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Late Middle Jurassic (Late Bathonian-Early Callovian) Radiolarian Cherts from the Neotethyan Bornova Flysch Zone, Spil Mountains, Western Turkey[1]

U. Kagan Tekin[a] and M. Cemal Goncuoglu[b]

[a] *Hacettepe University, Geological Engineering Department, 06532, Beytepe- Ankara, Turkey*
[b] *Middle East Technical University, Geological Engineering Department, 06531, Ankara, Turkey*
e-mail: uktekin@hacettepe.edu.tr, mcgoncu@metu.edu.tr

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Abstract—Alternating radiolarian cherts and mudstones associated with basaltic lavas occur in a olistolith within the Late Cretaceous Bornova Flysch in W Anatolia. Cherts yielded diverse and moderately preserved, Nassellaria-dominated radiolarian faunas of late Bathonian-early Callovian age. Associated volcanic rocks are geochemically classified as remnants of oceanic seamounts. This is so far the first late Middle Jurassic age from the crust of the Neotethyan Izmir-Ankara Ocean in W Anatolia, and suggests that its spreading started earlier. Similar ages were reported from the Vardar and Meliata-Hallstadt Tethyan oceanic branches in Greece and Serbia, which also opened in Late Triassic but closed earlier.

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Key words: Mélange, Middle Jurassic, Neotethys, radiolarians, W Turkey.

INTRODUCTION

Palaeotectonic interpretations on the evolution of oceanic basins are largely dependent on accurate dating of volcanic units and associated deep-water sediments. Both of these are common ingredients of the melange complexes in the eastern Mediterranean, representing various branches of the Paleo- and Neotethys (sensu Sengor and Yilmaz, 1981). The Izmir-Ankara-Erzincan branch of the Neotethys is one of these branches and was located between the Sakarya microcontinent in the N and the Tauride-Anatolide microcontinent in the S during the Mesozoic. The closure of this oceanic basin resulted in the emplacement of ophiolites, ophiolitic melanges and high pressure-low temperature metamorphic rocks onto the N margin of the Tauride-Anatolide platform (Okay et al., 1996; Goncuoglu et al., 1997; Robertson, 2004). The final obduction during late Maastrichtian—Early Paleocene was accompanied by deposition of an olistostromal flysch within a flexural trough formed in front of the advancing allochthonous oceanic assemblages (Goncuoglu et al., 1992, 2000, 2006a, b). Ongoing compression resulted in a 150 km-wide and 1500 km-long tectonic zone, the Izmir-Ankara-Erzincan suture belt (Fig. 1).

In NW Anatolia, the suture belt is characterized by tectonic slices of ophiolites, ophiolitic melanges, the Late Cretaceous flysch (Bornova flysch of Konuk, 1977) and platform-margin carbonates of the Tauride-Anatolide microcontinent. It forms a distinct imbricated zone named as the Kutahya-Bolkardag belt (Ozcan et al., 1989; Goncuoglu et al., 1997, 2000, 2003) in NW and inner Anatolia. Bornova flysch zone (Erdogan et al., 1988; Erdogan, 1990a, b; Okay and Siyako, 1993) is a specific name of a part of this belt in W Anatolia to the NW and N of the Menderes massif (Fig. 1).

The "Spil Dag National Park" in NW Anatolia (Fig. 2) is one of the localities where the Izmir-Ankara ophiolitic melange and the Bornova flysch include several huge olistoliths and/or tectonic slices of volcanic units and deep-water sediments, mainly radiolarian cherts. It had been studied by the authors within the frame of two successive field-mapping projects (Yaliniz and Goncuoglu, 2005; Tekin et al., 2006) to date the radiolarian cherts and evaluate the palaeotectonic setting of the associated basaltic rocks.

In this study, authors will present their new and unpublished late Middle Jurassic radiolarian data obtained from a 20m-thick succession of radiolarian chert-mudstone alternation. The presented data is so far the first record of late Bathonian—early Callovian radiolarian cherts within the lava-flows in the Izmir-Ankara suture belt in NW Anatolia. Hence, the correlation of this finding with neighboring Tethyan oceanic branches and interpretation is of palaeotectonic significance in regard to the geological history of the Neotethys.

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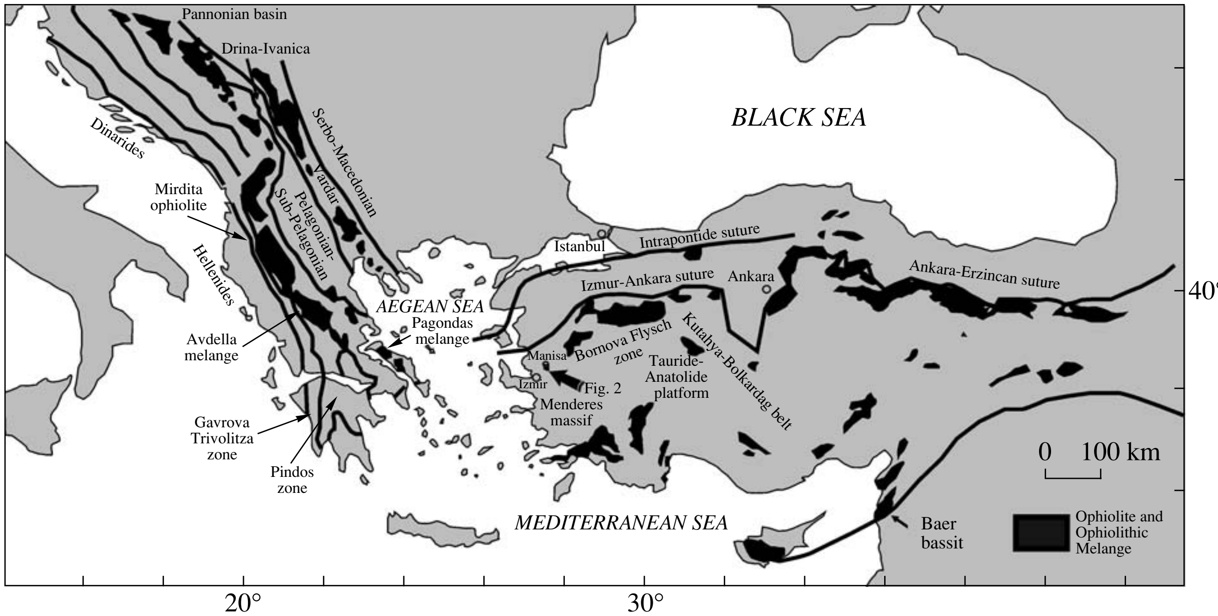


