) and Kozur (2003). However, FAD of *E. curionii* was accepted in 2005 by IUGS Executive Committee as the basalmost Ladinian stage (Brack, Rieber, Nicora, & Mundil, 2005) and due to this fact, the Anisian/Ladinian boundary for radiolarians is tentatively placed to the upper part of the *Ladinocampe vicentinensis* subzone of the *Ladinocampe multiperforata* zone by Stockar et al. (2012). On the basis of this new zonal scheme, the age of the sample 10-IPS-6 is assigned to the middle Late Anisian (Figure 6).

The radiolarian assemblages of the samples 12-TC-303F and 12-TC-303G display close similarities to each other in the third slice of the Pelitören section. While *Capnodoce anapetes* De Wever (Figure 7(f)), *C. sarisa* De Wever (Figure 7(g)), *Capnuchosphaera theloides theloides* De Wever (Figure 7(h)), *Xiphosphaera fistulata* Carter (Figure 7(i)), *Syringocapsa turgida* Blome (Figure 7(j)), *Pachus multinodosus* (Figure 7(k)) and *Japonocampe nova* (Yao) (Figure 7(l)) form the radiolarian assemblage of the sample 12-TC-303F, the radiolarian assemblage of the sample 12-TC-303G includes *Capnodoce sarisa* (Figure 7(m)), *Renzium adversum* Blome (Figure 7(n)), *Nodocapnuchosphaera altineri* Tekin (Figure 7(o)), *Kinyrosphaera helicata goekcamensis* Tekin (Figure 7(p)), *Palaeosaturnalis dumitricai* Tekin (Figure 7(q)), *Xiphosphaera fistulata* Carter (Figure 7(r)), *Syringocapsa batodes* De Wever (Figure 7(s)) and *Whale-*

