ELSEVIER

Geobios 35 (2002) 127–135

GEOBIOS

www.elsevier.com/locate/geobios

First evidence of Late Carnian radiolarians from the Izmir–Ankara suture complex, central Sakarya, Turkey: implications for the opening age of the Izmir–Ankara branch of Neo-Tethys

Première découverte de radiolaires d'âge carnien supérieur dans la zone de suture Izmir–Ankara (région centrale de Sakarya, Turquie nord occidentale) ; implications sur l'âge de l'ouverture de la branche Izmir–Ankara de la Néo-Téthys

U. Kağan Tekin [a,*], M. Cemal Göncüoğlu [b], Necati Turhan [a]

[a] *Maden Tetkik ve Arama Genel Müdürlüğü, Jeoloji Etüdleri Dairesi Eskişehir Yolu, 06520 Balgat-Ankara, Turkey*
[b] *Orta Doğu Teknik Üniversitesi, Jeoloji Mühendisliği Bölümü, 06531 Ankara, Turkey*

Received 5 March 2001; accepted 8 August 2001

Abstract

Within the Late Cretaceous *mélange* complex of the Izmir–Ankara suture zone in central Sakarya area, north-western Turkey, a megablock with radiolarian cherts associated with basaltic pillow lavas has been dated by radiolarians. The studied radiolarian assemblage and conodonts yielded an early Late Carnian age. This age is the oldest obtained from the chert blocks all along the suture belt and has important implications for the rifting/opening age of the Izmir–Ankara branch of the Tethys ocean in north-western Turkey. Based on this new data, it is concluded that during the Late Triassic the Izmir–Ankara seaway was connected to the other Tethyan oceanic branches and deep enough to provide chert sedimentation and exchange radiolarians with the main open oceans. It is further suggested that the long-lasting misinterpretation of a Liassic rifting/opening of the Izmir–Ankara ocean should be revised. © 2002 Éditions scientifiques et médicales Elsevier SAS. All rights reserved.

Résumé

Dans la zone de mélange tectonique d'âge crétacé supérieur jalonnant la suture ophiolitique Izmir–Ankara un mégabloc à radiolarites associées à des laves sous marines en coussins est daté directement par radiolaires et conodontes de la base du Carnien supérieur. Cette datation est la plus ancienne obtenue à ce jour pour des sédiments appartenant à la suture Izmir–Ankara, un tel âge a des implications majeures en ce qui concerne le calendrier du rifting et de l'océanisation de cette branche de la Néo-Téthys dans le nord ouest de la Turquie. Une autre retombée de cette découverte concerne la mise en communication des circulations océaniques et donc d'échanges faunistiques entre les diverses branches de l'océan neo-téthysien au moins depuis le Carnien supérieur. Cette datation remet drastiquement en cause l'âge liasique communément admis pour l'ouverture/rifting de l'océan Izmir Ankara, le vieillissant ainsi de plusieurs dizaines de millions d'années. © 2002 Éditions scientifiques et médicales Elsevier SAS. Tous droits réservés.

Keywords: Late Carnian; Radiolarians; Neo-Tethys; Suture Izmir–Ankara ocean; Turkey

Mots clés: Carnien supérieur; Radiolaires; Suture Izmir–Ankara; Neotéthys; Turquie

* Corresponding author. Fax: +90-312-2854271.
E-mail address: kagan@mta.gov.tr (U.K. Tekin).

PII: S 0 0 1 6 - 6 9 9 5 (0 2) 0 0 0 1 5 - 3

1. Introduction

Turkey is located on an east–west trending segment of the Alpine–Himalayan orogenic belt, on the boundary between Gondwana in the south and Laurasia in the north. Within this belt, different continental and oceanic assemblages related to the opening and closure of the Palaeozoic and Mesozoic oceanic basins are found. These oceanic basins are collectively named the Tethyan oceans (e.g. Proto-, Palaeo- and Neo-Tethys; for a brief discussion see Stampfli, 2000). One of the most prominent branches of the alpine Tethyan ocean (Neo-Tethys sensu Şengör and Yılmaz, 1981) in Turkey is known as the Izmir–Ankara–Erzincan segment of Neo-Tethys (Fig. 1A). Its remnants are represented by the Izmir–Ankara–Erzincan suture zone (IAESZ), which extends roughly in an east–west direction for more than 2000 km from the Aegean coast to the Lesser Caucuses, where it joins the Sevan–Akera suture. The western continuation of the IAES across the Aegean sea is very probably the Vardar suture in the Balkan region. The IAES separates the Sakarya composite terrane to the north from the Tauride–Anatolide microcontinent to the south (Göncüoğlu et al., 1996–1997). It occurs generally as a more than 10-km-wide zone rather than a single scarp. The 'suture zone complex' mainly comprises allochthonous assemblages that are made up of subduction–accretion units, ophiolites and metamorphic equivalents of the continental margin sequences. All along its length in only a few areas the suture zone is restricted to a very narrow zone along which two continental plates juxtapose.

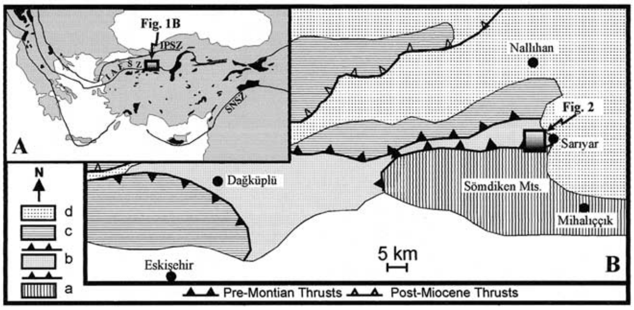

Fig. 1. **A.** The inset map shows the location of the alpine sutures in eastern Europe and Mediterranean realm (simplified after Göncüoğlu et al., 1996–1997; Stampfli, 2000) IPSZ: Intra-Pontide suture zone, IAESZ: Izmir–Ankara–Erzincan suture zone, SNSZ: Southern Neo-Tethys suture zone. **B.** Simplified map of the main structural units in the Central Sakarya area (after Göncüoğlu et al., 2000) Explanations: **a**, Sömdiken Metamorphics (Tauride–Anatolide platform); **b**, Central Sakarya ophiolitic complex; **c**, Sakarya composite terrane; **d**, tertiary cover.

A, Localisation des sutures alpines en Europe de l'Est et sur la marge méditerranéenne (simplifiée d'après Göncüoğlu et al., 1996–1997 Stampfli, 2000) IPSZ: Zone de Suture Intra-Pontine, IAESZ: Zone de Suture Izmir-Ankara-Erzincan, SNSZ: Zone de Suture du Sud de la Neotéthys. **B**, Carte simplifiée des unités structurales principales de la Zone du Sakarya central (d'après Göncüoğlu et al., 2000). **a**, Terrains métamorphiques du Sömdiken (Plate-forme Tauride-Anatolide); **b**, Complexe ophiolitique du Sakarya central; **c**, Terranes composites du Sakarya; **d**, Couverture Tertiaire.