Fig. 1. Suture belts and geological units in the eastern Mediterranean region (compiled after Goncuoglu et al., 1997 and Robertson, 2004) and location of the study area.

GEOLOGICAL FRAMEWORK

The Bornova flysch zone and the ophiolites in the Spil Mountain cover an E-W trending area of about 127 km^2, bounded in the N and S by oblique faults. Regionally, the "flysch" rests with a transitional contact above the Triassic-Cretaceous carbonates of the Tauride-Anatolide platform. In the Spil mountain area, the lowermost unit includes the gray to beige biomicritic limestones and cherty limestones (Anadag limestone of Akdeniz et al., 1986). Towards the top, rudist-limestones with intraclasts are rich in pelagic foraminifera. The fossil data suggests a continuous succession including the whole Upper Cretaceous. In the transition zone between the limestones and the clastic rocks, a discontinuous formation (Damlacik formation of Akdeniz et al., 1986) with green-red- pink and gray marls with chert interlayers and mudstones is encountered. They yield micro-fossils of late Maastrichtian to Thanetian age.

The basis of the Belkahve formation or the Bornova flysch formation (Konuk, 1977; Yagmurlu, 1980) includes sporadic olistostomes and grades into a several thousand meters thick clastic series with olistolithes of varying sizes. The clastic rocks of the "flysch" include olistostromal conglomerates, litharenites and mudstones. In the Spil mountain area, the dominating olistolithes are Mesozoic limestones (Fig. 2) that reach up to a few hundred meters in length. Olistolithes of basaltic pillow-lavas associated with radiolarian cherts as well as radiolarites make up almost 30% of the exotic blocks. Serpentinites, diabases, tuffs and cherty limestones are also found as blocks within the flyschoidal sediments.

The youngest syn-sedimentary mudstones within the Bornova flysch formation (Besiktas litharenite-shale unit of Yagmurlu, 1980) may reach up to Middle Paleocene. The oldest sedimentary cover unconformably overlying the Bornova flysch zone is characterized by molasse-type fluvial clastics, dominated by alluvial fan conglomerates. The age of this formation is Early Eocene based on fossil data in Izmir-Manisa (Konak et al., 1980) and Kutahya regions (Ozcan et al., 1989).

LOCALITY DESCRIPTION AND METHODS

Radiolaria bearing samples were collected from radiolarian chert block located immediately to the S of the Manisa city center on the road to the "Spil Dag National Park," 1.5 km to the E of the "Spil Dag Monument" (Fig. 2). Its UTM coordinates are 372797 Easting and 73423 Northing. As a whole, this block represents an approximately 20-meters-thick succession of thin-bedded, mainly red, rarely green chert and mudstone alternations (Figs. 2 and 3). Laterally, it is about 120 meters long and is surrounded by spilitic basalts. Four samples (04-Manisa-174, 175, 176 and 177) were obtained from this block. Diverse late Bathonian—early Callovian radiolarian fauna were extracted from samples 04-Manisa-175 and 176. All chert samples were processed by diluted hydrofluoric acid (5–10% HF) following the Pessagno and Newport's (1972) method.

