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Early-middle Carnian radiolarian cherts within the Eymir Unit, Central Turkey: Constraints for the age of the Palaeotethyan Karakaya Complex

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ABSTRACT

A chert-pelagic carbonate formation within the mass flow deposits of the Palaeotethyan Karakaya Complex (mélange) in Ankara has yielded poorly preserved radiolaria. The critical fauna: *Paronaella claviformis* (Kozur and Mostler), *Canoptum cucurbita* (Sugiyama), *Canoptum inornatum* Tekin and *Canoptum levis* Tekin is the late Early Carnian to the early Middle Carnian in age, corresponding to "unnamed radiolarian Zone" and "*Tetraporobrachia haeckeli* Zone" and partly to *Capnuchosphera* Lowest-Occurrence Zone. This is so far the first finding of deep marine sediments from the Karakaya Complex in primary association with the olistostromes including the olistoliths of high pressure/low temperature (HP/LT) metabasic rocks and Paleozoic carbonates in the Ankara area. Considering the available data, we suggest that during the Late Triassic the mélange-forming processes in the South Palaeotethyan margin, which is of both tectonic and sedimentary character, included subduction of Mid-Triassic oceanic islands, HP/LT metamorphism, exhumation and transportation into the foreland basins on the Sakarya continental crust.

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1. Introduction

It is indisputably accepted that there have been a number of seaways (whether of small or gigantic size) that separated the continental fragments from each other during the geodynamic evolution of the earth. Of these oceanic seaways, collectively named the "Tethys", the one that is believed to have existed between the Middle Paleozoic and the Early Mesozoic is known as the "Palaeotethys" (e.g. Sengör and Yilmaz, 1981; Sengör et al., 1984). The northern part of Turkey provides a good opportunity to study the Palaeotethyan events as it holds the evidences related to the closure of the Palaeotethys, or the Cimmeride Orogeny (Sengör and Yilmaz, 1981; Sengör et al., 1984). In Turkey, the remnants of the Cimmeride Orogeny are represented by the Karakaya Complex that extends as an east–west trending belt throughout the northern Turkey (Fig. 1a and b; e.g. Sengör et al., 1984; Okay et al., 1996; Göncüoglu et al., 2000). The Karakaya Complex is of critical importance to understand the fate of the Palaeotethys, since it holds the record of the closure that occurred as a result of the collision between the Laurasian and Gondwanan-derived plates.

The Karakaya Complex constitutes a part of the pre-Liassic basement of the Sakarya Composite Terrane (Göncüoglu et al., 1997), and it is composed of several mélange units with variably metamorphosed rock assemblages (Okay and Göncüoglu, 2004; Sayit and Göncüoglu, 2009a; Sayit et al., 2010). In the NW of Ankara the Karakaya Complex and its Jurassic-Late Cretaceous cover (the Ankara Group in Fig. 1c) have been thrust onto the Ankara Mélange that represents the Late Cretaceous Melange Complex (the Anatolian Complex in Fig. 1c) of the Neotethyan Izmir-Ankara Ocean. Recently, Sayit et al. (2010) reevaluated and redefined two of the main constituents of the Karakaya Complex, namely the Nilüfer and Eymir Units. The former is mainly characterized by an assemblage of metabasaltic lavas associated with volcaniclastics and carbonates, and sits in variably deformed and metamorphosed mass flow deposits. These mass flow deposits forming the matrix material in which the Nilüfer Unit and platform-type Devonian-Permian limestone olistoliths are embedded are collectively named the Eymir Unit (Sayit, 2010). In this study, we present the first radiolarian age finding acquired from a chert band interbedded with the clastics within the Eymir Unit, and discuss its significance in the Palaeotethyan context.

2. Geological framework

The Eymir Unit is composed of clastic rocks which have experienced variable degrees of deformation and metamorphism. It consists largely of arkosic sandstones and greywackes alternating with shales. In the areas where the degree of metamorphism is low slates, phyllites and coarser-grained metaclastics

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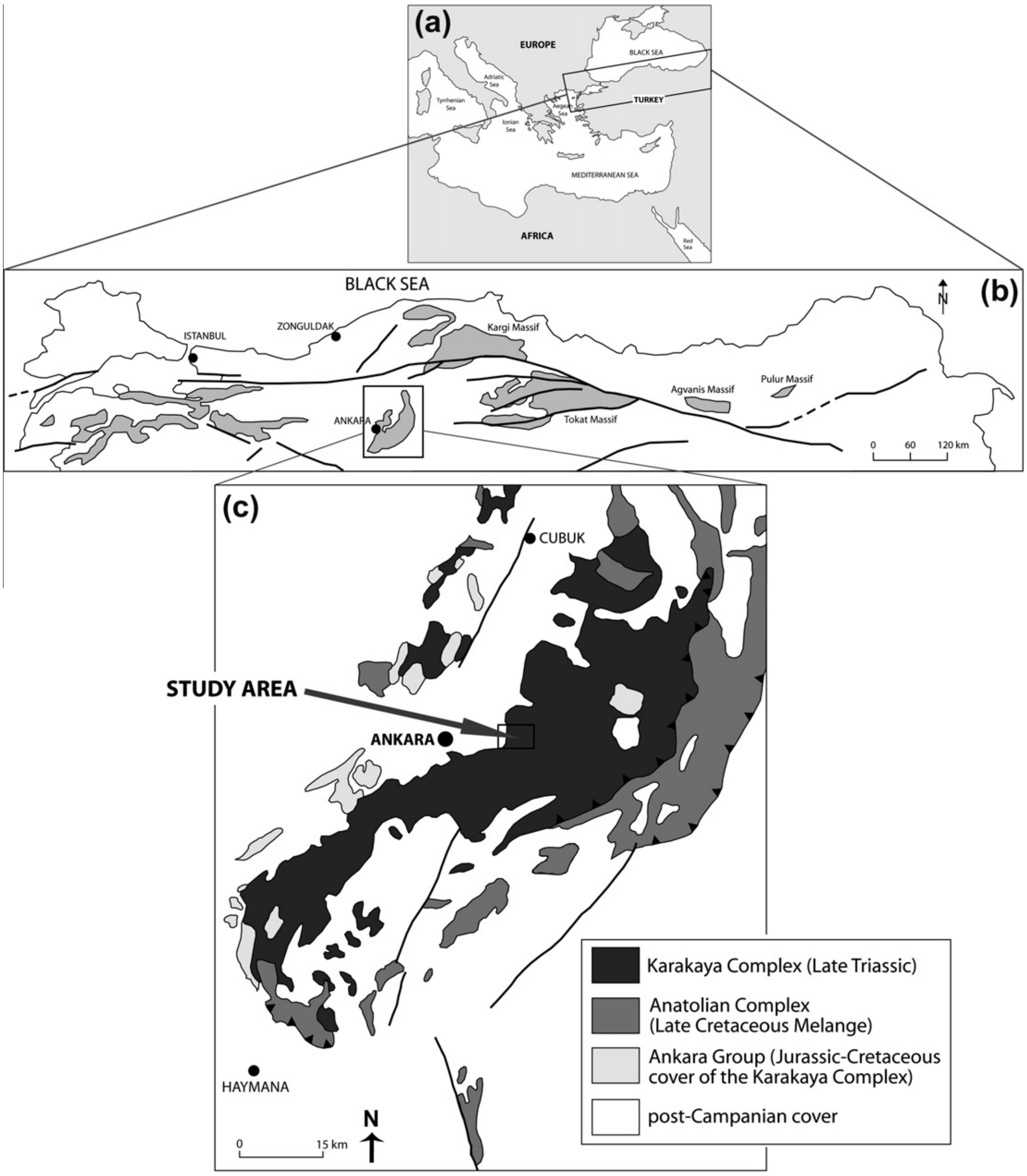

