Radiolarian assemblages of Middle and Late Jurassic to early Late Cretaceous (Cenomanian) ages from an olistolith record pelagic deposition within the Bornova Flysch Zone in western Turkey

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Key words. – Jurassic, Cretaceous, Radiolaria, Radiolarites, Bornova Flysch Zone, Turkey.

Abstract. – The Bornova Flysch Zone (BFZ) in NW Anatolia comprises several olistoliths or tectonic slivers, representing various parts of the Izmir-Ankara ocean. Radiolarian assemblages extracted from one of the olistoliths of the BFZ, cropping out along the Söğütlü section, to the NE Manisa city, were studied in detail. The lowermost part of the section contains latest Bajocian – early Callovian radiolarian taxa, followed by radiolarian assemblages indicating Late Jurassic to early Late Cretaceous (Cenomanian) ages. Previous studies reveal that the Izmir-Ankara oceanic basin was initially opened during late Ladinian – early Carnian. The new radiolarian data obtained from this olistolith reveals that relatively condensed, and possibly more or less continuous, pelagic sedimentation took place during the late Middle Jurassic to early Late Cretaceous in a non-volcanic oceanic basin closer to the Tauride-Anatolide platform margin.

INTRODUCTION

The closure of the Neotethyan oceanic branches during the Alpine tectonic epoch in Turkey [e.g. Şengör and Yilmaz, 1981; Göncüoğlu et al., 1997; Robertson, 2004] has resulted in the formation of mélangé complexes that are now text-book examples. Their formation was due to a combination of tectonic and sedimentary processes; they have been subject of a number of pioneering studies [e.g. Bailey and Mc Callien, 1950], which attempted to understand the details of these events.

Mélangé complexes marking former subduction-accretion prisms are junk boxes with products of a number of events formed during the closure of oceanic realms. They include not only huge and continuous successions of oceanic lithosphere (ophiolites s. l.) but also olistoliths of various sizes representing platform margins and metamorphosed sediments. During the advanced stages of oceanic closure, all of these lithologies were transported and deposited in peripheral foreland deposits. The mélangé complexes that are situated along the Intra-Pontide, Izmir-Ankara and SE Anatolian suture belts provide excellent examples for both partly preserved or dismembered ophiolitic successions as well as very thick sedimentary deposits of the foreland basins with olistoliths and olistostromes of the accreted material.

The Bornova Flysch Zone (BFZ) (fig. 1) represents this type of rock-units formed in one of the largest basins in NW Anatolia, along the Izmir-Ankara suture belt. It stretches from the Aegean coast for about 250 km towards NE to join the Kütahya-Bolkardag Belt [Göncüoğlu et al., 1997, 2003] that surrounds the northern and eastern periphery of the

 Associations de radiolaires d’âge jurassique moyen-supérieur à crétacé supérieur (Cénomanien) issus d’un olistolithe enregistrent une sedimentation pélagique au sein de la zone de Flysch de Bornova en Turquie occidentale

Mots-clés. – Jurassique, Crétacé, Radiolaires, Radiolarites, Zone de Flysch de Bornova, Turquie.

Résumé. – La zone de Flysch de Bornova (BFZ) dans le Nord-Ouest de l’Anatolie comprend de nombreux olistolithes ou de lames tectoniques, représentant des différentes parties de l’océan d’Izmir-Ankara. Des associations de radiolaires extrait d’un olistolithe de la BFZ, lequel affleure le long de la coupe de Söğütlü, au NE de la ville de Manisa, ont été étudiés en détail. La partie basale de la coupe contient des radiolaires du Bajocien terminal à Callovien inférieur, suivie par des associations de radiolaires d’âge jurassique supérieur à partie basale du Crétacé supérieur (Cénomanien). Les études précédentes révèlent que le bassin océanique d’Izmir-Ankara a été initialement ouvert durant le Ladinien supérieur – Carnien inférieur. Les nouvelles données de radiolaires obtenues de cet olistolithe révèlent qu’une sedimentation pélagique condensée, et probablement quasi-continue, a eu lieu durant la partie supérieure du Jurassique moyen à la partie basale du Crétacé supérieur dans un bassin océanique non-volcanique lequel était plus proche de la marge de plate-forme Tauride-Anatolide.
Menderes Massif. The BFZ was initially named by Okay and Siyako [1993] to describe a flysch basin, which was formed along a transform plate boundary (Soma Transform Fault) within the Izmir-Ankara ocean. Erdogan [1990] used the name ‘Bornova Mélange’ for this unit and suggested that the rock units in the area represent remnants of a short-lived (Maastrichtian – Danian) oceanic basin within the Tauride-Anatolide platform.