Along the IAESZ, the presence of ophiolite-bearing *mélange* complexes or subduction–accretion prism rock assemblages have been known since the pioneering work of Bailey and McCallien (1950) in the Ankara region. There is an overall agreement that the *mélange* complexes were formed during the closure of the main Neo-Tethyan oceanic seaway (Izmir–Ankara–Erzincan ocean) during the Late Cretaceous (for a brief discussion see Yalınız et al., 2000). These *mélange* complexes contain numerous blocks of radiolarites and/or biomicritic limestones associated with the pillow lavas. The detailed dating of these lithologies is of crucial importance, as it may help to decipher the geological evolution of the Neo-Tethyan realm. The preliminary studies on the radiolarian cherts/limestones were mainly concentrated on the 'Ankara Mélange' that is nothing but the eastern continuation of the Central Sakarya ophiolitic complex.

The Central Sakarya area, north-western Turkey, is an area where the Central Sakarya unit of the Sakarya composite terrane is separated from the Tauride–Anatolide platform by a few kilometres thick, south-verging suture complex (Fig. 1). This area is considered as the root zone of the Izmir–Ankara suture complex (Göncüoğlu et al., 2000).

The suture complex (Central Sakarya ophiolitic complex of Göncüoğlu et al., 2000) comprises blocks and slices of dismembered ophiolites, blueschists, basic volcanic rocks associated with radiolarites and recrystallised limestones. Geochemical data from the basaltic rocks from various slices suggest mid ocean ridge- and supra subduction-type tectonic settings within the Neo-Tethyan Izmir–Ankara ocean.

The dating of the radiolarites associated with the basic volcanic rocks has a very important bearing on the timing of the evolution of the Izmir–Ankara oceanic crust. Preliminary radiolarian data from the Central Sakarya ophiolitic complex (Göncüoğlu et al., 2000) had shown that the earliest proven depositional age of the radiolarites and hence the age of the oceanic volcanism was Late Bathonian–Early Tithonian. Here, we describe new radiolarian and conodont age data of some radiolarian cherts from the eastern part of the Central Sakarya ophiolitic complex. This data is aimed at answering a very critical problem associated with the life span of the Izmir–Ankara oceanic crust.

2. Geological framework

In the Central Sakarya region, the Central Sakarya ophiolitic complex is represented by an east–west trending tectonic unit almost 100 km long. It comprises an upper slice of more or less ordered ophiolite (Taştepe Ophiolite) with subophiolitic metamorphic rocks at its base and a lower disrupted *mélange* complex (Dağküplü Mélange) (Fig. 1B). The latter is further subdivided into two mappable units: the Emremsultan olistostrome and the Sarıyar complex (Göncüoğlu et al., 1996, 2000).

The Taştepe Ophiolite occurs as an almost 4-km-thick nappe package, which predominantly comprises slices of tectonites and mafic/ultramafic cumulates. The members of the dyke complex and lava sequence are found only as either small slices between the main ultramafic body and the underlying *mélange* complex or as huge blocks within the *mélange*.

The Sarıyar complex of the Dağküplü Mélange comprises blocks of spilitic metabasalts, glaucophane–lawsonite schists, radiolarian cherts, pelagic limestones, serpentinites and recrystallised neritic limestones of mainly Mesozoic age (Göncüoğlu et al., 1996). These lithologies make up about 90% of the *mélange* blocks. The blocks are up to several kilometres across and display in general tectonic contacts. To the south-west of Sarıyar dam, a well-foliated turbiditic matrix with south-verging structural elements is encountered. The Sarıyar complex has originally a very complex imbricated internal structure with east–west trending shear zones and thrust faults. The overall structural picture is further complicated during its emplacement on to the continental margin sequences of the Tauride–Anatolide platform and Tertiary compressional events (Göncüoğlu et al., 1996), respectively.

The dominant rock unit within the Sarıyar complex is basic volcanic rocks, mainly pillow lavas with interlayers of volcanic–clastic rocks, radiolarian cherts and micritic limestones. Petrological studies conducted on these basic volcanic rocks indicate the presence of four different compositional groups with distinctive magmatic affinities (Yalınız et al., 1998; Göncüoğlu et al., 2000) that range in composition from Island Arc Tholeiite (IAT)–Mid Ocean Ridge Basalt (MORB)–Ocean Island Basalt (OIB)–Calcalkaline Basalt (CAB). The combination of these distinctive magma types suggests a subduction–accretion complex with blocks accreted from various oceanic settings.

One of these megablocks to the west–south-west of Sarıyar dam, around Iğdecik village (Figs 1 and 2) has been studied in detail along the Iğdecik–Sarıyar road section. In this area, the Sarıyar complex juxtaposes the metamorphic rocks (Sömdiken Metamorphics) of the Tauride–Anatolide platform along the east–west trending Türkmendağı detachment fault. The initial thrust-contact between the Central Sakarya ophiolitic complex and the Tauride–Anatolide platform is preserved to the south-east of Iğdecik village (Fig. 2). Tertiary (? Miocene) sediments unconformably overlay the Sarıyar complex. The contact between them runs almost parallel to the Iğdecik–Sarıyar road.

The studied megablock around Iğdecik is bounded toward the north by a block-in-matrix-type *mélange* that contains smaller olistoliths of blueschists, recrystallised limestone, diabase and chert. The megablock itself displays a ghost stratigraphy. The lowermost part is observed on the Igdecik–Sarıyar road cuttings (Fig. 3). This part mainly consists of highly altered augite–phyric basalts (samples TO-22 and 00UKT190) with ca. 5-m-thick bands and irregularly shaped lenses of basaltic breccia. Toward the east–south-east on the eastern escarpment of the road the basaltic breccia dominates. This part of the succession is almost 20 m thick and includes an alternation of red, thin to medium-bedded cherts with a few pink carbonate-rich mudstone levels (from bottom to top samples 00UKT189, 00UKT188, 00UKT186, 00UKT185, 99UKT33 and 00UKT184) and very fine-grained basalts (samples TO-23, TO-24, 00UKT187, and TO-25). The basaltic rocks are typically olivine-and augite-phyric with spinifex texture and have a devitrified groundmass. The upper part of the succession is mainly made up of basaltic lavas (samples TO-26 and TO-27) with rare carbonate-rich lenses (00UKT183).

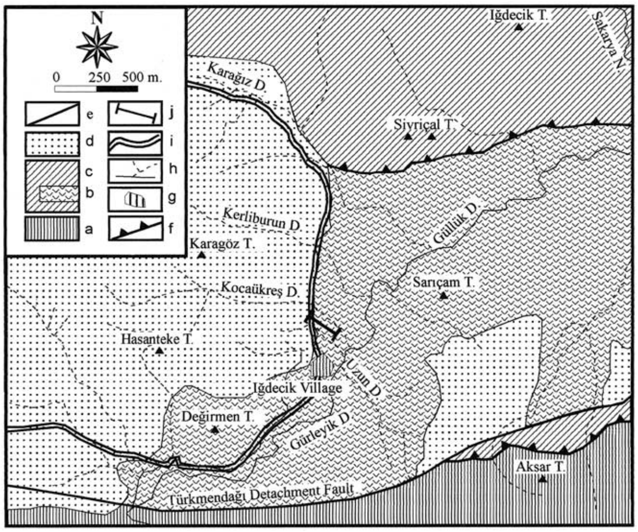

Fig. 2. The geological map of the Iğdecik area and the location of the studied section. Explanations: **a**, Sömdiken Metamorphics of the Tauride–Anatolide platform; **b–c**, Central Sakarya ophiolitic complex; **b**, blocks of cherts and volcanics alternations; **c,** undifferentiated melange complex; **d**, tertiary cover; **e**, fault; **f**, thrust; **g**, settlement; **h**, drainage system; **i**, main roads; **j**, location of cross-section (after Göncüoğlu et al., 2001).
Carte géologique de la zone de Iğdecik et localisation de la coupe étudiée. **a**. Terrains métamorphiques du Sömdiken de la plate-forme Tauride-Anatolide; **b-c**. Complexe ophiolitique du Sakarya central; **b**. Alternances de volcanites et de blocs siliceux; **c**. Complexe indifférencié; **d**. Couverture Tertiaire; **e**. Failles; **f**. Chevauchements; **g**. Affaisements; **h**. Système de drainage; **i**. Routes principales; **j**. Localisatin de la coupe (d'après Göncüoğlu et al., 2001)