Fig. 1. (a and b) Distribution of the Karakaya Complex in northern Turkey (based on the terrane map of Göncüoglu et al., 1997) and (c) geological map of the Ankara region (modified from Kocyigit, 1991).

with well-developed foliation can be observed. Some parts of the Eymir Unit reflect olistostromal character, containing clasts of different origins. Some studies (e.g. Bingöl et al., 1973; Akyürek et al., 1984; Kocyigit, 1987; Altiner and Kocyigit, 1993; Genc and Yilmaz, 1995) interpreted these metaclastics as primarily associated with the metabasaltic rocks of the Nilüfer Unit, while the others treated them separately (e.g. Okay, 2000; Sayit and Göncüoglu, 2009b; Sayit et al., 2010).

In the Ankara region, the Eymir Unit partially comprises the Eymir Complex (Kocyigit, 1992) or the Emir Formation (Akyürek et al., 1984), the Elmadag Formation (Akyürek et al., 1984), the Elmadag Blocky Series (Erol, 1956), the Limestone Blocky Mélange (Norman, 1973), and the Kulm Flysch Formation (Erk, 1977). The Eymir Unit differs from these previously defined units in that it does not include any metabasic rocks in primary relation with the sediments. Lithologically, the Eymir Unit corresponds to the Diskaya Formation (Kaya et al., 1986; Kaya, 1991) and the Orhanlar Greywacke (Okay et al., 1991) in NW Turkey. The age of the Eymir Unit has been obtained from its relatively less metamorphosed portions. The "Halobia shales" occurring as blocks within the olistostromal parts of the unit indicate a Norian (Late Triassic) age (Kaya et al., 1986). Similar *Halobia* macrofauna that constrains the age of these clastics to the Late Triassic has also been reported by some other studies (Okay et al., 1991; Wiedmann et al., 1992; Leven and Okay, 1996; Okay and Altiner, 2004). Okay and Altiner (2004) suggested the same age (Late Triassic) on the basis of the neritic limestones that they interpreted them to be primarily associated with the clastics. In the Ankara region, a similar age has also been obtained for the Eymir Unit. Özgül (1993) suggested a Carnian–Rhaetian age (Late Triassic) on the basis of the fossil fauna (foraminifers) in the limestones of the unit. However, Akyürek et al. (1984) proposed a wider interval, assigning an Early to Late Triassic age to the unit.

In the present study, a Carnian–Norian age (Late Triassic) is obtained from a red chert band within the clastics of the Eymir Unit. This new finding appears to be consistent with the previous

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observations suggesting a Late Triassic age. Furthermore, it is of particular importance, since this is the first time that an age data has been acquired from the cherts primarily related with terrigenous clastics of the Eymir Unit in the Ankara region.

3. Field observations

The radiolarian chert layers occur within the Eymir Formation in Ortaköy Village, to the north of Ankara (Fig. 2). In the southeast outskirts of the village the olistostromal conglomerates of the Eymir Unit rest on a large block of the Nilüfer Unit made of an alternation of pillow lavas associated with volcaniclastics, red-pink mudstones and micritic limestones. The conglomeratic levels are dominated by gray-pinkish gray limestone boulders and deformed dacites. They alternate with green-gray greywackes (Fig. 3) that constitute the matrix. The greywackes comprise angular mineral fragments of plagioclase, quartz, biotite, epidote, muscovite, tourmaline, zircon together with rock fragments such as granite, dacite, rhyolite, sandstone, muscovite-chlorite schist, limestone, and lydite. Fine-grained muscovite occurs along the foliation planes in the sheared rocks. Upward, they are followed by gray and black shales. They are characterized by slaty cleavage and include very fine-grained white mica neoformations. The thickness of the shales reaches up to 6 m. The transition to the overlying limestone-chert-mudstone package with fossiliferous samples is marked by slightly recrystallized beige limey mudstones.

