C. R. Palevol 14 (2015) 73–84

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

General Palaeontology, Systematics and Evolution (Micropalaeontology)

Upper Cretaceous Radiolarian ages from an arc–back-arc within the Yüksekova Complex in the southern Neotethys mélange, SE Turkey

Âges Crétacé supérieur de Radiolaires en provenance d'un couple arc–arrière-arc au sein du complexe de Yüksekova dans le mélange néo-téthysien méridional, Sud-Est de la Turquie

Ugur Kağan Tekin[a,*], Melek Ural[b], Mehmet Cemal Göncüoğlu[c], Mehmet Arslan[d], Sevcan Kürüm[b]

[a] *Hacettepe University, Department of Geological Engineering, 06800, Beytepe, Ankara, Turkey*
[b] *Fırat University, Department of Geological Engineering, 23119 Elazığ, Turkey*
[c] *Middle East Technical University, Department of Geological Engineering, 06800 Ankara, Turkey*
[d] *Karadeniz Technical University, Department of Geological Engineering, 61080 Trabzon, Turkey*

ARTICLE INFO

Article history:
Received 16 June 2014
Accepted after revision 1st October 2014
Available online 28 January 2015

Handled by Daniele Grosheny

Keywords:
Southern Neotethys
Yüksekova Complex
Pillow basalts
Radiolarians
Upper cretaceous
Turkey

Mots clés :
Néo-Téthys méridionale
Complexe de Yüksekova
Basaltes en coussins
Radiolaires
Crétacé supérieur
Turquie

ABSTRACT

The Yüksekova complex in SE Turkey is a part of a continuous belt of ophiolites and subduction–accretion complexes that stretches from Troodos in the west to Oman in the east, representing the remnants of the Southern Branch of Neotethys. This complex mainly comprises a tectonically chaotic assemblage of basaltic dykes and pillow lavas associated with radiolarian cherts, shales and pelagic limestones. Detailed petrological work on submarine basaltic lavas from Elazig-Malatya area in SE Turkey revealed the presence of two distinct tectonomagmatic groups displaying island arc and back-arc characteristics. Radiolarian assemblages are described for the first time from radiolarian cherts in primary depositional contact with the basaltic rocks in this belt. Two distinct assemblages are recognized as Upper Cenomanian to Lower Turonian and Lower Coniacian to Lower Maastrichtian based on the characteristic radiolarian taxa. The new fossil data supports the suggestions that the southern branch of Neotethys has closed by intra-oceanic subduction where the arc and back-arc type oceanic crust generation was involved not earlier than Upper Cretaceous.

RÉSUMÉ

Le complexe de Yüksekova dans le Sud-Est de la Turquie constitue une partie d'une ceinture continue d'ophiolites et de complexes subduction–accrétion qui s'étend des Troodos, à l'ouest, à l'Oman, à l'est, et représente les reliques de la branche méridionale de la Néo-Téthys. Cet ensemble comprend le plus souvent un assemblage tectoniquement chaotique de dykes basaltiques et de laves en coussins, associés à des cherts à radiolaires, argiles et calcaires pélagiques. Une étude pétrologique détaillée des laves basaltiques sous-marines de

* Corresponding author.
E-mail addresses: uktekin@hacettepe.edu.tr (U. Kağan Tekin), melekural@gmail.com (M. Ural), mcgoncu@metu.edu.tr (M. Cemal Göncüoğlu), marslan@ktu.edu.tr (M. Arslan), skurum@firat.edu.tr (S. Kürüm).

http://dx.doi.org/10.1016/j.crpv.2014.10.002

la région d'Elazığ-Malatya dans le Sud-Est de la Turquie révèle la présence de deux groupes tectono-magmatiques distincts, présentant les caractéristiques d'arcs et d'arrière-arcs insulaires. Les assemblages de radiolaires sont décrits, pour la première fois, dans des cherts à radiolaires, en contact dépositionnel primaire avec les roches basaltiques de cette ceinture. Deux assemblages distincts sont reconnus, l'un du Cénomanien supérieur au Turonien inférieur, l'autre du Cognacien inférieur au Maastrichtien inférieur, à partir de taxons de radiolaires caractéristiques. Les nouvelles données sur ces fossiles soutiennent l'hypothèse selon laquelle la branche méridionale de la Néo-Téthys s'est fermée par subduction océanique, là où une génération de croûte océanique de type arc ou arrière-arc était impliquée, et ce, pas avant le Crétacé supérieur.