3. Systematic palaeontology

Moderately preserved radiolarians were obtained from red chert–mudstone alternation from the studied section around Iğdecik village. The following radiolarians together with conodont elements have been found from the block of chert (sample 99UKT33):

Capnuchosphaera sp. cf. *C. crassa* YEH, *Capnuchosphaera* sp. cf. *C. theloides* DE WEVER, *Capnuchosphaera* sp., *Sarla vetusta* PESSAGNO, *Orbiculiforma* sp., *Trias socrucella* sp. cf. *T. augustum* (PESSAGNO), *Paronaella mocki* (KOZUR & MOSTLER), *Paronaella* sp. cf. *P.*

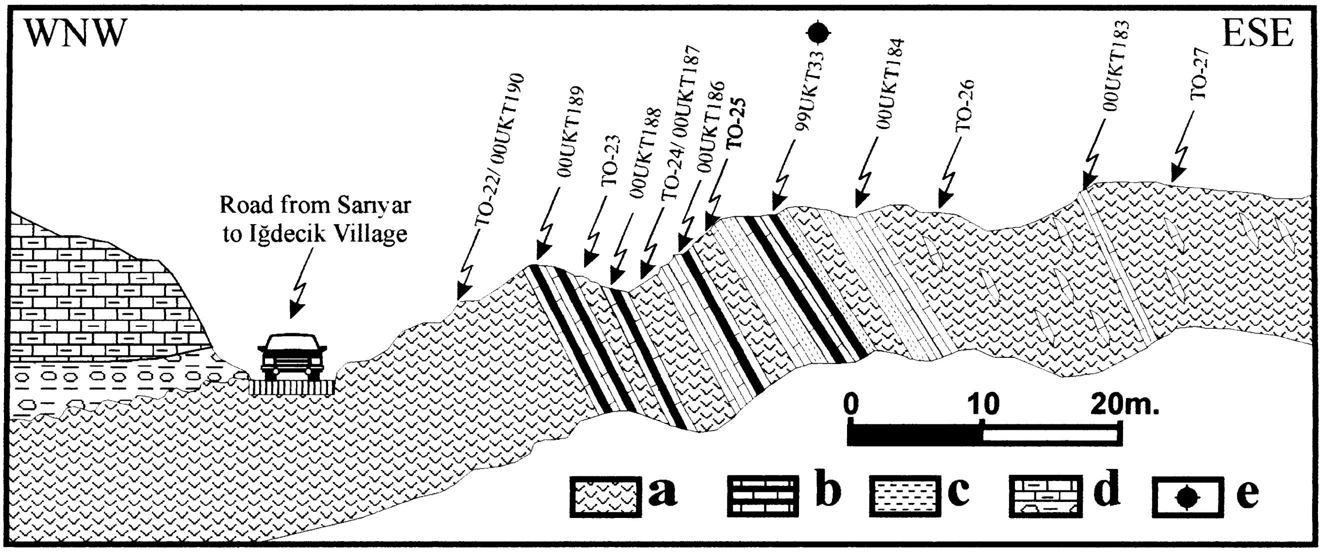

Fig. 3. Detailed cross-section of the studied succession and the location of the samples. Explanations: **a**, green to brownish basalts; **b**, alternation of red, thin to medium occasionally thick-bedded limestones and cherts; **c**, green to red mudstones; **d**, Tertiary cover; **e**, radiolaria bearing sample.
Coupe détaillée de la succession étudiée et localisation des échantillons. **a**. Basaltes verts à bruns; **b**. Alternance de calcaires rouges finement à moyennement laminés et de cherts; **c**. Mudstones verts à rouges; **d**. Couverture Tertiaire; **e**. Échantillons contenant des radiolaires.

trammeri (KOZUR & MOSTLER), *Canoptum farawayense* BLOME, *Xiphotheca karpenissionensis* DE WEVER, *Xiphotheca rugosa* BRAGIN (Figs 4 and 5). The systematic palaeontology of the determined taxa is given in the following.

Suborder SPUMELLARIINA Ehrenberg, 1875

Family CAPNUCHOSPHAERIDAE De Wever et al., 1979 emend. Pessagno et al., 1979; emend. Blome, 1983

Subfamily CAPNUCHOSPHAERINAE De Wever, 1982

Genus ***Capnuchosphaera*** DE WEVER ET AL., 1979 emend. Pessagno et al., 1979; emend. Blome, 1983

1979 *Capnuchosphaera* DE WEVER in De Wever, Sanflippo, Riedel & Gruber, p. 23.

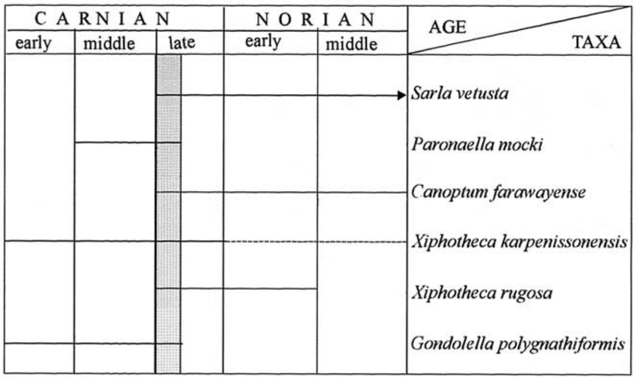

Fig. 4. Stratigraphic ranges of selected taxa from sample 99UKT33 in Iğdecik area. The dotted area shows the supposed age of the studied assemblage. The broken lines show the supposed part of stratigraphic intervals of the taxa.
Répartition stratigraphique de taxons sélectionnés dans l'échantillon 99UKT33 de la zone Iğdecik. La zone en pointillés indique l'âge estimé de l'assemblage étudié. Les lignes indiquent les intervalles stratigraphiques supposés de ces taxons.

1981 *Sulovella* KOZUR & MOCK in Kozur & Mostler, p. 77.

Type-species – *Capnuchosphaera triassica* DE WEVER ET AL., 1979.

Capnuchosphaera sp. cf. *C. crassa* YEH, 1990

Fig. 5.1

cf. 1990 *Capnuchosphaera crassa* YEH, p. 8, pl. 1, figs 8, 11–13, 18–19.

cf. 1992 *Capnuchosphaera crassa* YEH – Yeh, p. 57, pl. 9, fig. 14.

cf. 1995 *Capnuchosphaera crassa* YEH – Halemic & Gorican, pl. 2, fig. 12.

cf. 1999 *Capnuchosphaera crassa*YEH – Tekin, p. 70, pl. 3, figs 10–11.

cf. 1999 *Capnuchosphaera crassa* YEH – Gorican, Karamata & Batocanin-Sreckovic, figs. 3–6.