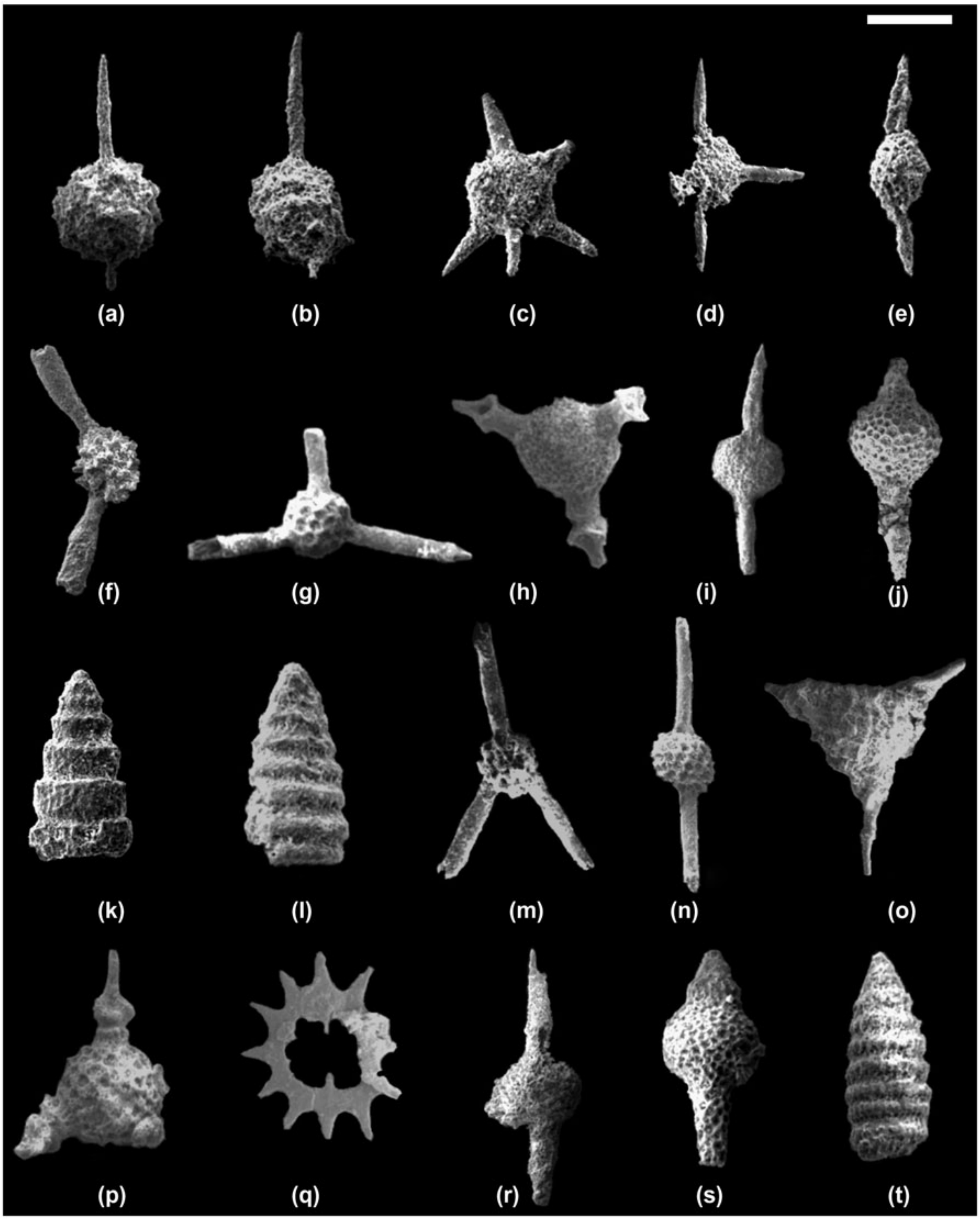

Figure 7. Scanning electron micrographs of the most critical Middle to Late Triassic radiolarians from the IntraPontide Suture Zone, northern Turkey. Scale number of microns for each figure: (a–e) Late Anisian radiolarians from the sample 10-IPS-6 in the Pelitören section: (a–b) *Paroertlispongus multispinosus* Kozur & Mostler, scale bar for both specimens- 190 μm; (c) *Paurinella trispinosa* (Lahm), scale bar- 150 μm; (d) *Tetrapaurinella tetrahedrica* Kozur & Mostler, scale bar- 300 μm; (e) *Pseudostylosphaera coccostyla acrior* (Bragin), scale bar- 120 μm. (f–l) Late Early Norian radiolarians from the sample 12-TC-303F in the Pelitören section: (f) *Capnodoce anapetes* De Wever, scale bar- 140 μm; (g) *Capnodoce sarisa* De Wever, scale bar- 140 μm; (h) *Capnuchosphaera theloides theloides* De Wever, scale bar- 150 μm; (i) *Xiphosphaera fistulata* Carter, scale bar- 240 μm; (j) *Syringocapsa turgida* Blome, scale bar- 105 μm; (k) *Pachus multinodosus* Tekin, scale bar- 110 μm; (l) *Japonocampe nova* (Yao), scale bar- 100 μm. (m–t) Late Early to early Middle Norian radiolarians from the sample 12-TC-303G in the Pelitören section: (m) *Capnodoce sarisa* De Wever, scale bar- 150 μm; (n) *Renzium adversum* Blome, scale bar- 140 μm; (o) *Nodocapnuchosphaera altineri* Tekin, scale bar- 1890 μm; (p) *Kinyrosphaera helicata goekcamensis* Tekin, scale bar- 170 μm; (q) *Palaeosaturnalis dumitricai* Tekin, scale bar- 140 μm; (r) *Xiphosphaera fistulata* Carter, scale bar- 200 μm; (s) *Syringocapsa batodes* De Wever, scale bar- 115 μm; and (t) *Whalenella* sp., scale bar- 110 μm.