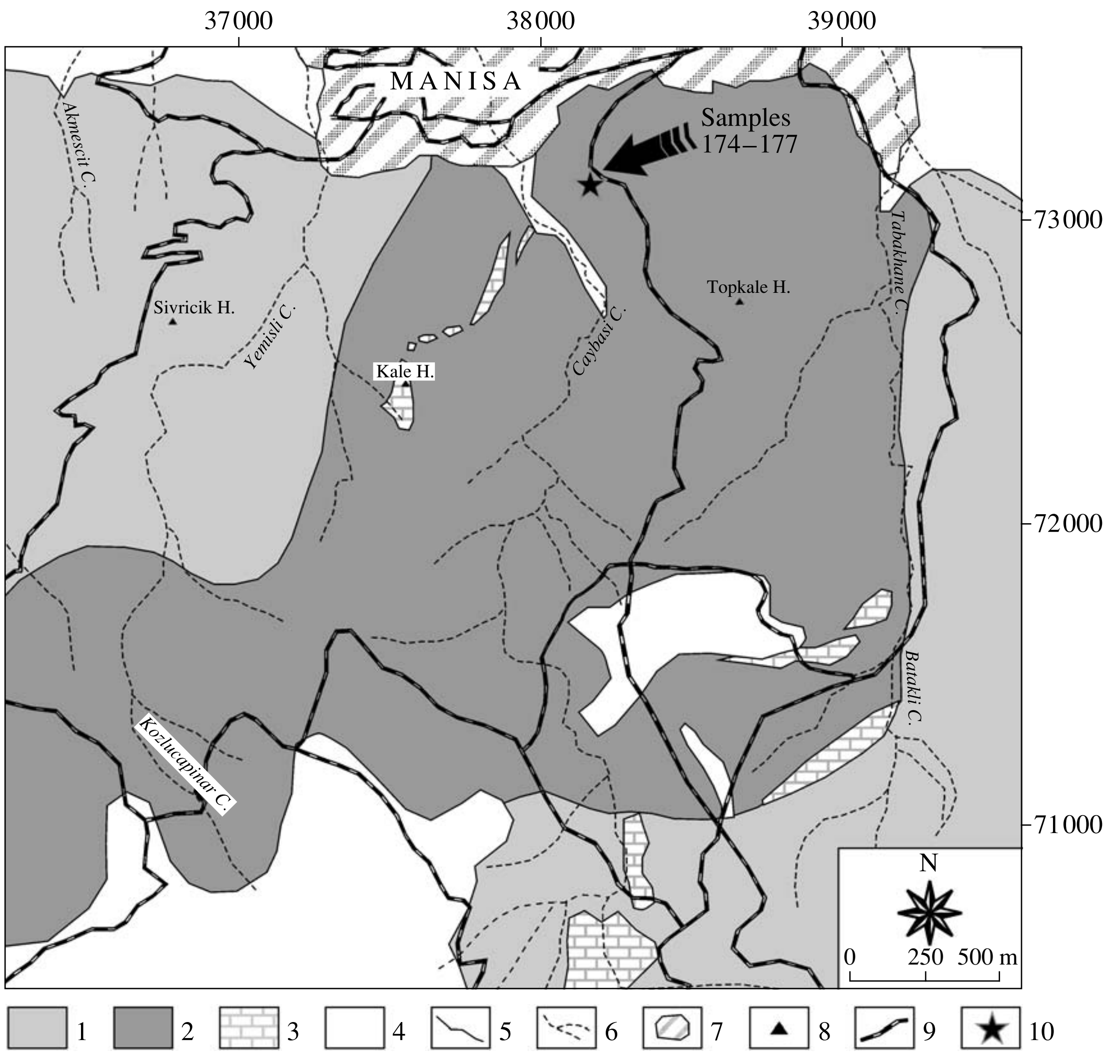


Fig. 2. Geological map (modified after Akdeniz et al., 1986) of Spil Mountain area and the location of the dated radiolarite block associated with basalts: (1) undifferentiated mélange; (2) volcanic olistoliths in mélange; (3) limestone olistoliths in mélange; (4) post-Mesozoic rock units; (5) boundary; (6) drainage system; (7) settlements; (8) main peaks; (9) main roads; (10) location of studied block where samples 04-Man-174 to 04-Man-117 were collected.

DESCRIPTIONS, COMPARISONS AND DATING OF RADIOLARIAN FAUNAS

Radiolarians obtained from sample 04-Man-175 are very diverse and moderately to well-preserved. Radiolarian fauna of this sample is characterized by a clear dominance of Nassellaria while Spumellarian type radiolarian fauna were also encountered in a minor amount. Total 30 taxa were determined and their ranges were evaluated (Fig. 4). They are as follows.

Triactoma parablakei Yang and Wang, *Tritrabs* sp. cf. *T. exotica* (Pessagno), *Paronaella mulleri* Pessagno, *Archaeospongoprunum* sp., ?*Droltus* sp., *Parahsuum carpathicum* Widz and De Wever, *P.* sp. aff. *P. transiens* Hori and Yao, *Transhsuum brevicostatum* (Ozvoldova), *T. maxwelli* (Pessagno) gr., *Archaeodictyomitra prisca* Kozur and Mostler, *A. rigida* Pessagno, *Cinguloturris carpatica* Dumitrica, *Mirifusus guadalupensis* Pessagno, *Tethysetta dhimenaensis* ssp. A sensu Baumgartner et al., *Stichomitra* ? *tairai* Aita, *Striatojaponicapsa plicarum* (Yao) s. l., *Spongocapsula palmerae* Pessagno, *Sethocapsa cometa* (Pantanelli), *Belleza decora* (Rüst), *Protunuma ? ochiensis* Matsuoka, *Williriedellum carpathicum* Dumitrica, *Williriedellum* sp. A sensu Matsuoka, *Zhamoidellum ventricosum* Dumitrica, *Pseudoeucyrtis* sp. J sensu Baumgartner et al., *Stichocapsa naradaniensis* Matsuoka, *S. tuscanica* Chiari et al., *S.* sp. aff. *S. ulivii* Chiari et al., *Eucyrtidiellum bortolotii* Chiari et al., *E. nodosum* Wakita and *E. ptyctum* (Riedel and Sanfilippo)) (Plates 1 and 2).

Within the radiolarian fauna of sample 04-Man-175, two taxa (*Triactoma parablakei* and *Stichocapsa naradaniensis*) disappear at the end of early Callovian (Baumgartner et al., 1995). Moreover, four taxa (*Parahsuum carpathicum, Stichomitra* ? *tairai, Williriedellum carpathicum* and *Cinguloturris carpatica*)