Range – Late Triassic; Late Carnian.

Occurrence – Busuanga and Uson Islands, Philippines; Northwest Croatia; Antalya Nappes, Kemer, Antalya and Iğdecik Village, Central Sakarya, Turkey; Sjenica, SW Serbia.

Remarks – Two broken primary spines do not allow exact identification of this form. Both cortical shell and shape of one tumidispinae resemble those of *C. crassa* YEH. If the third spine of this form is tricarinate, this form also resembles *Dicapnuchosphaera carterae* TEKIN, but it can be differentiated from *D. carterae* TEKIN by having a smaller cortical shell.

Capnuchosphaera sp. cf. *C. theloides* DE WEVER ET AL., 1979

Fig. 5.2

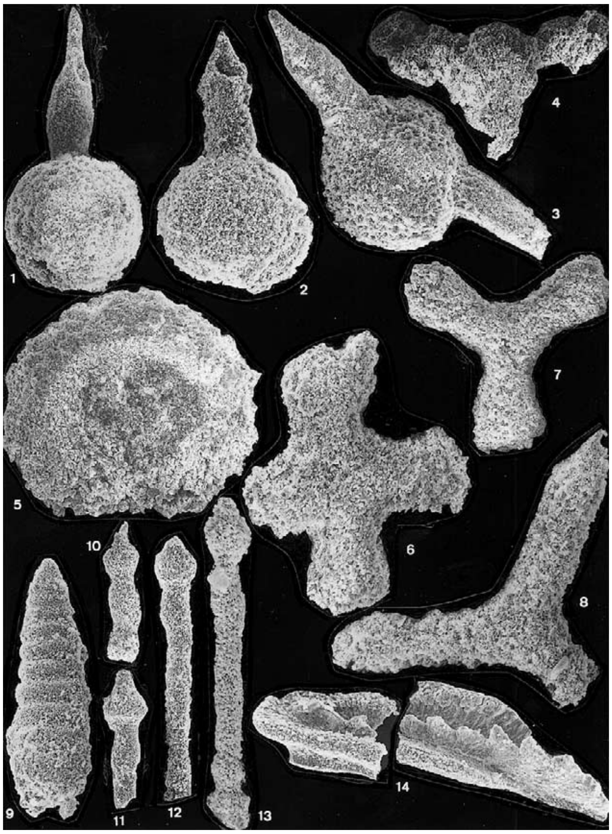

Fig. 5. Scanning electron micrographs of Late Carnian fauna (radiolaria and conodont) from Iğdecik village, Sakarya. All materials are from the sample 99UKT33. **1–13**, Radiolarians. **1**, *Capnuchosphaera* sp. cf. *C. crassa* YEH (scale bar = 100 µm). **2**, *Capnuchosphaera* sp. cf. *C. theloides* DE WEVER (scale bar = 100 µm). **3**, *Capnuchosphaera* sp. (scale bar = 100 µm). **4**, *Sarla vetusta* PESSAGNO (scale bar = 100 µm). **5**, *Orbiculiforma* sp. (scale bar = 100 µm). **6**, *Triassocrucella* sp. cf. *T. augustum* (PESSAGNO) (scale bar = 88 µm). **7**, *Paronaella mocki* (KOZUR & MOSTLER) (scale bar = 100 µm). **8**, *Paronaella* sp. cf. *P. trammeri* (KOZUR & MOSTLER) (scale bar = 88 µm). **9**, *Canoptum farawayense* BLOME (scale bar = 100 µm). **10-11**, *Xiphotheca karpenissionensis* DE WEVER (scale bar for both two figures = 130 µm). **12-13**, *Xiphotheca rugosa* BRAGIN (scale bar for fig. 12 = 130 µm, scale bar for fig. 13 = 88 µm). **14**, Conodont. *Gondolella polygnathiformis* BUDUROV & STEFANOV (scale bar = 100 µm).

Photographies au microscope électronique à balayage de la faune du Carnien terminal (radiolaires et conodontes) du village Iğdecik, Sakarya. Tout le matériel provient de l'échantillon 99UKT33. **1-13** Radiolaires. **1**, Capnuchosphaera sp. cf. C. crassa YEH (Échelle = 100 µm). **2**, Capnuchosphaera sp. cf. C. theloides DE WEVER (Échelle = 100 µm). **3**, Capnuchosphaera sp. (Échelle = 100 µm). **4**, Sarla vetusta PESSAGNO (Échelle = 100 µm). **5**, Orbiculiforma sp. (Échelle = 100 µm). **6**, Triassocrucella sp. cf. T. augustum (PESSAGNO) (Échelle = 88 µm). **7**, Paronaella mocki (KOZUR & MOSTLER) (Échelle = 100 µm). **8**, Paronaella sp. cf. P. trammeri (KOZUR & MOSTLER) (Échelle = 88 µm). **9**, Canoptum farawayense BLOME (Échelle = 100 µm). **10-11**, Xiphotheca karpenissionensis DE WEVER (Échelle pour les deux figures = 130 µm). **12-13**, Xiphotheca rugosa BRAGIN (Échelle pour la fig. 12 = 130 µm, échelle pour la fig. 13 = 88 µm). **14**, Conodont. Gondolella polygnathiformis BUDUROV & STEFANOV (Échelle = 100 µm).

cf. 1979 *Capnuchosphaera theloides* DE WEVER in De Wever, Sanflippo, Riedel & Gruber, pp. 83–84, pl. 3, figs 10–13.

cf. 1979 *Capnuchosphaera theloides* DE WEVER – Nakaseko & Nishimura, p. 75, pl. 7, figs 1–3, pl. 12, fig. 6.

cf. 1982 *Capnuchosphaera theloides* DE WEVER – De Wever, pp. 157–158, pl. 5, figs 5–8; pl. 6, fig. 2.

cf. 1982 *Capnuchosphaera theloides* DE WEVER – Yao, pl. 2, fig. 23.

cf. 1982 *Capnuchosphaera theloides* DE WEVER – Yao, Matsuoka & Nakatani, pl. 1, fig. 23.

cf. 1986 *Capnuchosphaera theloides* DE WEVER – Yoshida, pl. 12, fig. 4.

cf. 1990 *Capnuchosphaera theloides* DE WEVER – Yeh, p. 9, pl. 2, fig. 13; pl. 3, fig. 12.

cf. 1991 *Capnuchosphaera theloides* DE WEVER – Bragin, pp. 77–78, pl. 5, figs 14, 15.

? cf. 1995 *Capnuchosphaera theloides* DE WEVER – Halemic & Gorican, pl. 2, fig. 13.

cf. 1999 *Capnuchosphaera theloides* DE WEVER – Tekin, p. 72, pl. 4, figs 3.

cf. 1999 *Capnuchosphaera theloides* DE WEVER – Gorican, Karamata & Batocanin-Sreckovic, fig. 3–4.

Range – Late Triassic; Late Carnian.