The BFZ includes a number of S-verging thrust-slices, with a structural thickness of more than 30 km. The dominant rock-type of the ‘flysch’ is olistostromal clastics with blocks/olistoliths of ophiolites, accretionary prism material (members of an ophiolitic melange and blueschists) and platform margin rocks (mainly carbonates), including continental slope and thinned continental crust. The size of these blocks varies from pebble to boulder size to several kilometres. In a number of recent studies in the central and southern parts of the BFZ [Yaliniz and Göncüoğlu, 2005; Tekin et al., 2006; Tekin and Göncüoğlu, 2007, 2009] we examined the geochemical features of the basalts and their ages based on radiolarians extracted from associated cherts and mudstones. These ages were spot ages, representing a limited time span in the history of the oceanic crust development.

In this study, however, we will report the radiolarian based ages in a single block of radiolarian chert and mudstone that covers a rather large part of the late Middle Jurassic to early Late Cretaceous interval.

GEOLOGICAL SETTING OF THE SÖGÜTLÜ SECTION

The studied section is located in the BFZ to the NE of Manisa city, between the Akhisar and Sindirgi towns (fig. 1). In this area, outcrops of different allochthonous blocks of pelagic sediments, mafic volcanic rocks, ophiolites, blue- and greenschists are observed together with slices of recrystallized carbonates incorporated into the olistostromes. The carbonates are part of the carbonate platform that was developed at the northern margin of the Tauride-Anatolide plate. Fossil data, mainly foraminifers,

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**Fig. 1.** Simplified geological map of the Bornova Flysch zone (simplified after Konak [2002]). A. Paleozoic-Mesozoic carbonate sequences of the Tauride-Anatolide platform; B. Sakarya composite terrane; C. Ophiolites and ophiolitic mélange complexes of the Izmir-Ankara suture belt; D. Eocene to Recent rock units; E. Boundary between Sakarya and Tauride-Anatolide units; F. Stratigraphic contact; G. Fault; H. Thrust; I. Drainage system; J. Railway; K. Highway. The inset map displays geographical distribution of the Menderes Massif and the Kütahya Bolkardag belt and the locality of the figure 1. Abbreviations: TAP: The Tauride Anatolide platform; LN: The Lycian Nappes [after Göncüoğlu, 2011].

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indicate a Norian to Late Jurassic depositional age for the platform [Göncüoğlu et al., 2003]. In the autochthonous successions, the carbonates are conformably covered by an alternation of red cherty limestones, micritic limestones and mudstones indicating that the platform has submerged. The onset of this pelagic deposition is variable (late Middle Jurassic to early Early Cretaceous) along the Kütahya-Bolkardag Belt (fig. 1, inset map). In the Bornova area, the oldest ages obtained are Early Cretaceous. To the east of the BFZ in the Kütahya area, pelagic carbonates are transitional to radiolarian cherts with red and green mudstone interlayers [Göncüoğlu et al., 2003], which in turn are followed by turbiditic clastics with olistostromes. The latter includes pebbles of blueschists and peridotites and was interpreted as the transition from slope-deep basin to foreland deposition due to the arrival of the ophiolitic nappes from the closing Izmir-Ankara Ocean in the north. In the BFZ, Konuk [1977] reported Campanian to Danian depositional ages at this transitional zone, whereas the calciturbiditic intercalations in the same interval yielded in Kütahya area Maastrichtian fossils [Göncüoğlu et al., 2003]. In the BFZ, the platform carbonates and their pelagic cover sometimes occur as olistoliths within the olistostromal sediments that include a large number of chert blocks, together with blocks of oceanic rocks. The size of the chert blocks varies between a few centimeters to 2 km.

The Sögütlü section is measured in such an olistolith, situated at the northwestern bank of the Cemal creek, along the road to the Sögütlü village (Balikesir J20d1 quadrangle, between 43.36.227 N/5.88.954 E and 43.36.272 N/5.89.045 E UTM coordinates) from which the name of the section is derived (fig. 2).

The total thickness of the section is 75.5 meters. At the bottom and top of the section cherts are bounded by small faults (figs. 2, 3) against conglomeratic olistostromes with brown to red turbiditic mudstone intercalations. The basal and central part of the section is represented by alternation of red to green, medium to thick-bedded chert and mudstone. Some thin-bedded chert beds can be observed at the bottom of the section. Red colored units dominate over
the green colored ones (fig. 4A). From this part, eleven samples (03-Man-26 to 03-Man-36) were collected for radiolarian determinations.