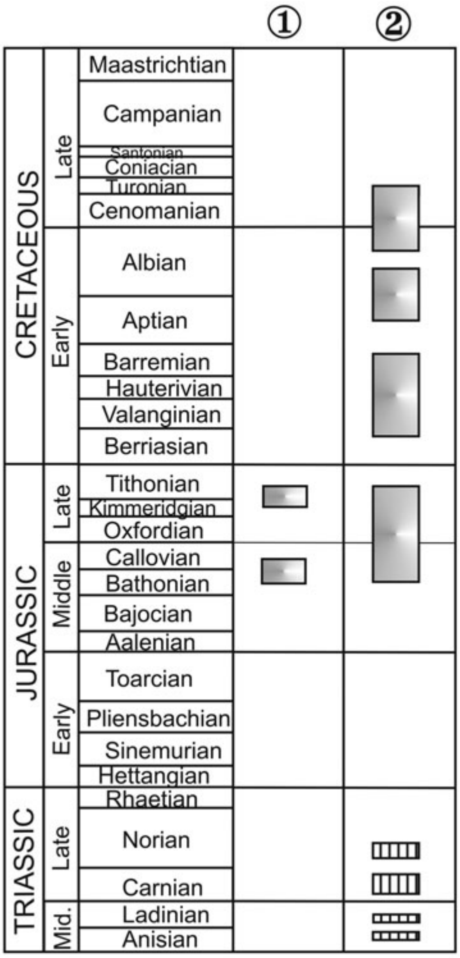

Figure 8. Radiolarian ages from IntraPontide Suture Zone: (1) Middle Bathonian-early Callovian age from sedimentary cover of the Aylı Dag Ophiolite sequence (Göncüoğlu et al., 2012) and late Kimmeridgian-early Tithonian age from slice in IPS (Göncüoğlu et al., 2008) (2) Radiolarian ages recently obtained in from IPS, ages shown with stripes indicate radiolarian ages illustrated in this study.

nella sp. (Figure 7(t)). Both assemblages are very similar and well correlative to the radiolarian fauna of the Kunga group, Queen Charlotte Island by Carter (1991) and fauna from the Antalya Nappes, SE Turkey by Tekin (1999) and Tekin and Yurtsever (2003). Both of them clearly indicate a late Early–early Middle Norian age based on the co-occurrence of *Xiphosphaera fistulata* with abundant *Capnodoce sarisa* in the sample 12-TC-303F and co-occurrence of *Xiphosphaera fistulata, Nodocapnuchosphaera altineri and Kinyrosphaera helicata goekcamensis* with abundant *Capnodoce sarisa* in the sample 12-TC-303G (Figure 6).

5. Geodynamic implications of the new radiolarian data from the IPS belt

Within the mélange complexes of the IPS, a (see Figure 2(b) for the sample locations) wide range of paleontological ages were obtained from the slide-blocks (e.g. Göncüoğlu et al., 2008, 2012, in press). The majority of these ages indicate that the deposition of these slide-blocks was realized within the late Bathonian to early Turonian interval (Figure 8). In some cases, the deposition is accompanied by submarine volcanism, where the geochemistry of the lavas could give a clue about their original geological setting. For instance, a number of MOR-type basaltic lavas in the Bolu area were dated by radiolarians as the Late Jurassic (Göncüoğlu et al., 2008). Further east, however, a well-developed back-arc type ophiolitic succession (the Aylı Dağ Ophiolite, Göncüoğlu et al., 2012) was dated as the Middle Jurassic, based upon the radiolarians of its volcano-sedimentary cover. Overall, most of the available data are indicative for a supra-subduction environment for the IPO crust during the Late Jurassic and Early Cretaceous (for radiolarian data see Figure 9).

By this, the finding of the Middle to Late Triassic (late Anisian to early Middle Norian) radiolarian cherts, as reported for the first time in this paper, is of particular interest for the evolution of the IPO.

The radiolarian cherts in the Pelitören outcrop we found are in tectonic contact with the pillow-basalts (Figure 3). Consequently, there is no indication for their geochemical character that could provide reliable data on their site of deposition. What so ever the primary relation with the oceanic crust generation, the new finding of the Middle Triassic radiolarian cherts within the IPO mélanges clearly indicate that the IPO basin or its margins had reached the deep-water conditions by the Middle Triassic. This fact, in turn, provides new complexities on the pre-existing geodynamic models and constraints for the evolution of the Paleo- and Neotethyan branches in NW Anatolia.