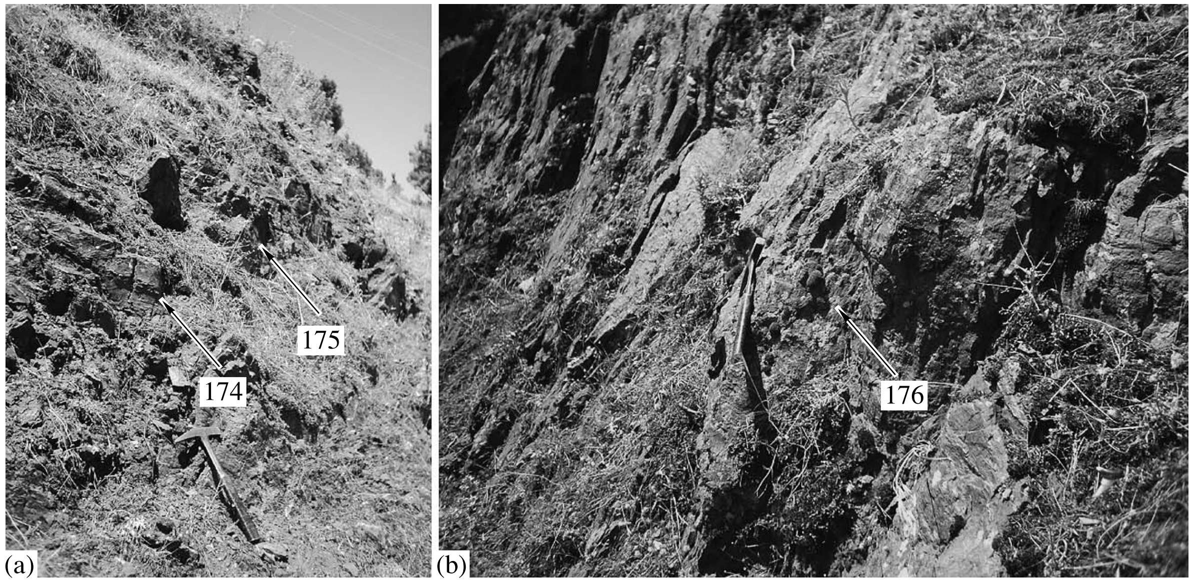


Fig. 3. (a) View from the basal part of the block composing of thin-bedded, mainly red, rarely green chert and mudstone alternations in the Spil mountain. Arrows indicate levels, where samples 04-Man-174 and 175 were collected; (b) upper part of the same block where the sample 04-Man-176 were taken. Arrow shows the sampling point of sample 04-Man-176.

obtained from this sample have their first appearance in late Bathonian (Baumgartner et al., 1995).

Although in previous studies (Aita, 1987; Widz and De Wever, 1993), presence of *Parahsuum carpathicum* and *Stichomitra* ? *tairai* were reported from younger strata than lower Callovian, co-occurrence of them in upper Bathonian—lower Callovian strata were pointed out in recent study (Bragin et al., 2002). According to previous studies (Dumitrica, 1970; Aita, 1987; Widz and De Wever, 1993; Chiari, 1994; Baumgartner et al., 1995; Chiari et al., 1997), three species (*Stichocapsa tuscanica, Sethocapsa cometa* and *Zhamoidellum ventricosum*) appear for the first time in middle Callovian or even younger, it seems to be related with insufficient data about their stratigraphic distribution and they were encountered in upper Bathonian—lower Callovian strata in Spil mountain. Other taxa (*Archaeodictyomitra prisca, Tethysetta dhimenaensis* ssp. A, *Transhsuum maxwelli* etc.) have long stratigraphic ranges (Fig. 4). Based on the co-occurrence of these taxa, it can be assumed that the age of the sample 04-Man-175 is late Bathonian—early Callovian and the radiolarian fauna of this sample is well-correlative with radiolarian fauna of U. A. 7 proposed by Baumgartner et al. (1995).

Radiolarian fauna of 04-Man–176 is very similar to radiolarian fauna of sample 04-Man-175 but it is not diverse and completely composed of Nassellarians (*Parahsuum carpathicum* Widz and De Wever, *Transhsuum brevicostatum* (Ozvoldova), *T. maxwelli* (Pessagno) gr., *Archaeodictyomitra prisca* Kozur and Mostler, *Cinguloturris carpatica* Dumitrica, *Cinguloturris* ? *venusta* Chiari et al., *Mirifusus guadalupensis* Pessagno, *Gongylothorax sakawaensis* Matsuoka, *Williriedellum carpathicum* Dumitrica, *Williriedellum* sp. A sensu Matsuoka, *Stichocapsa naradaniensis* Matsuoka, *S. tuscanica* Chiari et al., *Eucyrtidiellum nodosum* Wakita, *E. ptyctum* (Riedel and Sanfilippo)) (Fig. 5; Plates 1 and 2).

In the fauna, already two well-known taxa (*Gongylothorax sakawaensis* and *Stichocapsa naradaniensis*) have their last appearance in early Callovian and two stratigraphically well-controlled taxa (*Cinguloturris carpatica* and *Williriedellum carpathicum*) appear for the first time in late Bathonian (Baumgartner et al., 1995). Within the fauna, although *Cinguloturris* ? *venusta* was first reported from middle Callovian to upper Oxfordian strata in Italy (Chiari et al., 1997), Ozvoldova (1998) found similar specimen to the holotype of this species in lower Bathonian strata from western Carpathians, therefore the total range of this species is presumably estimated as early Bathonian to late Oxfordian (Fig. 5). Due to the presence of these radiolarian taxa, the age of the sample 04-Man-176 is assigned as late Bathonian—early Callovian, similar to sample 04-Man-175, corresponding to U. A. 7 suggested by Baumgartner et al. (1995).

From the Mediterranean Neotethys, late Middle Jurassic radiolarian cherts were described from the SW part of the Pannonian basin (e.g. Halamic et al., 1999, Medvednica cherts), and from the Vardar Zone (Dimitrijevic, 1995). In the Mirdita ophiolites in Albania, radiolarian cherts associated with pillow lavas also yielded middle Bathonian—early Callovian fossils (e.g. Prela et al., 2000).

Across the Aegean, in the Avdella melange in the Pindos Mountains (NW Greece) Jones et al. (1992) have found late Bathonian—early Callovian radiolarians (reviewed after recent biozonation of Baumgartner et al.