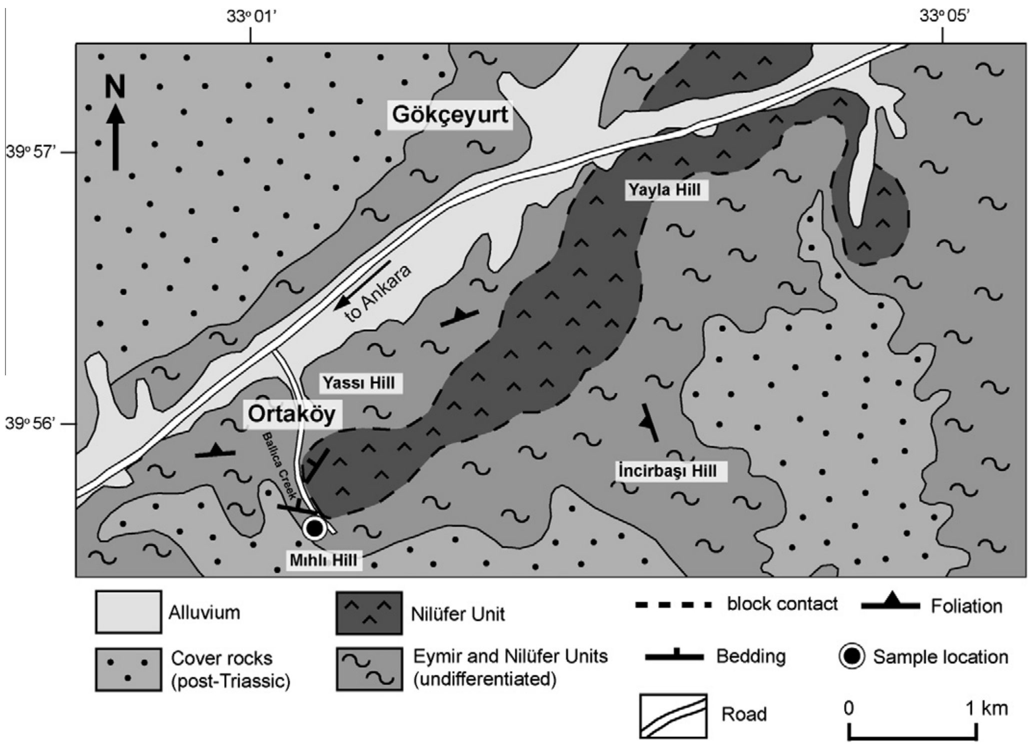

Fig. 2. Geological map of the area between Ortaköy and Gökceyurt (modified from the 1/100,000 scale MTA geological map compiled by Dönmez et al., 2008).

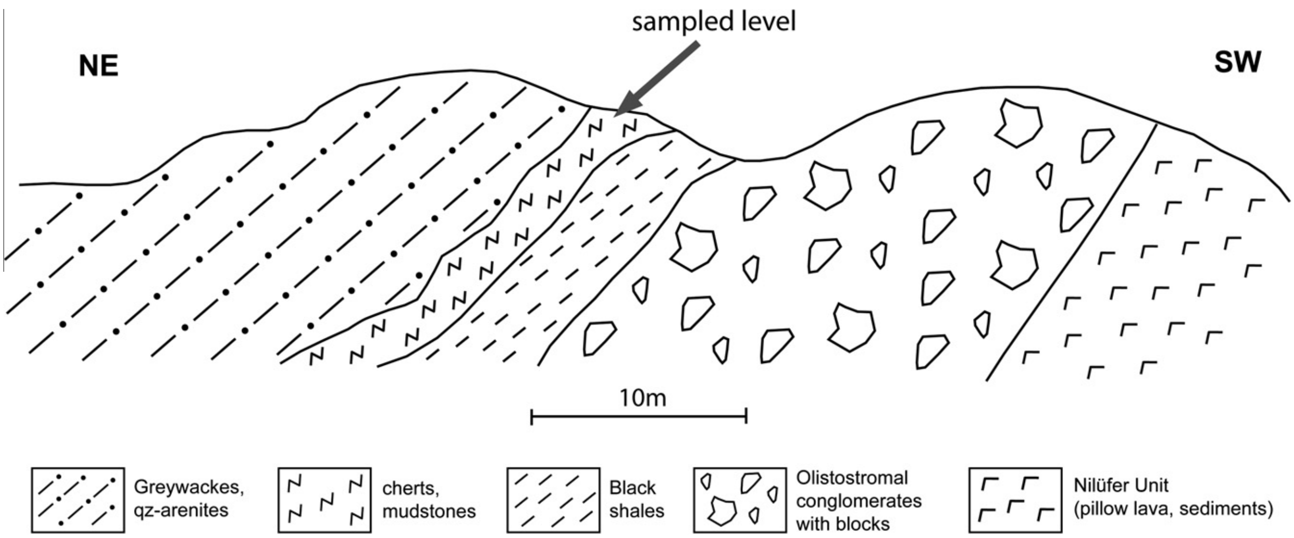

Fig. 3. Cross-section of the studied succession in the Ortaköy area.

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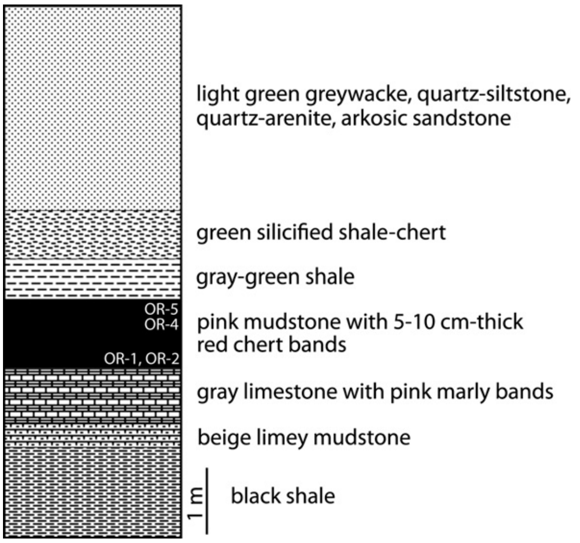

Fig. 4. Measured columnar section of the studied succession. Samples examined are shown on the figure.

The limestone-chert-mudstone package is about 3.5 m thick (Fig. 4) and can be followed more than 100 m along-strike at the right bank of the Ballica Creek to the north of the Mihli Hill (Fig. 2). The outcrops at the feet of the high-voltage energy transmittance mast are the most complete ones. The lower ninety centimeters of the package includes pinkish gray limestone with pink marly bands. The overlying red mudstone band of about 1 m thick includes intervals of brick-red radiolarian chert layers that range between 5 and 10 cm in thickness (Fig. 4). The cherts are locally offset by microfaults and cut by quartz-veins. Five samples were taken from these chert layers, from which only two yielded radiolarians. The host red mudstones are laminated and include carbonate and mica-rich intervals.

The fossiliferous package is overlain by gray and greenish gray shales, transitional to the overlying green silicified shales and green cherts (Fig. 4). The overlying succession is characterized by a thick package of light gray and greenish greywackes alternating with quartz-siltstone, quartz-arenite and arkosic sandstone.