Occurrence – Karpenission, Greece; Ispartacay Formation, Isparta and Antalya Nappes, Kemer, Antalya, and Iğdecik Village, Central Sakarya, Turkey; Southwest and Central Japan; Busuanga Islands, Philippines; Sikhote-Alin, Far East Russia;? Northwest Croatia, Sjenica, SW Serbia.

Remarks – Although two tumidispinae are broken off in the specimen, the shape of preserved tumidispina and cortical shell are similar to those of *C. theloides* DE WEVER.

Capnuchosphaera sp.

Fig. 5.3

Range – Late Triassic; Late Carnian.

Occurrence – Iğdecik Village, Central Sakarya, Turkey.

Remarks – Due to poor preservation, species definition could not be confirmed.

Subfamily SARLINAE De Wever, 1982

Genus ***Sarla*** PESSAGNO ET AL., 1979

1979 *Sarla* PESSAGNO in Pessagno, Finch & Abbott, p. 174.

Type-species – *Sarla prietoensis* PESSAGNO ET AL., 1979.

Sarla vetusta PESSAGNO ET AL., 1979

Fig. 5.4

1979 *Sarla vetusta* PESSAGNO in Pessagno, Finch & Abbott, pp. 174–175, pl. 7, figs 4, 6–7, 13–14.

1983 *Sarla* sp. aff. *S. vetusta* PESSAGNO – Blome, p. 19, pl. 3, figs 4, 13, 17.

1984 *Sarla* sp. aff. *S. vetusta* PESSAGNO – Blome, p. 32, pl. 4, fig. 4.

1984 *Sarla vetusta* PESSAGNO – Blome, p. 32.

1991 *Sarla vetusta* PESSAGNO – Donofrio, p. 209, pl. 3, fig. 3.

1997 *Sarla vetusta* PESSAGNO – Sugiyama, p. 187, fig. 50-1.

1999 *Sarla vetusta* PESSAGNO – Tekin, p. 87, pl. 8, fig. 13.

Range – Late Triassic; Late Carnian–late Middle Norian-?Late Norian.

Occurrence – Baja California Sur, Mexico; East-Central Oregon, USA; Aghderband, Iran; Mino terrane, Central Japan; Antalya Nappes, Kemer, Antalya, and Iğdecik Village, Central Sakarya, Turkey.

Family ORBICULIFORMIDAE Pessagno, 1973

Genus ***Orbiculiforma*** PESSAGNO, 1973

1973 *Orbiculiforma* PESSAGNO, pp. 71–72.

1978 *Praeorbiculiformella* KOZUR & MOSTLER, p. 163.

Type-species – *Orbiculiforma quadrata* PESSAGNO, 1973.

Orbiculiforma sp.

Fig. 5.5

Range – Late Triassic; Late Carnian.

Occurrence – Iğdecik Village, Central Sakarya, Turkey.

Remarks – This form differs from other species of *Orbiculiforma* PESSAGNO by having a roughly spherical outline and highly elevated rim. No equatorial spines were observed.

Family PATULIBRACHIIDAE Pessagno, 1971 emend. Baumgartner, 1980

Subfamily PATULIBRACCHIINAE Pessagno, 1971 emend. Baumgartner, 1980

Genus ***Triassocrucella*** KOZUR, 1984

1984 *Triassocrucella* KOZUR, pp. 33–34.

Type-species – *Hagiastrum baloghi* KOZUR & MOSTLER, 1978.

Triassocrucella sp. cf. *T. augustum* (PESSAGNO ET AL., 1979)

Fig. 5.6

cf. 1979 *Hagiastrum augustum* PESSAGNO in Pessagno, Finch & Abbott, p. 165, pl. 3, figs 3–5, 16.

cf. 1984 *Triassocrucella augustum* (PESSAGNO ET AL., 1979): Kozur, p. 33.

Range – Late Triassic; Late Carnian.

Occurrence – Baja, California Sur, Mexico; Iğdecik Village, Central Sakarya, Turkey.

Remarks – Although the general shape of the form is similar to the *Triassocrucella augustum* (PESSAGNO), poor preservation does not allow exact identification.

Genus ***Paronaella*** PESSAGNO, 1971 emend. Baumgartner, 1980

1971 *Paronaella* PESSAGNO, pp. 46–47.

1987 *Sontonaella* YEH, p. 44.

Type-species – *Paronaella solanoensis* PESSAGNO, 1971.

Paronaella mocki (KOZUR & MOSTLER, 1978)

Fig. 5.7

1978 *Dictyocoyrne* ? *mocki* KOZUR & MOSTLER, pp. 152–153, pl. 1, figs 7, 9; pl. 5, figs 5–6.

Range – Late Triassic; Middle Carnian–early Late Carnian.

Occurrence – Göstling, Austria; Iğdecik Village, Central Sakarya, Turkey.

Paronaella sp. cf. *P. trammeri* (KOZUR & MOSTLER, 1978)

Fig. 5.8

cf. 1978 *Rhopalodictyum trammeri* KOZUR & MOSTLER, p. 152, pl. 1, figs 3, 8; pl. 3, figs 8–11, 16?

cf. 1981 *Paronaella trammeri* (KOZUR & MOSTLER, 1978) – Kozur & Mostler, p. 61.

cf. 1999 *Paronaella trammeri* (KOZUR & MOSTLER, 1978) – Tekin, p. 90, pl. 10, fig. 4.

Range – Late Triassic; Late Carnian.

Occurrence – Göstling, Austria; Antalya Nappes, Kemer, Antalya, and Iğdecik Village, Central Sakarya, Turkey.

Remarks – Due to poor preservation, exact definition could not be realised.

Suborder NASSELARIINA Ehrenberg, 1875

Family CANOPTIDAE Pessagno et al., 1979

Genus ***Canoptum*** PESSAGNO ET AL., 1979

1979 *Canoptum* PESSAGNO in Pessagno, Finch & Abbott, pp. 182, 184.

Type-species – *Canoptum poissoni* PESSAGNO ET AL., 1979.

Canoptum farawayense BLOME, 1984

Fig. 5.9

1984 *Canoptum farawayense* BLOME, p. 47, pl. 11, figs 7, 8, 13, 19.

1989 *Canoptum farawayense* BLOME – Blome, Reed & Tailleur, pl. 33.1–20.

Range – Late Triassic; Late Carnian–late Middle Norian.

Occurrence – East-central Oregon and Northern Alaska, USA; Iğdecik Village, Central Sakarya, Turkey.

Family XIPHOTHECIDAE Kozur & Mostler, 1981

Genus ***Xiphotheca*** DE WEVER ET AL., 1979

1979 *Xiphotheca* DE WEVER in De Wever, Sanflippo, Riedel & Gruber, p. 93.

Species type – *Xiphotheca karpenissionensis* DE WEVER ET AL., 1979.

Xiphotheca karpenissionensis DE WEVER ET AL., 1979

Figs 5.10–11

pars 1979 *Xiphotheca karpenissionensis* DE WEVER in De Wever, Sanflippo, Riedel & Gruber, p. 93, pl. 7, figs 1, 2 non 3, 4, 5.

pars 1982 *Xiphotheca karpenissionensis* DE WEVER – De Wever, pp. 318-319, pl. 47, figs 2, 3, 5 non 4.

1995 *Xiphotheca karpenissionensis* DE WEVER – Halemic & Gorican, pl. 1, fig. 25.