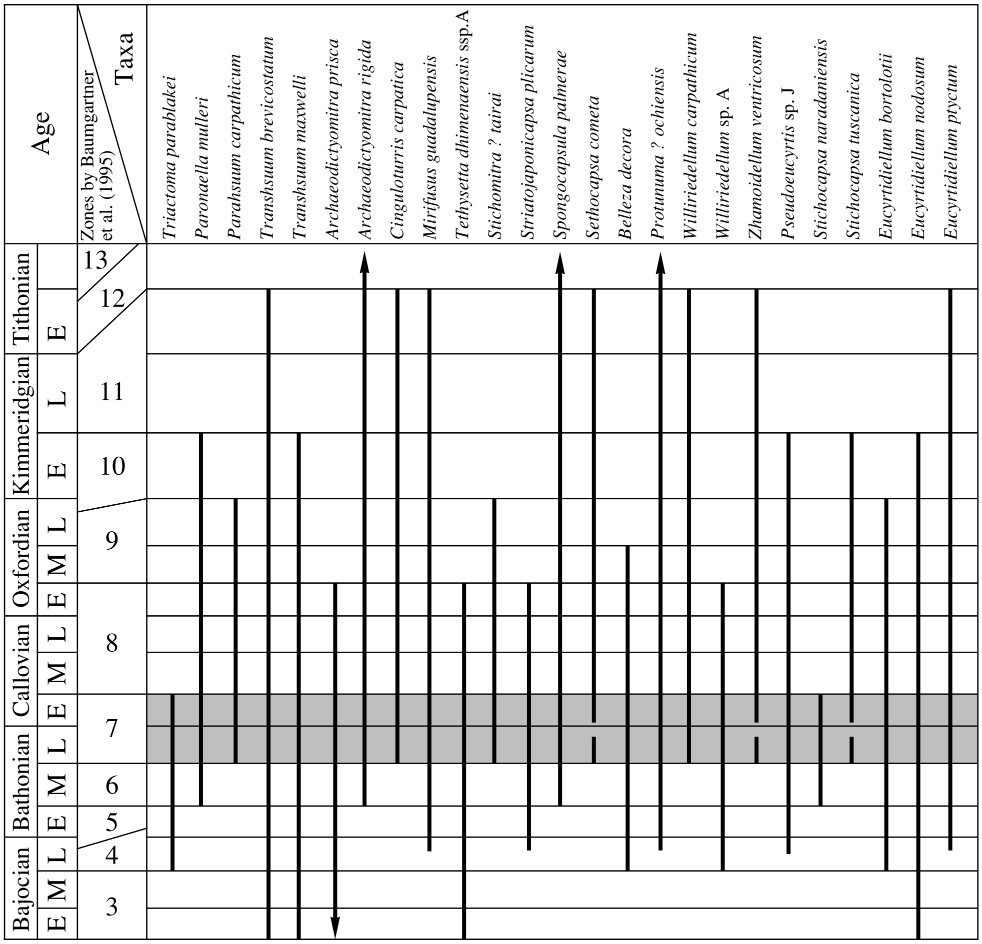
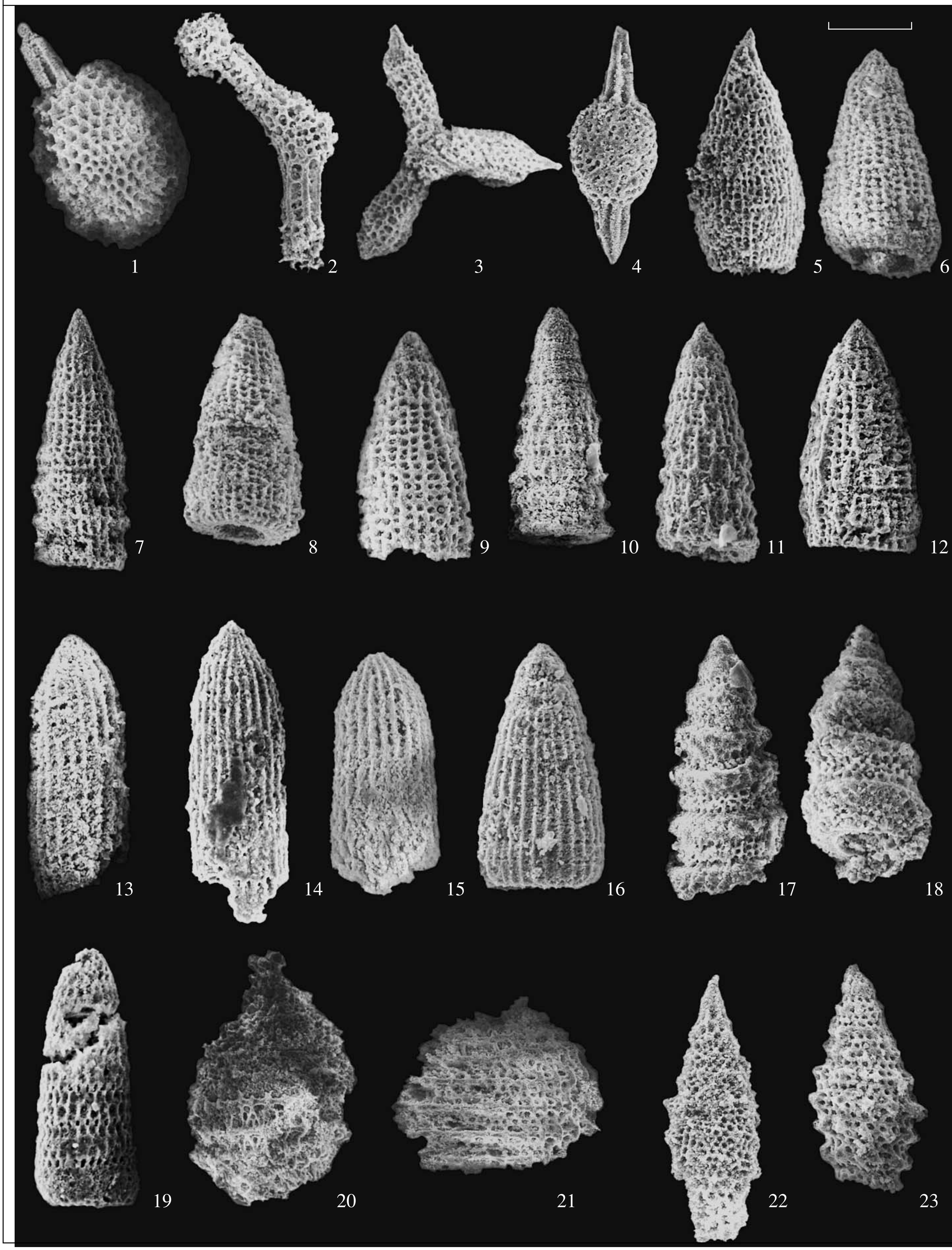


Fig. 4. Stratigraphic ranges of radiolarian taxa obtained from sample 04-Man-175 in Spil mountain near Manisa city. Grey area shows the supposed age of assemblage. Dotted lines reveal the supposed parts of stratigraphic intervals of taxa.