1. Introduction

The remnants of the "Southern Branch of Neotethys" (sensu Şengör and Yılmaz, 1981) are represented by a distinct belt of ophiolites and ophiolitic melanges that can be followed from the Troodos Mountains in Cyprus via SE Anatolia to Zagros Mountains and Oman in the east (Fig. 1). They were formed during the closure of the Southern Neotethys Ocean at the end of Mesozoic and Lower Tertiary (Michard et al., 1985; Robertson, 2002, 2004). Ongoing compression along the suture during the Tertiary resulted in a thick pile of nappes that include oceanic assemblages together with the variably metamorphosed units of continental margins of both the northern Tauride–Anatolide Terrane and the southern Arabian Plate (e.g., Göncüoğlu et al., 1997; Yılmaz, 1993).

The earliest overstep sequence on this nappe pile is represented by the Maden Complex composed of Eocene volcano-sedimentary sequences (e.g., Perinçek, 1979). However, subsequent compressional events during the Middle and Upper Tertiary have resulted in repeated episodes of allochthonies and the compression is still continuing today along the Bitlis–Zagros Thrust Zone (Fig. 1).

In the Anatolian realm, the suture belt is named as the Amanos–Elazığ–Van Suture Belt (Göncüoğlu, 2010; Göncüoğlu et al., 1997) and includes several bodies characterizing an oceanic lithosphere including oceanic islands, an island arc together with subduction–accretion complexes formed during the closure of the Southern Neotethys. The Yüksekova Complex is one of these pieces of oceanic lithosphere, mainly made of crustal rocks with some mantle contributions (Aktaş and Robertson, 1984; Beyarslan and Bingöl, 2000; Hempton, 1984, 1985; Perinçek, 1980; Rızaoğlu et al., 2006, 2009). There have been copious studies (e.g., Bingöl and Beyarslan, 1996; Beyarslan, 2005; Çolakoğlu et al., 2013; Parlak et al., 2009) that dealt with the geochemistry and petrogenesis of the intrusive and extrusive rocks of the Yüksekova Complex and their equivalents, known by different names (e.g., Kömürhan Ophiolite, Guleman Ophiolite, etc.). These geochemical studies contribute very much to the tectono-magmatic setting of the oceanic units. However, the information on their ages is limited to a few radiometric data (for a brief review see Karaoğlan et al., 2012) that constraint our understanding for the geodynamic evolution. To overcome this problem, the authors sampled in the area