1999 *Xiphotheca* sp. cf. *X. karpenissionensis* DE WEVER – Tekin, p. 174, pl. 42, fig. 12.

Range – Late Triassic; Early Carnian–Late Carnian- ? Middle Norian.

Occurrence – Karpenission, Greece; Northwestern Croatia; Bozkir, Konya and Iğdecik Village, Central Sakarya, Turkey.

Xiphotheca rugosa BRAGIN, 1991 emend. Tekin, 1999

Figs 5.12–13

pars 1979 *Xiphotheca karpenissionensis* DE WEVER in De Wever, Sanflippo, Riedel & Gruber, pl. 7, fig. 3 non 1,2, 4,

pars 1982 *Xiphotheca karpenissionensis* DE WEVER – De Wever, pp. 318-319, pl. 47, fig. 4 non figs 2, 3, 5

1991 *Xiphotheca rugosa* BRAGIN, pp. 107–108, pl. 5, figs 11, 13.

1992 *Xiphotheca* sp. – Otsuoka, Kajima & Hori, pl. 3, figs 20, 21.

1995 *Xiphotheca* sp. – Halemic & Gorican, pl. 1, figs 23–24.

1999 *Xiphotheca* sp. – Gorican, Karamata & Batocanin–Sreckovic, fig. 3–12.

1999 *Xiphotheca rugosa* BRAGIN – Tekin, p. 175, pl. 42, figs. 15-18; pl. 43, figs 1-5.

1999 *Xiphotheca rugosa* BRAGIN – Bragin & Krylov, p. 567, figs 13 A–C, I.

Range – Late Triassic; Late Carnian–Early Norian.

Occurrence – Karpenission, Greece; Sikhote-Alin, Far-east Russia; Oman; Northwestern Croatia; Antalya Nappes, Antalya and Iğdecik Village, Central Sakarya, Turkey; Mamonia Complex, Mamonia; Sjenica, SW Serbia.

4. Description and comparison of the radiolarian assemblage

Capnuchosphaera and *Xiphotheca* are abundant and characteristic in the sample from Iğdecik village (Figs 4 and 5). *Capnuchoshaera* first appears in the Early to Middle Carnian, becomes abundant in Late Carnian, and Early Norian, and disappears at the end of the Middle Norian. *Xiphotheca* first appears in the Middle Carnian and becomes abundant during Late Carnian to Middle Norian. *Xiphoteca rugosa* BRAGIN is an index form found only in the Late Carnian to Early Norian both in far east Russia and Turkey (Bragin, 1991; Tekin, 1999). This species has not been recorded in the Middle Carnian neither in Austria nor in Turkey (Kozur and Mostler, 1972, 1978, 1979, 1981; Tekin, 1999).

The radiolarian assemblage of the chert does not resemble the Middle Carnian fauna well-known from both Austria and Turkey. According to Kozur and Mostler (1994), the index fossil of the Middle Carnian is *Tetraporobrachia haeckeli* KOZUR & MOSTLER. This form and many associated taxa do not exist in the chert sample from Iğdecik village.

Notably, *Capnodoce* does not exist in the radiolarian assemblage obtained from the chert band. According to Carter et al. (1989) and Carter (1991) *Capnodoce* first appears in middle Late Carnian (lower Nodosus Conodont Zone) and becomes more abundant in the Latest Carnian (lower Primitius Conodont Zone). Abundant *Capnodoce* were also reported by Tekin (1999) in the Latest Carnian–Earliest Norian levels in Turkey. Thus, the age of chert block could be older than Latest Carnian.

As the radiolarian fauna of sample 99UKT33 is not similar to the Middle Carnian radiolarian fauna, lacks *Capnodoce*, and contains abundant *Xiphotheca* especially *Xiphotheca rugosa* BRAGIN and *Capnuchosphaera*, the age could be early Late Carnian (Fig. 4). This age determination is also confirmed by conodont data (*Gondolella polygnathiformis* BUDUROV & STEFANOV, written comm., Prof. Dr. Ismet Gedik, Trabzon-Turkey).

5. Discussions and conclusions

Within the 'Ankara Mélange', Bocaletti et al. (1966) described the first radiolarian assemblages of Early–Middle Jurassic age. Rojay et al. (1995) studied the biomicritic limestones associated with ocean island alkali basalts and shown by the aid of foraminifera that these are Callovian to Hautervian in age. A more detailed biostratigraphical study on the blocks with mudstone–chert associations was performed by Bragin and Tekin (1996). These authors dated various radiolarian chert blocks with various radiolarian assemblages of Late Norian, Early Jurassic, Early Cretaceous and Albian–Turonian ages, respectively.

From the Central Sakarya area the only age date for the basaltic rocks alternating with radiolarian cherts is given in Göncüoğlu et al. (2000). In this study, spot samples from cherts associated with pillow basalts yielded Late Bathonian–Early Tithonian and Latest Hauterivian–Early Aptian radiolarian assemblages (determined by Dr. K. Tekin, Ankara).

The new radiolarian ages obtained in this present study are so far the oldest ones and have important implications for the geological history of the Izmir–Ankara–Erzincan segment of Neo-Tethys (sensu Şengör and Yılmaz, 1981). In the previous studies, the suggestion of Görür et al. (1983) postulating a late Early Liassic opening age for the Neotethys in northern Turkey dominated for a long while the geodynamic evolutionary models of the eastern Mediterranean (eg. Şengör et al., 1984; Yılmaz et al., 1997). This suggestion was strongly contrasting with the event stratigraphy of the platform–margin sequences in the northern Tauride–Anatolide platform (Kütahya–Bolkardag Belt of Göncüoğlu et al., 1992) where the rift-related continental clastics of Early Triassic age unconformably overly various successions that range from Pre-Cambrian to Late Permian in age. Moreover, detailed paleontological work on the Beyşehir–Hoyran and Lycian nappes, that are univocally accepted to be derived from the northernmost margin of the Tauride–Anatolide platform include rift-related and transitional N-MORB-type volcanic rocks associated with Late Triassic pelagic limestones (Tekin, 1999). The Late Norian ages obtained from the radiolarian chert blocks within the 'Ankara Melange' (Bragin and Tekin, 1996; Tekin, 1999) is another clue for a basinal (oceanic) deposition to the north of the Tauride–Anatolide platform.

These considerations together with our new radiolarian data from cherts associated with the pillow basalts from the Central Sakarya area strengthen the statement (e.g. Göncüoğlu et al., 1992; Bragin and Tekin, 1996) that the Early Jurassic opening model of the Izmir–Ankara–Erzincan branch of Neo-Tethys, mainly based on the suggestion of Görür et al. (1983) should be revised.

Another implication for our new data concerns the worldwide distribution of the Late Carnian fauna we found in the Central Sakarya area. The Late Carnian radiolarian assemblage described in this study exhibits a close relationship to those of not only the Mediterranean but also to the circum-Pacific region. This conclusion is in accordance with the suggestion of Bragin (1991) and may help for the correlation of these main provinces.

The data may contribute to supposed discussion on the Triassic palaeooceanography of Triassic and Jurassic in the Neo-Tethyan realm. The similarity of the Late Triassic radiolarian fauna in the Izmir–Ankara branch of Neo-Tethys with further western Tethyan basins (Kozur and Mostler, 1978, 1981; Halemic and Gorican, 1995; Gorican et al., 1999) and the major oceans may indicate that these were already connected and the former was deep enough for a major deep water exchange with the open oceanic areas, even with the Pacific.