The opening age of the IPO was not supported by any evidence in the initial suggestion, in which Şengör and Yılmaz (1981) had mentioned only a Liassic rifting age. The oceanization of the same was proposed as "the end of the Liassic" by Channell, Tüysüz, Bektaş, and Şengör (1996) or Early Jurassic (e.g. Robertson et al., 1996). Much earlier (Carboniferous) opening ages were also proposed (e.g. Yılmaz & Clift, 1990). Okay et al. (2008) as well accepted an early IPO, saying "probably formed the eastern extension of the Rheic Ocean during the Carboniferous." However, their model diverges in a Mid-Carboniferous closure and reopening "during the Triassic only to close again in the mid-Cretaceous" (Okay et al., 2008). Hence, the middle Late Anisian age as the oldest radiolarian record from the IPO will provide a time constraint for its opening age and for all earlier propositions.

Another conflict that will arise by the new fossil findings is the presumed numbers and locations of the other "inferred" oceanic basins in SE-European-NW Turkish area in previous studies. In a number of recent publications (e.g. Moix et al., 2008; Stampfli, 2000), the IPO is completely ignored and the Sakarya Terrane is

Sample No.	Radiolarian taxa	Age
11-07-11-05	*Zhamoidellum ventricosum* Dumitrica, *Protunuma* spp.	late Bathonian-
	Striatojaponicapsa plicarum (Yao), *Hemicryptocapsa carpathica* (Dumitrica)	early Oxfordian
10-IPS-13	*Emiluvia pessagnoi* s.l. Foreman, *Homoeparonaella elegans* (Pessagno)	middle Oxfordian-
	Cinguloturris carpatica Dumitrica, *Archaeodictyomitra apiarium* (Rüst)	early Tithonian
	A. sp. aff. *A. minoensis* (Mizutani), *Parapodocapsa amhitreptera* Foreman	
10-IPS-12	*Bernoullius spelae* Jud, *Paronaella trifoliacea* Ozvoldova,	late Berriasian -
	P. ? tubulata Steiger, *Tritrabs ewingi* s. l. (Pessagno)	late Hauterivian
	Pyramispongia barmsteinensis (Steiger), *Acanthocircus furiosus* Jud	
11-TC-183	*Cecrops septemporatus* (Parona), *Archaeodictyomitra* spp.,	late Valanginian–
	Pseudodictyomitra sp., *Tethysetta* sp., *Xitus* sp.	early late Barremian
04-07-11-03	*Angulobracchia* spp., *Godia decora* Li & Wu, *G. lenticulata* Jud,	middle Aptian-
	Thanarla brouweri (Tan), *Obeliscoites perspicuus* (Squinabol),	early Albian
05-07-11-02	*Halesium triacanthum* (Squinabol), *Pessagnobrachia fabianii* (Squinabol)	late Albian –
	Cavaspongia euganea (Squinabol), *Novixitus mclaughlini* Pessagno,	late Cenomanian
	Stichomitra communis Squinabol, *Ps. pseudomacrocephala* (Squinabol)	
11-TC-132	*Crucella cachensis* Pessagno, *Patellula ecliptica* O'Dogherty	early Turonian

Figure 9. Jurassic and Cretaceous radiolarian findings from IPS suture zone. The sample locations are shown in Figure 1(b).

considered together with the Istanbul and Zonguldak terranes as the southern margin of the Eurasian Variscan Cordillera, upon which a series of back-arc basins (i.e. Meliata, Maliac and Pindos oceans) opened from the Late Permian to Late Triassic interval (Figure 10(a–b)). Their rifting was ascribed to slab roll-back of a northward subducting "Palaeotethys", which was located between the Eurasian Sakarya and Gondwanan Tauride-Anatolide terranes. Consequently, they belong to a completely different oceanic system than the Paleotethys of Şengör (1987) and Şengör, Yılmaz, and Sungurlu (1984) that was located between the Sakarya terrane in the south and Variscan Cordillera to the south of Eurasia in the north (Figure 10(a–b)). Among the back-arc basins of Moix et al. (2008), the northernmost one was named the Meliata Ocean in the west, and the Küre Ocean in the east between the Istanbul-Zonguldak and the Sakarya terranes (Figure 10(c)). In this reconstruction, the Maliac-Küre oceanic system of Stampfli (2000) and Kozur et al. (2000) corresponds to the Paleotethys of Şengör & Yılmaz (1981).