Higher up in the section, alternation of intensely folded, red to green, thin to medium-bedded chert and mudstone have been encountered (figs. 3, 4B). The amount of mudstones amount increases towards the upper part of the section and green colored units dominate this time over the red-colored ones (fig. 4B). For Radiolaria determinations, this part (fig. 3) of the section proved to be the most productive.

**DATING OF RADIOLARIAN ASSEMBLAGES**

Eighteen samples have been collected along the Sögütlü section; seven of them (03-Man-26, 31, 33, 36, 40, 41 and 42) yielded diverse and determinable radiolarian faunas (fig. 3). All chert samples were processed with diluted hydrofluoric acid (5-10% HF) following the Pessagno and Newport’s [1972] method.

Diverse radiolarian assemblages (fig. 5) were obtained from sample 03-Man-26 at the basal part the Sögütlü section (Pl. I, figs. 1-11). Many taxa (e.g. *Hexasaturnalis nakasekoi*, *Mirifusus fragilis* s. l., *Spinosicapsa helvetica*, *Eucyrtidiellum unumaense* s. l. and *Palinandromeda praecrassa*) in the fauna indicate a Middle Jurassic age [Yao, 1979; Baumgartner, 1984; Baumgartner et al., 1995]. Due to the occurrence of *Ristola altissima major*, the age of the radiolarian fauna from sample 03-Man-26 can be assigned to the latest Bajocian – early Callovian [UAZ 5-7 based on the zonal scheme of Baumgartner et al., 1995].

Higher in the section, sample 03-Man-31 yielded relatively diverse and moderately-preserved radiolaria (fig. 5; pl. I, figs. 12-18). The presence of the two well-known taxa (*Parapodobursa spinosa* and *Cinguloturris carpatica*) in the fauna clearly points to a middle Callovian – early Tithonian age [Ozvoldova, 1979; Dumitrica and Mello, 1982; UAZ 8-11 based on the zonal scheme of Baumgartner et al., 1995].

Less diverse and well to moderately-preserved radiolarian fauna (fig. 5) have been determined from the sample 03-Man-33 in the section (Pl. II, figs. 1-6). For this fauna, although two well-known taxa (*Ristola altissima altissima* and *Transhsuum* sp. cf. *T. brevicostatum*) indicate the middle and late Jurassic time interval, its age can be
assigned as middle Oxfordian – early Tithonian [Ozvoldova, 1979; Baumgartner et al., 1980; UAZ 9-11 based on the zonal scheme of Baumgartner et al., 1995] with respect to the presence of *Fultacapsa sphaerica*.

Sample 03-Man-36, taken from the central part of the section, yielded diverse and age diagnostic radiolarians (fig. 5; pl. II, figs. 7-18). Some taxa (*Tritrabs hayi* and *Tetraditryma pseudopleona*) in the fauna are only known from Middle and Late Jurassic strata, other taxa (*Acastea umbilicata*, *Mirifusus dianae minor*, *Pseudoeucyrtis reticularis* and *Parapodocapsa amhitreptera*) are determined from Upper Jurassic and Lower Cretaceous strata [Pessagno, 1977; Baumgartner, 1980; Matsuoka and Yao, 1985; Baumgartner et al., 1995]. Taking into consideration
the LAD of *Tritrabs hayi* and FAD of *Acaeniotyle umbilicata*, sample 03-Man-36 can be assigned to the UAZ 10 of Baumgartner et al. [1995] and thus correlated with the late Oxfordian – early Kimmeridgian.

Three samples (samples 03-Man-40, 41, 42) from the upper part of the section include radiolarian faunas. The radiolarian faunas of sample 03-Man-40 are less-diverse and poorly-preserved (fig. 5; pl. III, fig. 1-3), with a limited number of determinable taxa; *Acaeniotyle umbilicata* is a long range species (late Oxfordian to early Aptian), while the presence of *Archaeodictyomitra* sp.cf. *A. lacrimula* and *Thanarla brouweri* may suggest a possible
Early Cretaceous (early Berriasian – early Aptian) age [Jud, 1994; Baumgartner et al., 1995; Dumitrica et al., 1997; Hori, 1999] for this sample. A Nassellaria dominated radiolarian assemblage was obtained from sample 03-Man-41 (fig. 5; pl. III, fig. 4-9). When considering the FAD of Stichomitra communis and LAD of Obeliscoites perspicuus, age of the sample is mid-Aptian to late Cenomanian corresponding to UAZ 5-19 based on the zonal scheme of O’Dogherty [1994]. A diverse radiolarian fauna in the section was derived from sample 03-Man-42 (fig. 5; pl. III, fig. 10-18). Based on the study of O’Dogherty [1994], Dactyliosphaera silviae is the index taxon of the Silviae Zone (Cenomanian, Unitary Associations 16-19 on the zonal scheme of O’Dogherty [1994]).