4. Radiolarian dating and comparison of the assemblages

Of the five samples, only OR-1 and -2 from the lowest chert bands (Fig. 4) yielded radiolarians. Although they are not well-preserved due to deformation, and not too much diverse (Fig. 5), four species occurring in the assemblage (*Paronaella claviformis* (Kozur and Mostler), *Canoptum cucurbita* (Sugiyama), *Canoptum inornatum* Tekin and *Canoptum levis* Tekin) are well-enough for dating (Fig. 6).

P. claviformis was first determined from the Grossreifling (Austria) by Kozur and Mostler (1978) from the lower Middle Carnian strata. Based on the studies on the western and southwestern Turkey (Tekin, 1999; Tekin and Göncüoglu, 2007), its range has been estimated as the late Ladinian to late Middle Carnian (Fig. 6). *C. cucurbita*, *C. inornatum* and *C. levis* have their first appearance datum in *Spongoserrula rarauna* zone of *Mulleritortis cochleata* zone corresponding to the middle late Ladinian and LAD of these taxa is at the early Middle Carnian based on the studies in central Japan (Sugiyama, 1997), Bosnia and Herzegovina (Tekin and Mostler, 2005) and western and southwestern Turkey (Tekin, 1999; Tekin and Göncüoglu, 2007; Fig. 6). Recent studies carried out on the radiolarian assemblages in SE Turkey (Tekin and Bedi, 2007a,b; Dumitrica et al., 2010) pointed out that these taxa are not present in the upper Middle Carnian strata.

Taxa belonging to genus *Paratriassoastrum* first appear at the basal part of the middle Carnian according to Kozur and Mostler (1978, 1981), Lahm (1984), Sugiyama (1997) and Tekin (1999). As the radiolarian faunas of the late Middle Carnian have been partly studied only in western and southwestern Turkey (Tekin, 1999; Tekin and Göncüoglu, 2007), the lower limit of the taxa belonging to these genus are not clear enough. Because of that we could not exclude the late Early Carnian age for these samples (Fig. 6).

Although taxa belonging to genus *Annulotriassocampe* have wider ranges (Fig. 6), poorly preserved taxa belonging to *Annulotriassocampe* (*Annulotriassocampe* sp. cf. *A. baldii* and *A.* sp. cf. *A. sulovensis*) in the samples from the Ortaköy stratigraphic section also reveals a presumable late Early to early Middle Carnian age for these samples comparing to the previous studies (e.g. Kozur and Mostler, 1981; 1994; Sugiyama, 1997; Tekin, 1999; Tekin and Göncüoglu, 2007). Furthermore, the samples from the Ortaköy stratigraphic section contain no specimens of *Tritortis kretaensis* (Kozur and Khrahl) indicating the latest Ladinian to early Early Carnian (Kozur and Krahl, 1984; Bragin, 1986, 1991; Kozur, 1988; Sugiyama, 1997; Tekin, 1999; Tekin and Göncüoglu, 2007), thus supporting the late Early Carnian – early Middle Carnian age for these samples.

Taking into consideration the ranges of these species, a late Early Carnian to early Middle Carnian age can be assigned to these samples, corresponding to " unnamed radiolarian Zone" and "*Tetraporobrachia haeckeli* Zone" by Kozur and Mostler (1994, 1996) and Kozur (2003). It partly corresponds to *Capnuchosphera* Lowest-Occurrence Zone by Sugiyama (1997) (Fig. 6).

5. Discussion

5.1. Correlation of the Karakaya rock-units and their ages

As previously mentioned, the olistostromal metaclastic assemblage defined as the Eymir Unit forms the matrix material in which the other Karakaya units are embedded. This is very apparent in the relationship between the Nilüfer Unit and the clastics of the Eymir Unit; the latter is definitely of sedimentary character. A similar feature is also described by Sayit and Göncüoglu (2009b) who regard the Bahcecik metabasaltic assemblages (the Nilüfer Unit) as megablocks within the Olukman-type metaclastics (now included in the Eymir Unit). According to Akyürek et al. (1984), however, these units (their Ortaköy and Elmadag Formations) are primarily related, and represent synsedimentary volcanism in a continental rift. They further mention that their Ortaköy and Elmadag Formations are transitional to each other. Kocyigit (1987), on the other hand, accepts the mélange character of these units, but suggests that these units were originally found together in a continental rift setting. This idea is also shared by Kocyigit (1991) and Altiner and Kocyigit (1993) who suggest that their Karakaya Group, composed of the Kendirli Formation (arkosic sandstones), the Bahcecik Formation (volcano-sedimentary succession) and the Olukman Formation (sedimentary mélange), displays a transitional relationship.

A primary relationship between the metabasic assemblages and metaclastics in a continental-rift basin is not supported by this study owing to three reasons. First, there is no continent-derived detritus found within the Nilüfer Unit, as also supported by a number of studies (e.g. Pickett and Robertson, 2004; Okay, 2000; Sayit et al., 2010). Second, the Nilüfer metabasaltic rocks are typical of ocean island/seamount origin, and reflect no continental contamination in terms of their geochemical character (Sayit et al., 2010). Third, the presence of some HP/LT varieties within the Nilüfer metabasic rocks (e.g. Okay et al., 1991) suggests that the Nilüfer Unit has been affected by subduction-accretion processes.