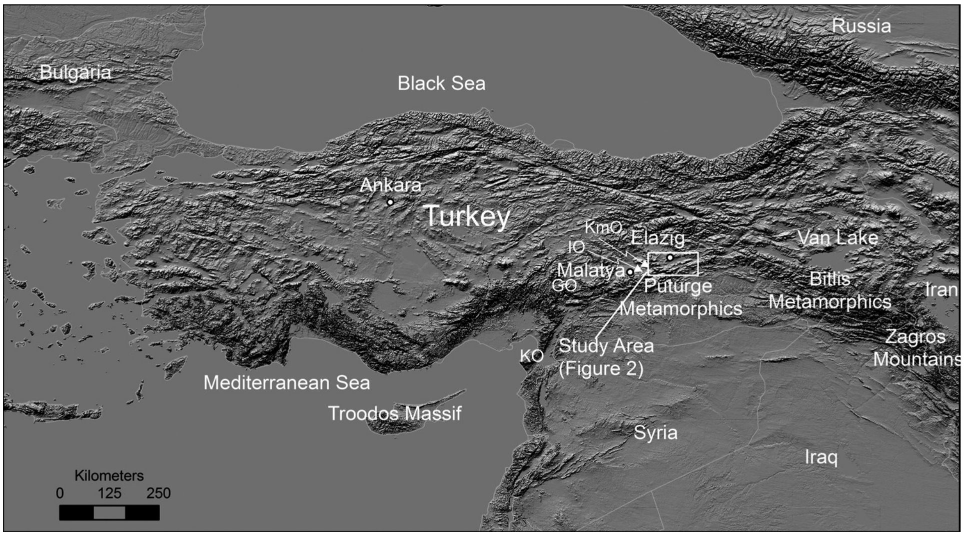

Fig. 1. Location of the study area on the Troodos–Bitlis–Zagros Belt. Abbreviations, KO: Kızıldağ Ophiolite, GO: Göksun Ophiolite, IO: Ispendere Ophiolite, KmO: Kömürhan Ophiolite.

Fig. 1. Localisation de la zone d'étude sur la ceinture Troodos–Bitlis–Zagros. Abbreviations : KO : Ophiolite Kızıldağ, GO : Ophiolite Göksum, IO : Ophiolite Ispendere, KmO : Ophiolite Kömûrhan.

around cities of Elazığ and Malatya the basaltic lavas within the mélanges of the Yüksekova Complex, which are in primary contact with oceanic sediments. A combined study based on geochemistry of the lavas (Ural, 2012; Ural et al., 2010,2012) and radiolarian biostratigraphy has been realized.

In this study, the authors will provide data on the radiolarian ages of the oceanic sediments in association with recently studied (Ural et al., 2010) basaltic pillow lavas with well-established tectonomagmatic settings. This age data is the first one based on radiolarians from the mélanges between the Tauride–Anatolide units and the Bitlis–Pütürge Metamorphics and will be used in evaluating the Upper Cretaceous evolution of the southern Branch of Neotethys.

2. Geological framework

The Amanos–Elazığ–Van Suture Belt (Göncüoğlu, 2010; Göncüoğlu et al., 1997) in SE Turkey is represented by an almost 700 km long and 70 km wide zone (Figs. 1 and 2). The oceanic assemblages of the suture belt are accreted between the continental crust units and/or their metamorphic equivalents. The northerly-located piece of continental crust represents the metamorphosed S margin sediments (the Malatya–Keban Metamorphics) of the Tauride–Anatolide Platform. The southerly located one, known as the Bitlis–Pütürge Metamorphics, on the other hand, stands for the northern margin of the Arabian Platform in the south (Göncüoğlu and Turhan, 1984). These continental crusts are believed to be separated from each other by the opening of the southern Branch of Neotethys during the Upper Permian–Lower Triassic period. By this, the pre-rifting successions of both units are very similar and the differences in stratigraphy concern their Mesozoic cover.

The remnants of the Southern Neotethys Ocean is found today as nappes and slide blocks of oceanic lithosphere origin together with rocks derived from oceanic islands, and island arcs forming a huge mélange complex. The accretion of the oceanic units was mainly realized at the end of Cretaceous. However, ongoing convergence along the suture belt at the end of Miocene resulted in an imbricated structure, where rock packages of syn -to post-accretional basins were also incorporated into the suture complex.

In the area between Malatya and Elazığ (Fig. 2), the mantle rocks of the oceanic lithosphere are best represented by the Guleman Ophiolite and its equivalents that occur as ultramafic bodies of variable sizes within the mélange complexes. The Guleman Ophiolite comprises its lower part abundant peridotites against lherzolites with podiform chromites and plagiogranites. Another body in Kömürhan consists of a very thick sequence (> 1 km) of ultramafic cumulates followed by massive and cumulate gabbros (Robertson, 2002). Geochemically, the Guleman Ophiolite is characterized by depleted mantle composition and its REE-patterns indicate to supra-subduction setting (Bağcı et al., 2005; Beyarslan and Bingöl, 2000; Parlak et al., 2004; Robertson, 2002; Robertson et al., 2007).