**DISCUSSION AND CONCLUSIONS**

The evolution of the most prominent branch of the Neotethys in the eastern Mediterranean, the Izmir-Ankara-Enzincan ocean, is still not well understood. Especially, the dataset on the timing of the oceanic lithosphere development is fragmentary. Most of the available data on this subject are based on combined research on the age of the radiolarian cherts and the petrological features of associated volcanic rocks [e.g. Gönçüoğlu et al., 2006b; Aldanmaz et al., 2008]. Figure 6 provides a summary of available age data from different parts of the Izmir-Ankara suture belt. The new data from the Sögütlü section fills some gaps of ocean basin deposition at end Jurassic and mid Early Cretaceous times (fig. 6).

The new finding also gives some clue on the palaeotectonic setting of the oceanic crust on which the Sögütlü succession was deposited. Considering that the studied succession is devoid of volcanic and volcanoclastic rocks it should have been deposited in a remote location from any voluminous igneous activity. By this, a position in the proximity of the ridge, oceanic islands or island arcs formed by intra-oceanic subduction within the Izmir-Ankara ocean can be excluded. A setting on the overriding plate that was located relatively to the north of the ocean during this
intraoceanic subduction can also be excluded, as the generation of supra-subduction-type volcanism commenced already before the late Cenomanian. A setting on the pre-latest Bajocian oceanic crust closer to the Tauride-Anatolide platform-margin is more appropriate, considering also the distribution of the oceanic basins with condensed chert successions in the Tethyan ocean [e.g. Folk and Mc Bridge, 1978; Jenkys and Winterer, 1982].

Such a setting is also in accordance with the depositional ages of pelagic sediments that are present in some slices with coherent successions in the Kütahya-
Bolkardag belt [Göncüoğlu et al., 2003], in the Antalya Nappes [Vrielynck et al., 2003] and in the Domuz Dag nappe of the Lycian nappes [e.g. Brunn et al., 1976]. In both, deposition of condensed pelagic carbonates commences already in early Late Jurassic and continues until Late Cretaceous. The tectonic slices or olistoliths representing the platform-margin sediments in the BFZ [e.g. Okay and Altiner, 2007] and Kütahya Bolkardag Belt [e.g. Göncüoğlu et al., 2003] display a similar development with some delay. In both units, Middle and Late Triassic platform carbonates are followed by condensed pelagic siliceous sediments of Late Jurassic—Early Cretaceous age.

Hence, it is concluded that the latest Bajocian to Cenomanian cherts and mudstones represented by the Söğütlü section could have been deposited on the Izmir-Ankara oceanic basin, located just to the north of the coeval condensed pelagic rocks of the Lycian Nappes, representing the slope sediments and the slightly younger pelagic sediments of the Tauride-Anatolide external platform. The distribution and ages of the above-mentioned successions is also the clue for the foundering of the Tauride-Anatolide margin in relation with the foundering of the relatively old and cool Izmir-Ankara oceanic lithosphere.

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FIG. 6. – A. Suture belts and ophiolite/ophiolitic mélanges in Turkey (compiled after Göncüoglu et al., [1997] and Robertson, [2004]) and locations of radiolarian ages from the Izmir-Ankara-Erzincan suture belt, shaded square indicate the study area, B. Ranges of radiolarian ages from the different parts of the Izmir-Ankara-Erzincan suture belt; 1. The Bornova Flysch Zone from Tekin et al. [2006], Göncüoglu et al. [2006a], Tekin and Göncüoglu [2007, 2009] and this study, part of the column shown by lines indicate dating in this study (the Sögütlü section); 2. The Dagküplü Mélange from Göncüoglu et al. [2000, 2006b, 2010], and Tekin et al. [2002]; 3. The Ankara Mélange from Bragin and Tekin [1996], and Tekin [1999]; 4. Cankiri region from Celik [2010], and Üner [2010]. 5. Tokat region from Bozkurt et al. [1997].

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