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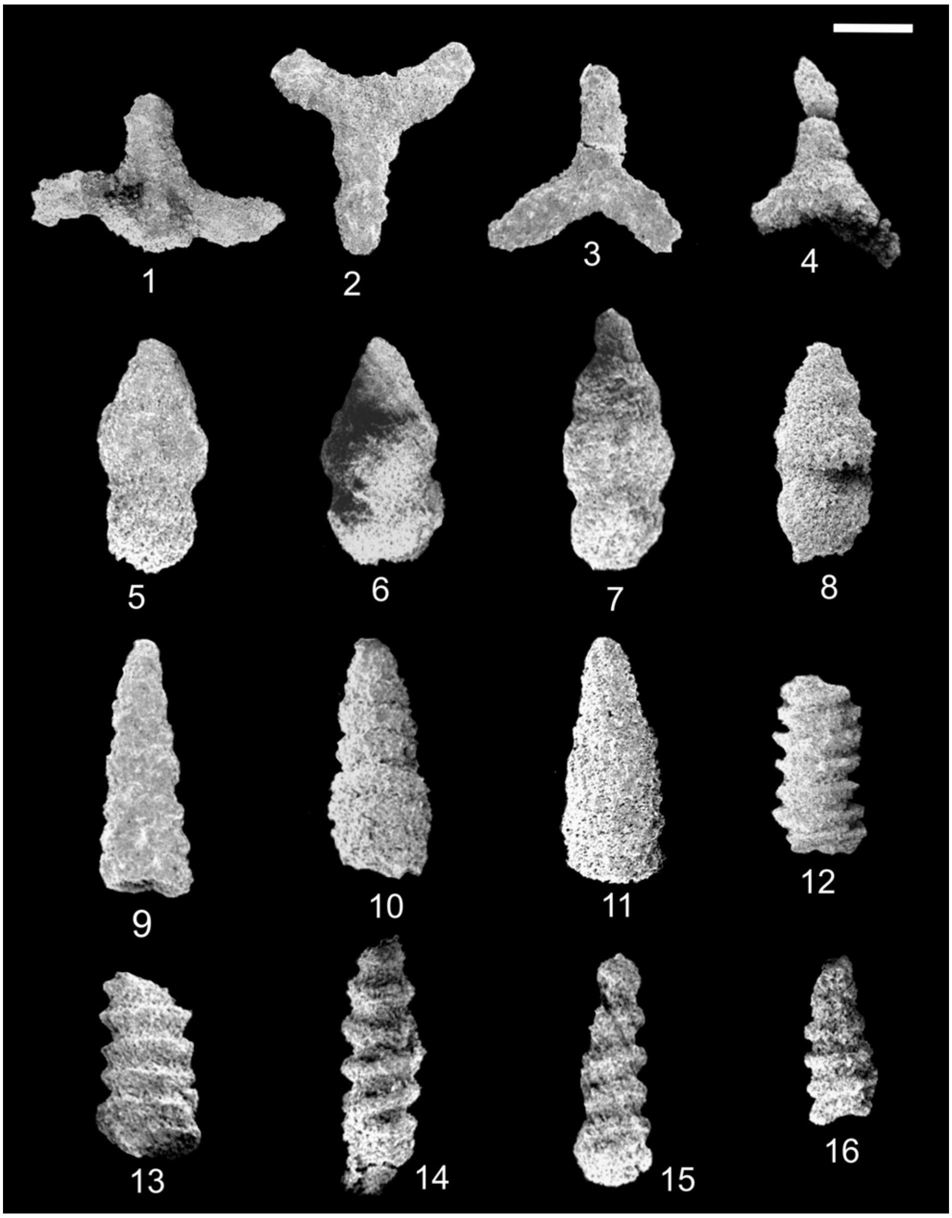

Fig. 5. Scanning electron micrographs of early to middle Carnian (Late Triassic) Spumellaria (Radiolaria) from the Karakaya Complex near city of Ankara. Scale = number of microns for each Fig. 1. Eptingidae indet., sample no. OR-1, scale bar = 250 μm; 2–3. *Paronaella claviformis* (Kozur and Mostler, 1978), both samples are from sample no. OR-1, scale bar for both figures = 225 μm; 4. *Paratriassoastrum* sp., sample no. OR-1, scale bar = 170 μm; 5–8. *Canoptum cucurbita* (Sugiyama, 1997), all samples are from sample no. OR-1, scale bar for all figures = 100 μm; 9. *Canoptum inornatum* Tekin, 1999, sample no. OR-1, scale bar = 100 μm; 10. *Canoptum levis* Tekin, 1999, sample no. OR-2, scale bar = 80 μm; 11. ? *Multimonilis* sp., sample no. OR-1, scale bar = 110 μm; 12–13. *Annulotriassocampe* sp. cf. *A. baldii* Kozur, 1994 Group, 12. Sample no. OR-1, 13. Sample no. OR-2, scale bar for both figures = 130 μm; 14–16. *Annulotriassocampe* sp. cf. *A. sulovensis* (Kozur and Mock, 1981), 14. Sample no. OR-1, 15–16. Sample no. 08-Orta-2, scale bar for all figures = 120 μm.

A coeval formation of the volcanic-volcanosedimentary as well as clastic lithologies in a rift basin is also not confirmed, as their ages are completely different (Nilüfer Unit: Anisian–Ladinian, Sayit and Göncüoglu, 2009b; Eymir Unit: Carnian–Norian, this study).

This study presents the first radiolarian finding acquired from the cherts primarily associated with metaclastics of the Eymir Unit in the Ankara region. Considering the age, the new finding is consistent with the previous works (Akyürek et al., 1984; Özgül, 1993). Actually, based on the foraminiferal fauna obtained from limestones, Akyürek et al. (1984) suggested a relatively wide interval, namely Early-Middle-Late Triassic, for the age of the Eymir Unit (their Elmadag Formation). It must be noted, however, that the Early and Middle Triassic ages based on foraminiferal fauna are from neritic limestone olistoliths. The in situ Carnian (Late Triassic) radiolarian chert finding obtained in this study, therefore, is of crucial importance to suggest installation of a relatively deep basin during the Late Triassic. Although the Chanxingian (Late Permian) age finding of Göncüoglu et al. (2004) in the Geyve area is also based on a chert layer within metaclastics, the overall geological framework suggests an earlier deepening on a Permian continental platform. The presence of the Gondwana-type shallow water Permian limestones in this area (Turhan et al., 2004; Okuyucu and Göncüoglu, 2010) is more consistent with the idea that this deepening may be related to an extensional basin within the platform. The Late Triassic metaclastics, on the other hand, should have developed in a different tectonic environment then the Late Perm-