(1995) by Danelian and Robertson (2001)). Danelian and Robertson (2001) reported Middle Jurassic radiolarian cherts from the Pagondas mélange in Evia (W Greece) which include *Cinguloturris carpatica* cooccuring with *Dictyomitrella* (?) *kamoensis* and *Stylocapsa catenarium* and also attributed to U. A. 7 of Baumgartner et al. (1995). Middle Jurassic radiolarian cherts are also known from platform-margin sediments in Baer-Bassit in N Syria (Al-Riyami et al., 2002) that is obviously not a part of the Izmir-Ankara-Erzincan branch of the Neotethys but to its southern branch (Goncuoglu et al., 1997).

P l a t e I. Scanning electron photomicrographs of radiolarians from samples 04-Man-175 and 04-Man-176 obtained from Spil Mountain near Manisa city. Length of scale bar = number of micrometers (μm) for each figure. (1) *Triactoma parablakei* Yang and Wang, sample no. 04-Man-175, scale bar = 100 μm; (2) *Tritrabs* sp. cf. *T. exotica* (Pessagno), sample no. 04-Man-175, scale bar = 95 μm; (3) *Paronaella mulleri* Pessagno, sample no. 04-Man-175, scale bar = 125 μm; (4) *Archaeospongoprunum* sp., sample no. 04-Man-175, scale bar = 75 μm; (5) ?*Droltus* sp., sample no. 04-Man-175, scale bar = 110 μm; (6) *Parahsuum carpathicum* Widz and De Wever, sample no. 04-Man-176, scale bar = 100 μm; (7) *Parahsuum* sp. aff. *P. transiens* Hori and Yao, sample no. 04-Man-175, scale bar = 90 μm; (8) *Parahsuum* sp. B sensu Matsuoka, sample no. 04-Man-176, scale bar = 75 μm; (9) *Parahsuum* sp., sample no. 04-Man-175, scale bar = 75 μm; (10) *Transhsuum brevicostatum* (Ozvoldova), sample no. 04-Man-175, scale bar = 90 μm; (11) *Transhsuum maxwelli* (Pessagno) gr, sample no. 04-Man-176, scale bar = 75 μm; (12) *Transhsuum* sp., sample no. 04-Man-175, scale bar = 70 μm; (13, 14) *Archaeodictyomitra prisca* Kozur and Mostler, sample no. 04-Man-175, scale bar = 55 and 60 μm, respectively; (15) *Archaeodictyomitra prisca* Kozur and Mostler, sample no. 04-Man-176, scale bar = 55 μm; (16) *Archaeodictyomitra rigida* Pessagno, sample no. 04-Man-175, scale bar = 60 μm; (17, 18) *Cinguloturris carpatica* Dumitrica: (17) Sample no. 04-Man-175, scale bar = 70 μm; (18) Sample no. 04-Man-176, scale bar = 65 μm; (19) *Cinguloturris* ? *venusta* Chiari et al., sample no. 04-Man-176, scale bar = 55 μm; (20, 21) *Mirifusus guadalupensis* Pessagno: (20) Sample no. 04-Man-175, scale bar = 115 μm, (21) Sample no. 04-Man-176, scale bar = 115 μm; (22, 23) *Tethysetta dhimenaensis* ssp. A sensu Baumgartner et al., sample no. 04-Man-175, scale bar = 80 and 75 μm, respectively.

Plate I



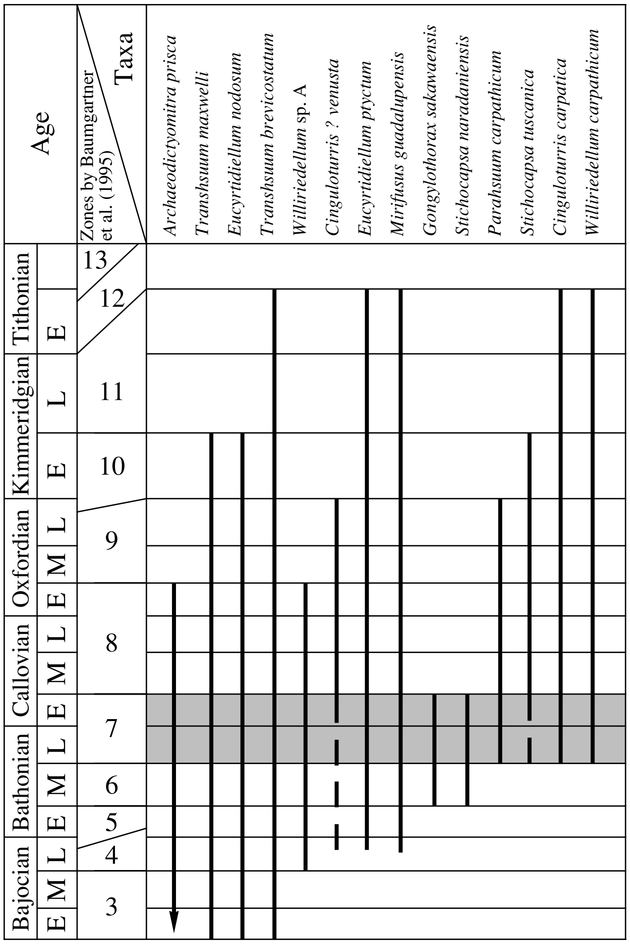


Fig. 5. Stratigraphic ranges of radiolarian taxa obtained from sample 04-Man-176 in Spil mountain near Manisa city. Dotted lines reveal the supposed parts of stratigraphic intervals of taxa. Grey area shows the supposed age of assemblage.