In order to conclude, the results of our new and preliminary data can be summarised as follows:

- Age determination using radiolarian data from a megablock within the Late Cretaceous subduction–accretion complex of the Izmir–Ankara–Erzincan Suture seems to indicate the presence of early Late Carnian radiolarian cherts associated with pillow lavas and minor pelagic limestones deposited around the CCD-level. This age is further confirmed by conodont data.
- This is the oldest radiolarian chert-basic lava formation reported from the Izmir–Ankara–Erzincan suture complex.
- The new data suggest that during the Late Triassic the Tethyan oceans in the east and west were not isolated; they were deep and connected to open oceanic areas.
- Our findings together with some new data from neighbouring areas (e.g. 'Ankara Melange'; Bragin and Tekin, 1996; Tekin, 1999) suggest that the models regarding a late Early Liassic rifting age of the Izmir–Ankara–Erzincan segment of the Neo-Tethys (e.g. Görür et al., 1983) should be abandoned.

. Biblios non appelées

(Blome et al., 1989; Bragin et al., 1999; Donofrio, 1991; Nakaseko and Nishimura, 1979; Otsualo et al., 1992; Sugiyama, 1997; Yao, 1982; Yao et al.; 1982, Yeh, 1987, 1992; Yoshida, 1986).

Acknowledgements

Authors acknowledge Professor Dr. Ismet Gedik, Karadeniz Technical University, Trabzon for his conodont determinations. Dr. Nikita Bragin, Institute of Russian Science Academy, Moscow, Dr. Elizabeth S. Carter, Portland State University, Portland, Oregon and Professor Dr. Patrick De Wever, Musėum National d'Histoire Naturelle, Paris are gratefully acknowledged for reviewing the manuscript and valuable suggestions. The SEM imaging took place in METU, Department of Metalogeny Engineering.

References

Bailey, E.B., McCallien, W.J., 1950. The Ankara *Mélange* and the Anatolian Thrust. Bulletin of the Mineral Research and Exploration Institute of Turkey 40, 17–22.

Baumgartner, P.O., 1980. Late Jurassic Hagiastridae and Patulibracchiidae (Radiolaria) from the Argolis Peninsula (Peloponnesus, Greece). Micropaleontology 26 (3), 274–322.

Blome, C.D., 1983. Upper Triassic Capnuchosphaeridae and Capnodocinae (Radiolaria) from east central Oregon. Micropaleontology 29 (1), 11–49.

Blome, C.D., 1984. Upper Triassic Radiolaria and Radiolarian zonation from western North America. Bulletins of American Paleontology 85 (318), 1–88.

Blome, C.D., Reed, K.M., Tailleur, I.L., 1989. Radiolarian biostratigraphy of the Otuk Formation. Geology and Exploration of the National Petroleum Reserve in Alaska. U.S. Geological Survey Professional Paper 1399. pp. 725–776.

Boccaletti, M., Bortolotti, V., Sagri, M., 1966. Richerche suite ofioliti della catena Alpina, 1, osservazioni sul' Ankara *Mélange* nella zoni di Ankara. Bolletino della Società geologica italiana 85, 485–508.

Bragin, N. Yu., 1991. Radiolaria and Lower Mesozoic Units of the USSR, east regions. Transaction of the Academy of Sciences of the USSR, 469, pp. 125 (in Russian with English summary).

Bragin, N.J., Tekin, K., 1996. Age of radiolarian-chert blocks from the Senonian ophiolitic *mélange* (Ankara, Turkey). Island Arc 5, 114–122.

Bragin, N.J., Krylov, K.A., 1999. Early Norian Radiolaria from Cyprus. Geodiversitas 21 (4), 539–569.

Carter, E.S., 1991. Late Triassic Radiolarian biostratigraphy of the Kunga Group, Queen Charlotte Islands, British Columbia. In: Woodsworth, G.J. (Ed.), Evolution and Hydrocarbon potential of the Queen Charlotte Basin, British Columbia. Geological Survey of Canada, 90–10, pp. 195–201.

Carter, E.S., Orchard, M.J., Tozer, E.T., 1989. Integrated ammonoid-conodont-Radiolarian biostratigraphy, Late Triassic Kunga Group, Queen Charlotte Islands, British Columbia. Current Research, Part H. Geological Survey of Canada, 89–1F, pp. 23–30.

De Wever, P., 1982. Radiolaires du Trias et du Lias de la Téthys (Systématique, Stratigraphie). Société géologique du Nord 7 (1–2), 599.

De Wever, P., Sanflippo, A., Riedel, W.R., Gruber, B., 1979. Triassic Radiolaria from Greece, Sicily and Turkey. Micropaleontology 25 (1), 75–110.

Donofrio, D.A., 1991. Radiolaria and Porifera (Spicula) from the Upper Triassic of Aghdarband (NE Iran). Abhandlungen der Geologie Bundesinstituts 38, 205–222.

Göncüoğlu, M.C., Dirik, K., Kozlu, H., 1996–1997. General characteristics of pre-Alpine and Alpine terranes in Turkey: Explanatory notes to the terrane map of Turkey. Annales Geologique de Pays Hellenique, Geological Society of Greece, Athens 37, 515–536.

Göncüoğlu, M.C., Özcan, A., Turhan, N., Işik, A., 1992. Stratigraphy of the Kütahya Region: Guide Book: A Geotraverse Across Suture Zones in NW Anatolia. Publication of the General Directorate of Mineral Research and Exploration, Ankara.

Göncüoğlu, M.C., Tekın, U.K., Turhan, N., 2001. Geç Kretase yaşlı Orta Sakarya Ofiyolitli Karmaşığı (KB Anadolu) içerisinde yeralan geç Karniyen radiyolaritli bazalt bloklarının jeolojik anlamı. 54th Geological Congress of Turkey, Proceeding CD, Proceeding.

Göncüoğlu, M.C., Turhan, N., Şentürk, K., Uysal, Ş., Özcan, A., Işik, A., 1996. Orta Sakarya'da Nallihan-Sarıcakaya Arasındaki Yapısal Birliklerin Jeolojik Özellikleri. The General Directorate of Mineral Research and Exploration Report (unpublished).

Göncüoğlu, M.C., Turhan, N., Şentürk, K., Özcan, A., Uysal, S., 2000. A geotraverse across NW Turkey: tectonic units of the Central Sakarya region and their tectonic evolution. In: Bozkurt, E., Winchester, J., Piper, J.A. (Eds.), Tectonics and Magmatism in Turkey and the Surrounding Area. Geological Society of London Special Publication, 173, pp. 139–161.

Gorican, S., Karamata, S., Batocanin-Sreckovic, D., 1999. Upper Triassic (Carnian-Norian) Radiolarians in cherts of Sjenica (SW Serbia) and the time span of the Oceanic Realm Ancestor of the Dinaridic Ophiolite Belt. Bulletin T. CXIX de l'Academie serbe des sciences et des arts, Classe des sciences mathematiques et naturelles, Sciences Naturelles.