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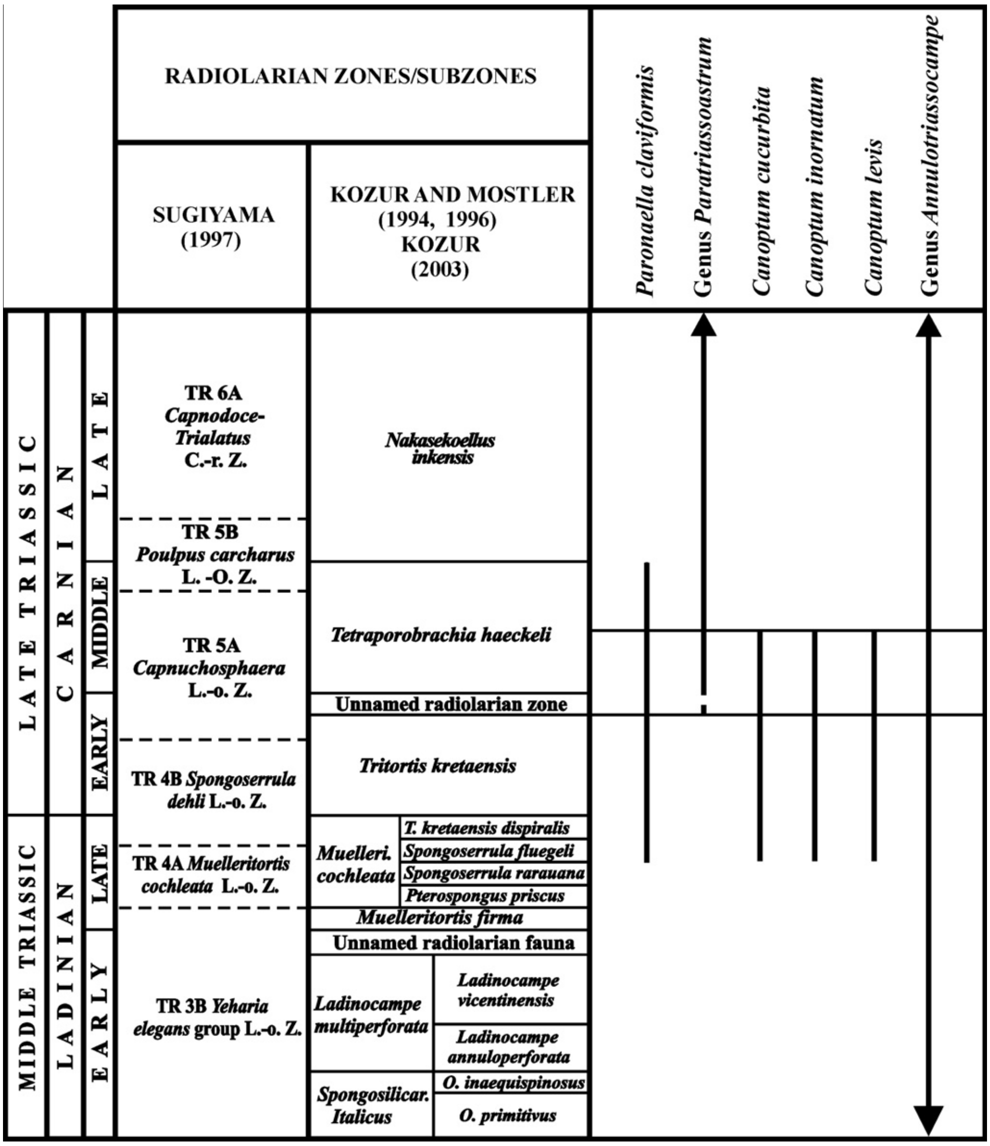

Fig. 6. Radiolarian zones and subzones for Ladinian–Carnian periods after Sugiyama (1997), Kozur and Mostler (1994, 1996), Kozur (2003) and stratigraphic ranges of selected radiolarian taxa from samples OR-1 and -2. The dotted area shows the supposed age of the studied assemblage. The broken lines show the supposed part of stratigraphic intervals of the taxa.

ian clastics. For example, the Rhaetian–Norian neritic limestone (the Kasal Limestone) within the Hodul Unit (now defined as the Eymir Unit) is interpreted to represent in situ shallow-marine carbonate deposition with the clastics (Okay and Altiner, 2004). The Late Triassic conodont finding of Önder and Göncüoglu (1989) from the recrystallized shallow-marine limestone found within the Iznik Metamorphics further supports this result. At this point, it is noteworthy to mention that this recrystallized limestone interbedded with chert and mud is bounded at its top and bottom by the terrigenous clastics which comprise metabasic lithologies (Göncüoglu et al., 1987). These clastics, in fact, may be associated with these metabasic rocks with a block-matrix relationship, analogous to the situation seen in the Ankara region. Therefore, the clastic assemblages evaluated under the term "Iznik Metamorphics" can be regarded as the equivalent of the Eymir Unit redefined in this study. The metaclastic assemblages alternating with carbonates found to the NW of Domanic may also be considered within the context of Eymir Unit. The carbonates interbedded with these clastics have yielded a Late Norian age (Kaya et al., 2001), in agreement with the other age findings noted above. Therefore, there are several lines of evidence indicating that the deposition of the Eymir-type clastics during the Late Triassic occured both in shallow (e.g. Kaşal-type neritic limestones) and deep marine (e.g. Halobia-bearing shales and radiolarian cherts) environments.

Another constraint for the origin and formation of these clastic rocks is related to their clast-type. The preliminary data from the microconglomerates and sandstones in the Ankara region (Sayit, 2005) and NW Anatolia (Tetiker et al., 2009) unquestionably indicate the presence of a source region where felsic magmatic rocks (granites, rhyolites–dacites), metamorphic rocks (chlorite-muscovite schist) and Paleozoic limestones have dominated.

By this, any geodynamic model for the evolution of the Karakaya complex should take the following evidences into consideration:

1. The Karakaya Complex represents a tectonic/sedimentary mélange complex, including oceanic assemblages (the Nilüfer Unit), associated with olistostromes with continent-derived

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detritus, olistoliths and shallow as well as deep marine sediments (the Eymir Unit). It resembles a broken formation, a feature obtained during its subduction and accretion.
2. It comprises slices where HP/LT metamorphism has affected both the Nilüfer-type assemblages and their Eymir-type matrix, next to non-metamorphic/initially metamorphic rocks of respective origin.
3. The oceanic lithologies incorporated into the accretionary prism represent oceanic islands and their platforms, and they are mainly of the Middle Triassic age.
4. The juxtaposition of the members of the complex and their metamorphism age is mainly the Late Triassic.
5. The Karakaya Complex rests upon a Late Paleozoic continental crust fragment and its Triassic cover. The contact between them appears to be mostly tectonic, though primary stratigraphic relationships with some clastic units have also been reported.