CHRACTERISTICS OF ASSOCIATED VOLCANIC ROCKS

Geochemical analysis were performed on several samples of the associated volcanic rocks in contact with the dark red mudstones and were published elsewhere (Yaliniz and Goncuoglu, 2005; Goncuoglu et al., 2006a, b; Aldanmaz et al., in print). To summarize, the studied pillow and massive lavas are plagioclase-clinopyroxene-phyric and display typical paragenesis of hydrothermal metamorphism. The matrix and the clinopyroxene phenocrysts are replaced by prehnite, chlorite and actinolite and the centers of the zoned plagioclases by epidote.

Geochemically the studied rocks are variably altered basalts (SiO_2: 45–48 wt %) with relatively high loss of ignition values (LOI: 4.4–5.7 wt %). They are alkaline basalts and relatively primitive as indicated by Mg# ~ 70, Ni_{ave} = 149 ppm, Cr_{ave} = 424 ppm. Their relatively low Y/Nb values (0.58–0.87) may signify an enriched mantle source and OIB-character. This is also supported by their marked enrichment in incompatible elements relative to N-MORB. The fractionated REE patterns with varying degrees of LREE enrichment relative to HREE ($[La/Yb]_N$ = 7.1–11.0) also supports their derivation from an OIB-like asthenospheric source. Overall consideration of these features suggests that the Spil basalts might represent seamounts or oceanic islands, installed on an oceanic crust.

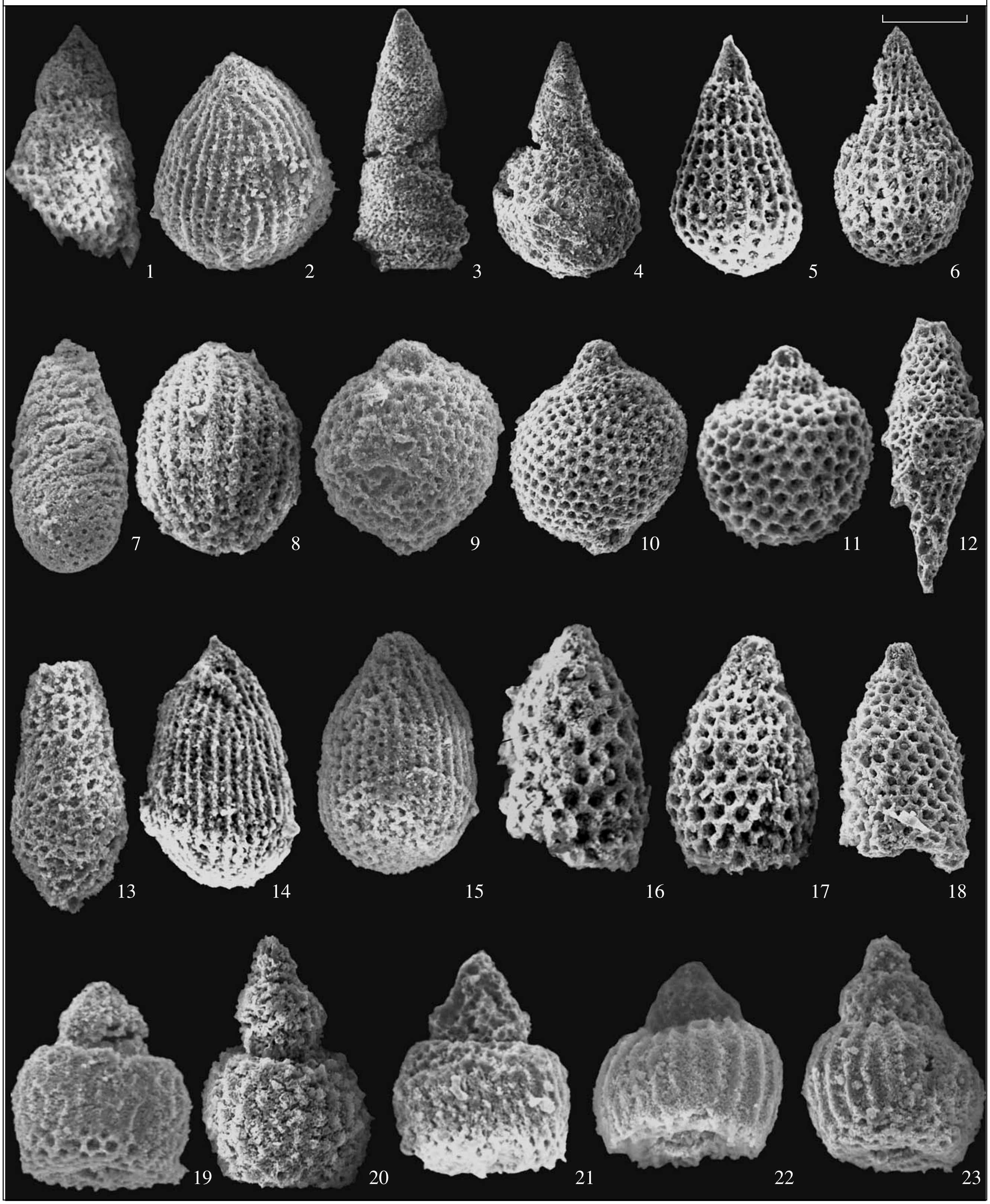
DISCUSSION AND CONCLUSIONS

The red-green chert and mudstone alternation associated with pillow and massive basalts within the Bornova flysch zone in the Spil Mountain yielded the first late Middle Jurassic radiolarians in W Anatolia. The regional geological considerations suggest that they were incorporated within the Maastrichtian-Paleocene flyschoidal sediments, formed within a flexural trough on the Tauride-Anatolide margin, in front of the advancing allochthonous oceanic assemblages of the Izmir-Ankara branch of Neotethys.