Görür, N., Şengör, A.M.C., Akkök, R., Yilmaz, Y., 1983. Pontidler'de Neo-Tetis'in kuzey kolunun açılmasına ilişkin sedimentolojik veriler. Geological Bulletin of Turkey 26, 11–20.

Halemic, J., Gorican, S., 1995. Triassic radiolarites from Mts. Kalnik and Med Vodnica (Northwestern Croatia). Geologica Croatica 48 (2), 129–146.

Kozur, H., 1984. The Triassic Radiolarian genus *Triassocrucella* gen. nov. and the Jurassic *Hagiastrum* HAECKEL, 1882. Journal of Micropaleontology 3 (1), 33–35.

Kozur, H., Mostler, H., 1972. Beiträge zur Erforschung der mesozoischen Radiolarien. Teil. 1, Revision der Oberfamilie Coccodiscacea Haeckel, 1862 emend. und Beschreibung ihrer triassischen Vertreter. Geologisch-Paläontologische Mitteilungen Innsbruck 2 (8/9), 1–60.

Kozur, H., Mostler, H., 1978. Beiträge zur Erforschung der mesozoischen Radiolarien. Teil II. Oberfamilie Trematodiscacea Haeckel, 1862 emend. und Beischreibung ihrer triassischen Vertreter. Geologisch-Paläontologische Mitteilungen Innsbruck 8, 123–182.

Kozur, H., Mostler, H., 1979. Beiträge zur Erforschung der mesozoischen Radiolarien.Teil III. Die oberfamilien Actinommacea Haeckel, 1862 emend., Artiscacea Haeckel, 1882, Multiarcusallacea nov. Der Spumellaria und triassische Nassellaria. Geologisch-Paläontologische Mitteilungen Innsbruck 9 (1–2), 1–132.

Kozur, H., Mostler, H., 1981. Beiträge zur Erforschung der mesozoischen Radiolarien. Teil IV. Thallossosphaeracea Haeckel, 1862, Hexastylacea Haeckel, 1862 emend Petruhevskaja 1979 Sponguracea Haeckel, 1862 emend. und weitere triassische Lithocycliacea, Trematodiscacea, Actinommacea und Nassellaria. Geologisch-Paläontologische Mitteilungen Innsbruck, Sonderband 1, 1–208.

Kozur, H., Mostler, H., 1994. Anisian to Middle Carnian Radiolarian zonation and description of some stratigraphically important Radiolarians. Geologisch-Paläontologische Mitteilungen Innsbruck 3, 39–255.

Nakaseko, K., Nishimura, A., 1979. Upper Triassic Radiolaria from southwest Japan. Sciences Report, Col. Educ., Osaka University 28 (2), 61–109.

Otsuoka, T., Kajima, M., Hori, R., 1992. The Batinah Olistostrome of the Oman Mountains and Mesozoic Radiolarians. News of Osaka Micropaleontologists Special Volume 8, 21–34.

Pessagno Jr, E.A., 1971. Jurassic & Cretaceous Hagiastridae from the Blake Bahama Basin (Site 5A, JOIDES Leg 1) and the Great Valley Sequence, California Coast Ranges. Bulletins of American Paleontology 60 (264), 1–83.

Pessagno Jr, E.A., 1973. Upper Cretaceous Spumellarina from the Great Valley Sequence, California Coast Ranges. Bulletins of American Paleontology 63 (276), 49–103.

Pessagno Jr, E.A., Finch, W., Abbot, P.L., 1979. Upper Triassic Radiolaria from San Hipolito Formation, Baja California. Micropaleontology 25 (2), 160–197.

Rojay, B., Yaliniz, M.K., Altiner, D., 1995. Age and origin of some spilitic basalts from 'Ankara Mélange' and their tectonic implications to the evolution of northern branch of Neotethys, Central Anatolia. IESCA Abstracts, Izmir.

Stampfli, G.M., 2000. Tethyan oceans. In: Bozkurt, E., Winchester, J., Piper, J.A. (Eds.), Tectonics and Magmatism in Turkey and the Surrounding Area. Geological Society of London Special Publication, 173, pp. 1–24.

Sugiyama, K., 1997. Triassic and Lower Jurassic Radiolarian biostratigraphy in the siliceous claystone and bedded chert units of the southeastern Mino Terrane, Central Japan. Bulletin of the Mizunami Fossil Museum 24, 79–193.

Şengör, A.M.C., Yilmaz, Y., 1981. Tethyan evolution of Turkey: a plate tectonic approach. Tectonophysics 75, 181–241.

Şengör, A.M.C., Yilmaz, Y., Sungurlu, O., 1984. Tectonics of the Mediterranean Cimmerides: nature and evolution of the western termination of Paleo-Tethys. In: Dixon, J.E., Robertson, A.H.F. (Eds.), The Geological Evolution of the Eastern Mediterranean. Geological Society of London Special Publication, 17, pp. 77–112.

Tekin, U.K., 1999. Biostratigraphy and systematics of late middle to late Triassic radiolarians from the Taurus Mountains and Ankara Region, Turkey. Geologisch-Paläontologische Mitteilungen Innsbruck, Sonderband 5, 297.

Yaliniz, K., Göncüoğlu, M.C., Floyd, P.A., 1998. Geochemistry and geodynamic setting of basic volcanics from the northernmost part of the Izmir-Ankara branch of Neotethys, Central Sakarya Region, Turkey. 3rd International Turkish Geology Symposium, 31 August-4 September,1998 Ankara, Abstracts.

Yaliniz, M.K., Göncüoğlu, M.C., Özkan-Altiner, S., 2000. Formation and emplacement ages of the SSZ-type Neotethyan Ophiolites in Central Anatolia, Turkey: paleotectonic implications. Geological Journal 35, 53–68.

Yao, A., 1982. Middle Triassic to Early Jurassic Radiolarians from the Inuyama Area, Central Japan. Journal of Geoscience, Osaka City University 25, 53–70.

Yao, A., Matsuoka, A., Nakatani, T., 1982. Triassic and Jurassic Radiolarian assemblage in the southwest Japan. Proceedings of the First Japanese Radiolarian Symposium, News of Osaka Micropaleontologists, Special Volume 5, pp. 27–43 (in Japanese with English Abstract).

Yeh, K., 1987. Taxonomic studies of Lower Jurassic Radiolaria from East-Central Oregon. Bulletin of the National Museum of Natural Science, Taichung, Taiwan 2, 169.

Yeh, K., 1990. Taxonomic studies of Triassic Radiolaria from Busuanga Island, Philippines. Bulletin of the National Museum of Natural Sciences, Taiwan 2, 1–63.

Yeh, K., 1992. Triassic Radiolaria from Uson Island, Philippines. Bulletin of the National Museum of Natural Sciences, Taiwan 3, 51–91.

Yilmaz, Y., Tüysüz, O., Yiğitbaş, E., Genç, S.C., Şengör, A.M.C., 1997. Geology and tectonic evolution of the Pontides. In: Robinson, A.G. (Ed.), Regional and Petroleum Geology of the Black Sea and Surrounding Region. AAPG Memoir, 68, pp. 183–226.

Yoshida, A., 1986. Upper Triassic to Lower Jurassic Radiolarian biostratigraphy in Kagamigahara City, Gifu prefecture, Central Japan. Journal of Earth Science. Nagoya University 34, 1–21.