5.2. Discussion on the evolutionary models

The continental-rift model (e.g. Bingöl et al., 1973; Sengör and Yilmaz, 1981; Kocyigit, 1987; Altiner and Kocyigit, 1993; Genc and Yilmaz, 1995) interprets the lithologies of the Karakaya Complex as the result of opening of an E–W trending basin on the northern margin of the Tauride–Anatolide Platform via back-arc spreading. This tectonic model was developed primarily to explain the presence of exotic limestone blocks as well as volcano-sedimentary assemblages composed mainly of mafic lavas interbedded with limestone and chert, greywackes and arkosic sandstones (Bingöl et al., 1973). However, in this case, the product is a small basin which does not reflect the main ocean, namely the Palaeotethys. Thus, this thought led those workers to think of a separate Karakaya ocean or basin that was isolated from the Palaeotethys. Consequently, the defenders of this idea suggest a Late Permian-Late Triassic period for the lifetime of this basin. However, the

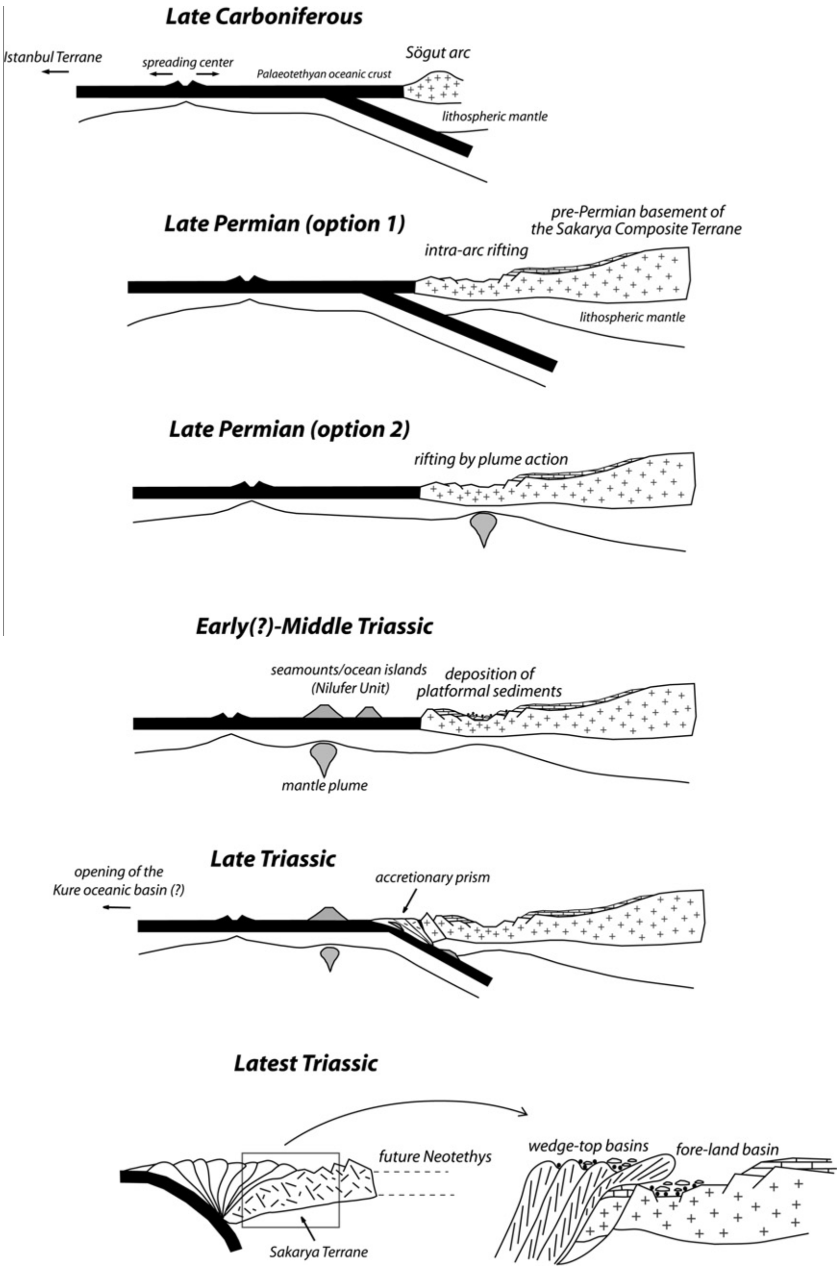

Fig. 7. Geodynamic model for the evolution of the Karakaya Complex study, combining both rift- and subduction/accretion-related processes.

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presence of pelagic sediments of the Late Carboniferous age (Okay and Mostler, 1994) requires the existence of a deep basin as old as Carboniferous. This is also supported by the Late Permian metamorphism age of the metabasic rocks from the eastern sector of the Karakaya Complex (Topuz et al., 2004). This suggests that the subduction process was still ongoing in the Late Permian, therefore indicating the existence of a deep basin before that time.

The other line of thought, which relates the generation of the Karakaya Complex to a subduction/accretion prism, appears to be a more appropriate solution (e.g. Pickett and Robertson, 1996; Okay, 2000; Sayit et al., 2010). In this alternative, some of the Karakaya-related assemblages are regarded to be purely oceanic, such as seamount or oceanic plateau, and they, at the final stage, were incorporated to an accretionary prism during the latest Triassic together with the other assemblages that derived from continental sources. Therefore, in the subduction/accretion model, initially put forward by Tekeli (1981), some of the tectonostratigraphic units should, at least, have developed on, or characterize the Palaeotethys itself.

A combination of rift and accretion models (Göncüoglu et al., 2000), on the other hand, is postulated to explain the co-existence of accreted oceanic material and olistoliths/detritus from the continental crust as well as rift-related sediments within the Karakaya Complex. In this model, the oceanic material derived from Palaeotethys is emplaced onto the Triassic rift-related sediments of the Sakarya Composite terrane. These last two models can also explain the presence of the Late Carboniferous pelagic lithologies and the Late Permian metamorphic ages reported by Topuz et al. (2004).

In order to understand the geodynamic evolution of the Palaeotethyan realm between the Late Paleozoic and latest Triassic, it is more appropriate to start with the end of the Permian, since there is no much data regarding the earlier periods.