The crustal rocks of the Southern Neotethys are named as the Yüksekova Complex (Perinçek, 1979) and attributed (e.g., Yazgan, 1984; Yazgan et al., 1983) to the remains of an "ensimatic arc". The intra-oceanic arc or supra-subduction character of the Yüksekova volcanic rocks have been confirmed by several recent geochemical studies (e.g., Parlak et al., 2009; Rızaoğlu et al., 2009; Robertson et al., 2007).

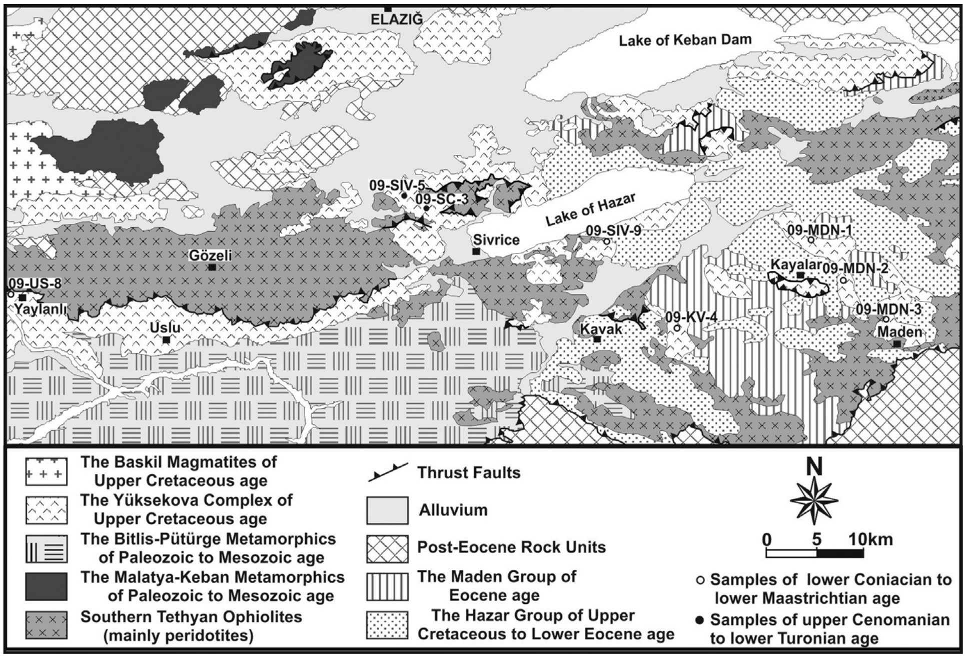

Fig. 2. The distribution of the Neotethyan oceanic and continental crust units in the area between cities of Malatya-Elazığ.

Fig. 2. Réparation des unités de croûtes océanique et continentale néo-téthysiennes dans la région située entre les villes de Malatya et d'Elaziğ.

Modified and simplified after MTA, 2002.

The name "Elazığ Magmatics" has been used in the last years (e.g., Beyarslan, 2005; Beyarslan and Bingöl, 2000; Bingöl and Beyarslan, 1996; Turan and Bingöl, 1991) for the same oceanic assemblage to include also plutonic and volcanic rocks of granodioritic-tonalitic-dacitic composition intruding them.