If the regional tectonic framework is not taken seriously into consideration, the new Middle Triassic radiolarian chert finding in this study would then indicate the presence of at least seven distinct oceanic basins during the Triassic in a rather restricted area: Paleotethys of Şengör and Yılmaz (1981), Paleotethys of Stampfli (2000), Paphlagonian basin of Kozur et al. (2000), Meliata-Küre, Maliac and Pindos oceans of Moix et al. (2008), and the IPO of Şengör and Yılmaz (1981). The distribution of the continental units revised in recent geological maps (Dönmez & Akcay, 2010) and our field-work in the NW Anatolian area (Göncüoğlu et al., 2012) do not support the existence of numerous sutures nor crustal inlayers that might have resulted in such a configuration. Hence, some of these "oceans" should be re-considered and the speculative ones should be eliminated.

Based upon the new age and structural data, some preliminary suggestions are provided. For instance, the Paphlagonian, Meliata-Küre (and Paleotethys sensu Şengör & Yılmaz, 1981) between Sakarya and Istanbul-Zonguldak terranes may represent a single system, formed as arc-back-arc basins upon a northward subducting Late Paleozoic-Triassic ocean. The IPO may represent a remnant part of this system that remains open until the early Late Cretaceous. The pre-Liassic Karakaya mélange *sensu* Okay and Göncüoğlu (2004) within the basement of the Sakarya terrane, on the other hand, may be the representative of the same oceanic crust, formed by the southward subduction and emplaced on the Sakarya Terrane (e.g. Göncüoğlu et al., 2000 (Figure 10(d)).

The Triassic oceanic assemblages in NW Anatolia between the Sakarya and the Tauride-Anatolide units, which were ascribed to Paleotethys sensu Stampfli (2000), on the other hand, have been proven (e.g. Tekin et al., 2002) to be parts of the Neotethyan Izmir-Ankara-Erzincan Ocean and is no more a part of the Paleotethyan puzzle.

Last but not least, the authors are aware of the fact that the data are still fragmentary to see the overall picture but would like to offer their critical comments for the records on the geological evolution of the Tethyan branches in this important area.