If the rift model (the first alternative) is integrated into the subduction/accretion model (the second alternative), a geodynamic model as the following can be proposed (Fig. 6). During the Early Carboniferous, the southward subduction of the Palaeotethyan oceanic slab resulted in arc-type magmatism producing the Sögüt-type assemblages and associated granitoid bodies (e.g. Yilmaz, 1981; Göncüoglu et al., 2000, 2007) on the northern margin of the Gondwanan Tauride–Anatolide Platform (Fig. 6). During the Late Permian, the continued subduction of the Palaeotethyan oceanic slab resulted in rifting of the northern margin of the Gondwanan Tauride–Anatolide Platform. This rift basin (will be called the Karakaya Rift Basin on the basis of this study), was opened on the assemblages represented by a Sögüt-type arc basement and an overlying Permian carbonate platform of Tauride–Anatolide character (Okuyucu and Göncüoglu, 2010. Alternatively, this rift basin may have been opened in response to a mantle plume rising beneath the Palaeotethyan lithosphere. However, in this case, one would expect a highly voluminous magmatism, such as the Oligocene flood volcanism in Yemen (Baker et al., 1996) or the Parana-Etendeka flood volcanism (Peate, 1997), but there is no such example within the Karakaya Complex. Thus, the first option, namely a back-arc rift-type opening, seems more likely. The Karakaya rift basin became gradually deepened to the end of Permian, as reflected by the Changxingian cherts alternating with arkosic sandstones.

During the Early?-Middle Triassic, the oceanic spreading brought the Palaeotethyan oceanic lithosphere over the mantle plume (Fig. 7), resulting in mainly alkaline OIB-like magmatism with enriched geochemical signatures (Sayit and Göncüoglu, 2009b; Sayit et al., 2010). These seamounts created in response to this mantle-plume related magmatism probably grew up to the sea-level or exceeded, and become oceanic islands that sit on the oceanic crust, as indicated by the Anisian neritic limestones interbedded with the metabasalts. In the deeper parts, the deep sea sediments (pelagic limestones, mudstones, cherts) have also been deposited synchronously with metabasalts along the flanks of the oceanic islands. The seamount/ocean island generation continued until the early-Late Triassic as indicated by the Ladinian?–Carnian cherts interbedded with metabasalts in Biga Peninsula, NW Anatolia (Sayit and Göncüoglu, 2009b). During the Late Triassic, with the ongoing subduction, the oceanic islands started to have been incorporated to the accretionary prism in front of the northern margin of the Sakarya platform (Fig. 7). Some of the slices with ocean island material in the subduction-accretion prism should have been deeply buried through the subducting slab as displayed by the development of metamorphic Na-amphibole found in the Nilüfer metabasaltic rocks. In the deeper subducted slices, some of these metabasic rocks also experienced amphibolite and eclogite facies metamorphism (Topuz et al., 2004; Okay and Monie, 1997; Okay et al., 2002). During accretion, olistostromes of continent-derived granitic detritus acted as a matrix for the blocks/slices of ocean-derived material (including exhumed HP rocks) and platform-derived carbonates to form a “sedimentary mélange”. Such a development is known from the circum-Pacific subduction-accretion prisms in Japan (e.g. Isozaki et al., 1990), in California (e.g. Isozaki and Blake, 1994) or in the Tethyan realm (e.g. Marroni et al., 2004).

In periods of tectonic quiescence the deposition of the continent-derived sediments dominated, and formed relatively thick successions of clastic rocks in piggy-back-type basins on top of the prism (Fig. 7). These small basins were the places where the Late Triassic radiolarian cherts (as described in this study) or Kaşal-type shallow-marine limestones (e.g. Okay and Altiner, 2004) were deposited. Over time, the mélange itself was sliced and partly subducted, as deduced from low-grade clastic rocks represented by phengitic slates, phyllites and quartzo-feldspatic schists in the Karakaya Complex.

At the end of the Triassic, the variably metamorphosed subduction prism material, associated sediments and platform-derived blocks were thrust towards south onto foreland basins and deformed together with the Late Paleozoic-Triassic cover of the Sakarya margin. The resulting picture is a chaotically mixed “mélange” where both sedimentary as well as tectonic processes played their role.

The last event we recorded from the Ankara area is dike-swarms of that back-arc-type diabases cutting across the “mélange” (Sayit and Göncüoglu, 2009b). This feature may support the idea that the subduction of the Palaeotethyan oceanic lithosphere was directed towards south, beneath the prism and the Sakarya margin (Fig. 7).

The Early Jurassic regional unconformity on the Karakaya Complex obviously marks the demise of this orogenic event, however there is no evidence indicating that the termination was due to collision with a northerly terrane (e.g. Istanbul–Zonguldak terrane) and complete closure of the Palaeotethys.

6. Conclusion

The Karakaya Complex in NW Anatolia is represented by mass-transport deposits, where variably metamorphosed OIB- and E-MORB-type mafic rocks and associated oceanic sediments occur in a mélange with block-in-matrix-type bodies together with slightly deformed stratigraphic successions. The presence of Na-amphibole in the metabasic rocks indicates their involvement in a subduction zone.

In the Ortaköy area, NE of Ankara, an almost 3.5 m thick package with limestone-chert-mudstone is observed within a slightly deformed sedimentary succession. The thin-bedded brick-red radiolarian cherts yielded, due to deformation, poorly-preserved and poor radiolarian fauna. Four species occurring in it (*P. claviformis*

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(Kozur and Mostler), *C. cucurbita* (Sugiyama), *C. inornatum* Tekin and *C. levis* Tekin) allow their attribution to the late Early Carnian to the early Middle Carnian. This is the first radiolarian age data from the Ankara region and is in accordance with the foraminiferal ages from shallow-marine limestones in NW Anatolia.

This finding clearly indicates that already after the Middle Triassic the subduction of oceanic islands, their uplift and incorporation of their parts (clasts and olistoliths of variable size) into wedge-top or foreland deposits with continent-derived granitoid material were in progress. Moreover, it is obvious that the processes related to subduction, metamorphism, exhumation and transportation into basins were continuous and persisted during the Late Triassic, as deduced from the paleontological data in this study as well as the metamorphism ages of Nilüfer-type HP/LT rocks (e.g. Okay et al., 2002). The termination of this event is defined by the lowermost Jurassic regional unconformity.

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