The Yüksekova Complex is made of massive/pillowed lavas and dykes associated with volcano-clastics, green and red mudstones and radiolarian cherts (Fig. 3). It locally shows several hundred meters thick, continuous and undisturbed successions. More commonly, however, the volcanic and sedimentary lithologies are blocks, embedded

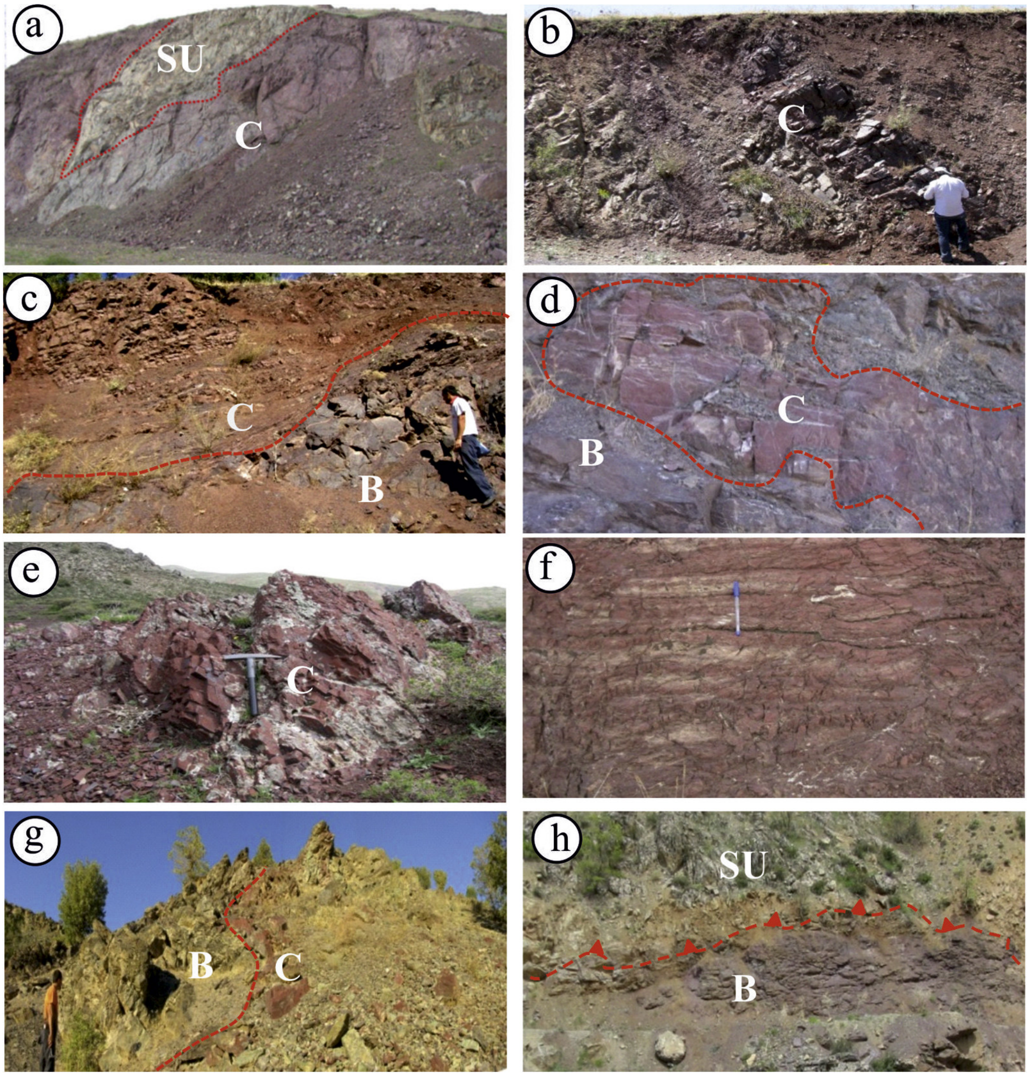

Fig. 3. (Color online.) Field views from the Yüksekova Complex. **a**. Serpentinized ultramafic rocks (SU) in tectonic contact with basalts alternating with cherts (C) and mudstones on the Elazığ–Sivrice highway. **b**. A m-thick radiolarian chert sequence (C) (location of sample 09-SIV-5) underlain by mudstones and basaltic pillow lava to the northwest of lake of Hazar. **c**. Basaltic lavas (B) in primary depositional contact with chert (C) and mudstone alternation to the northwest of town of Maden (location of sample MDN-1), **d**. Basaltic lavas (B) alternating with cherts (C) to the northwest of the town of Maden (location of sample 09-MDN-3). **e**. Radiolarian cherts (C) (location of sample 09-KV-4) within basaltic lavas to the east of town of Kavak. **f**. An alternation of radiolarian chert (location of sample 09-SIV-9) and mudstone to the south of lake of Hazar. **g**. Primary relations between pillow lavas (B) and radiolarian cherts (C) (location of sample 09-US-8) near village of Yaylanlı. **h**. Tectonic contact between peridotites (SU) and basaltic pillow lavas (B) of the Yüksekova Complex to the north of village of Uslu. (Locations of samples are shown on Fig. 2).