The dated volcanic rocks are typically of OIB-type alkali basalts and represent seamounts formed within the Izmir-Ankara oceanic crust (Goncuoglu et al., 2006b; Aldanmaz et al., in print). Consequently, the Izmir-Ankara oceanic crust must exist prior to the late Middle Jurassic. This finding is an additional evidence

Plate II. Scanning electron photomicrographs of radiolarians from samples 04-Man-175 and 04-Man-176 obtained from Spil mountain near Manisa city. Length of scale bar = number of micrometers (μm) for each figure. (1) *Stichomitra* ? *tairai* Aita, sample no. 04-Man-175, scale bar = 50 μm; (2) *Striatojaponicapsa plicarum* (Yao) s. l., sample no. 04-Man-175, scale bar = 40 μm; (3) *Spongocapsula palmerae* Pessagno, sample no. 04-Man-175, scale bar = 100 μm; (4) *Sethocapsa cometa* (Pantanelli), sample no. 04-Man-175, scale bar = 115 μm; (5, 6) *Belleza decora* (Rüst), sample no. 04-Man-175, scale bar = 55 and 70 μm, respectively; (7) *Gongylothorax sakawaensis* Matsuoka, sample no. 04-Man-176, scale bar = 60 μm; (8) *Protunuma* ? *ochiensis* Matsuoka, sample no. 04-Man-175, scale bar = 50 μm; (9) *Williriedellum carpathicum* Dumitrica, sample no. 04-Man-176, scale bar = 50 μm; (10) *Williriedellum* sp. A sensu Matsuoka, sample no. 04-Man-175, scale bar = 55 μm; (11) *Zhamoidellum ventricosum* Dumitrica, sample no. 04-Man-175, scale bar = 55 μm; (12) *Pseudoeucyrtis* sp. J sensu Baumgartner et al., sample no. 04-Man-175, scale bar = 70 μm; (13) *Guexella* sp. aff. *G. nudata* (Kocher), sample no. 04-Man-176, scale bar = 50 μm; (14, 15) *Stichocapsa naradaniensis* Matsuoka: (14) Sample no. 04-Man-175, (15) Sample no. 04-Man-176, scale bar = 45 and 40 μm, respectively; (16, 17) *Stichocapsa tuscanica* Chiari: (16) Sample no. 04-Man-175, (17) Sample no. 04-Man-176, scale bar for both figures = 40 μm; (18) *Stichocapsa* sp. aff. *S. ulivii* Chiari et al., sample no. 04-Man-175, scale bar = 40 μm; (19) *Eucyrtidiellum bortolotii* Chiari et al., sample no. 04-Man-175, scale bar = 40 μm; (20, 21) *Eucyrtidiellum nodosum* Wakita: (20) Sample no. 04-Man-175, (21) Sample no. 04-Man-176, scale bar for both figures = 35 μm; (22, 23) *Eucyrtidiellum ptyctum* (Riedel and Sanfilippo), sample no. 04-Man-175, scale bar for both figures = 35 μm.

Plate II



that the Izmir-Ankara branch of the Neotethys had opened earlier then late Middle Jurassic and supports the initial suggestion of Tekin et al. (2002).

The 30 taxa determined are well-correlative with radiolarian fauna of U. A. 7 proposed by Baumgartner et al. (1995) and were assigned to the late Bathonian—early Callovian. Similar assemblages were reported from the melanges in the Balkans across the Aegean but associated with different branches of Neotethys. From these, Pagondas and Avdella melanges in Greece (Danelian and Robertson, 2001), and melanges in Serbia (Dimitrijevic, 1995) were attributed to the Vardar ocean whereas the Medvednica cherts in the Pannonian basin were attributed to the Meliata-Hallstadt ocean (Halamic et al., 1999). Our new age data clearly indicate that the Izmir-Ankara branch was coexisting with the Vardar and Meliata-Hallstadt branches of the Neotethys. However, it has not closed at the end of the Jurassic as in the aforementioned cases (e.g. Robertson, 2004) but remained open until the Late Cretaceous, as evidenced by the presence of Cenomanian MORB-type basalts within the Izmir-Ankara melange complexes (Goncuoglu et al., 2006b).

A further implication of the recent data is that Norian to Early Jurassic radiolarian cherts were not yet encountered from several hundred samples studied for radiolarians in the Bornova flysch zone. Previously, late Norian and Early Jurassic radiolarian faunas were only found from radiolarian chert blocks in Ankara melange, central Turkey (Bragin and Tekin, 1996; Tekin, 1999) but these chert blocks were not associated to oceanic volcanic rocks.

The oldest cherts associated with turbidites and volcanoclastic detritus are Ladinian—middle Carnian and late Carnian in age and indicate to the formation of a transitional crust (Yaliniz et al., 1998; Tekin et al., 2002; Tekin et al., in review). The closest group of reliable ages to these is Middle Jurassic (Goncuoglu et al., 2006b and this study). This fact is also noticed by Danelian et al. (1996) for the NW Aegean melanges. Hence, it is of regional importance to interpret why no remains of Late Triassic—Early Jurassic oceanic crust was found yet in the mélange complexes. Our preliminary suggestion is that this earlier formed oceanic crust was cool and dense enough to be completely consumed by the late Early Cretaceous intra-oceanic subduction within the Izmir-Ankara Ocean that created the well-documented supra-subduction-type oceanic crust (Yaliniz et al., 2000; Goncuoglu et al., 2000, 2006a, b). Our ongoing study of the age of the radiolarian cherts and geochemistry of the associated basalts within the Izmir-Ankara Suture Belt will certainly help to improve the statements above.

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