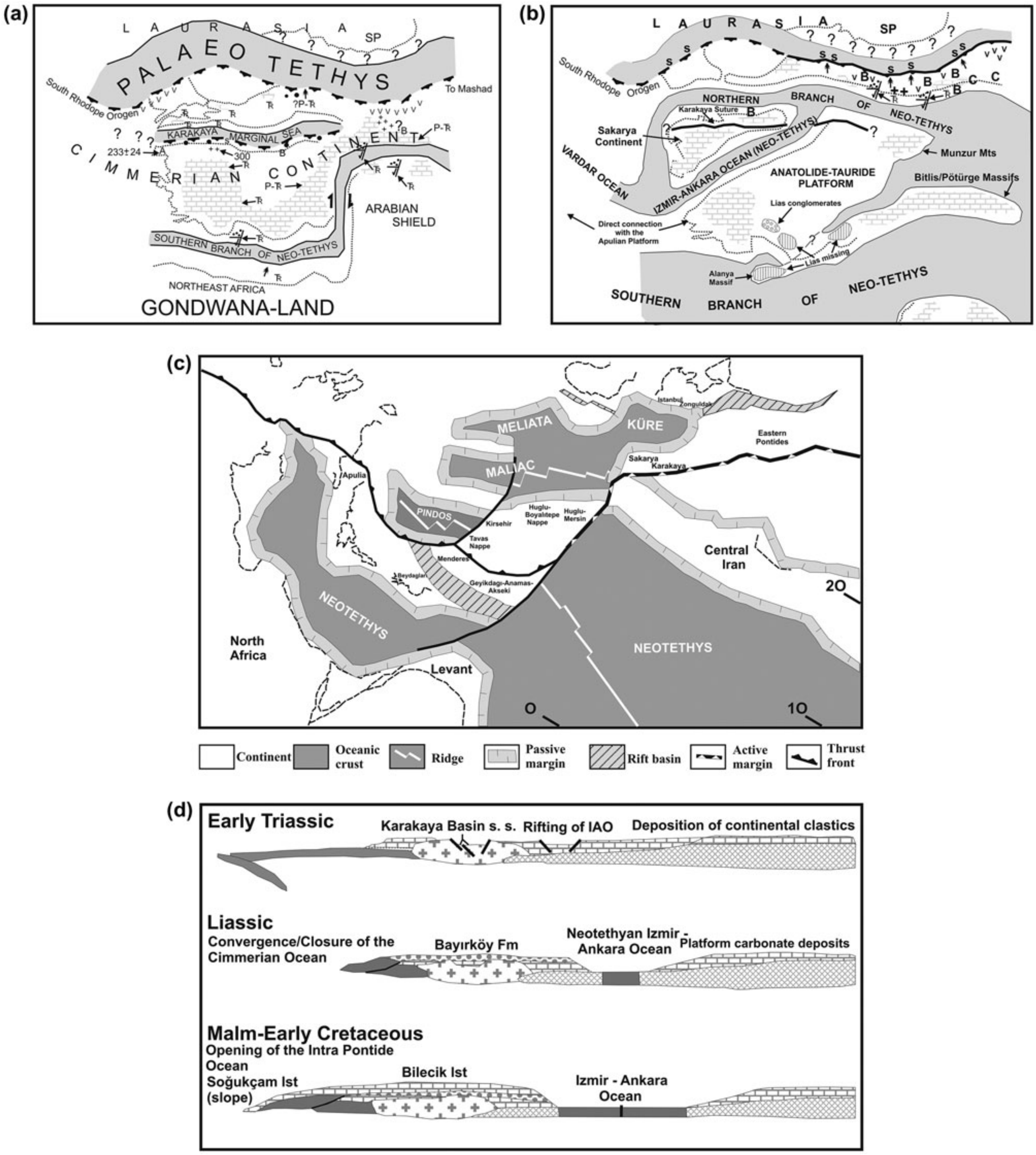

Figure 10. Sketches showing the distribution of the inferred Palaeo- and Neotethyan oceanic branches and terranes during the Triassic in SE Europe and NW Turkey. (a) (Permo-Triassic) and (b) (Early Jurassic): after Şengör and Yılmaz (1981) and Şengör et al. (1984), (c) Carnian paleogeography after Moix et al. (2008). (d) Early Triassic-Early Cretaceous after Göncüoğlu et al. (2000).

6. Conclusions

The Middle to Late Triassic cherts are found as slide-blocks within the Cretaceous IP mélange in central N Anatolia. This suggests that a pelagic sedimentation has occurred in IPO before the Late Jurassic when MORB-type oceanic spreading had been proven (Göncüoğlu et al., 2008). Further findings (e.g. Göncüoğlu et al., 2012, in press) from the basalt-radiolarian chert associations of the IP oceanic crust indicate that the majority of the volcanic rocks were generated in a supra-subduction (arc-back-arc) setting from the Jurassic to Late Cretaceous.

These Middle to Late Triassic ages are so far the oldest ones reported from NW and N Central Anatolia and indicate that the formation of IPO is older than previously suggested. Moreover, these ages suggest that IPO is contemporaneous with several inferred Palaeo- and Neotethyan oceanic branches. The detailed mapping and review of field data show that some of these oceanic basins are speculative and may be merged into a single Late Permian-Late Mesozoic northward subducting oceanic system between the Eurasian Istanbul-Zonguldak in the north and Gondwanan Sakarya Composite Terrane in the south.

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