Fig. 3. (Couleur en ligne.) Photos de terrain dans le complexe de Yüksekova. **a**. Roches ultramafiques serpentinisées (SU), en contact tectonique avec des basaltes alternant avec des cherts (C) et des mudstones sur la route Elazığ–Sivrice. **b**. Séquence métrique de chert à radiolaires (C) (localisation de l'échantillon 09-SIV-5) recouvert par des mudstones et des pillow lavas au nord-ouest du lac de Hazar. **c**. Laves basaltiques (B), en contact dépositionnel primaire avec les lits alternés de cherts (C) et de mudstones au nord-ouest de la ville de Maden (localisation de l'échantillon MDN-1). **d**. Laves basaltiques (B), alternant avec des cherts (C), au nord-ouest de la ville de Maden (localisation de l'échantillon 09-MDN-3). **e**. Cherts à radiolaires (C) (localisation de l'échantillon 09-KV-4) dans les laves basaltiques, à l'est de la ville de Kavak. **f**. Alternance de cherts à radiolaires (localisation de l'échantillon 09-SIV-9) et de mudstones au sud du lac de Hazar. **g**. Relations primaires entre pillow lavas (B) et cherts à radiolaires (C) (localisation de l'échantillon 09-US-8) près du village de Yaylanlı. **h**. Contact tectonique entre péridotites (SU) et pillow lavas basaltiques (B) du complexe de Yüksekova, au nord du village d'Uslu. (Les localisations d'échantillons sont données sur la Fig. 2.).

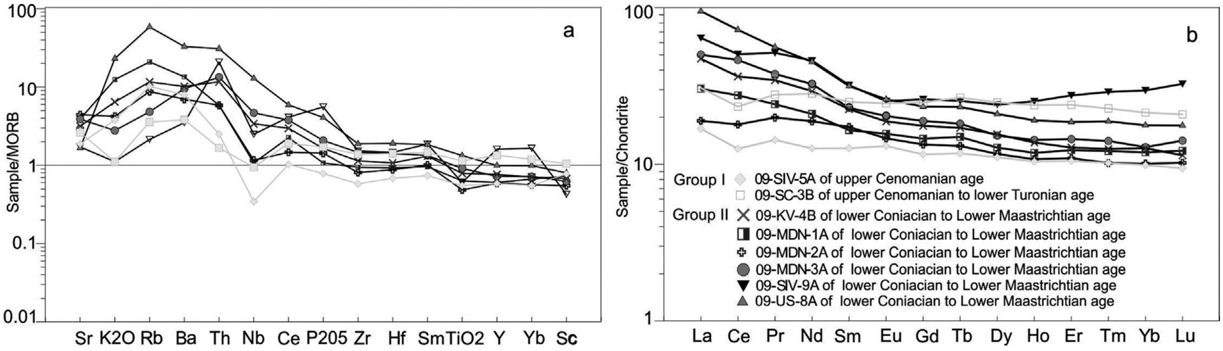

Fig. 4. Mid-ocean ridge basalt (MORB)-normalized trace element (a) and mid-ocean ridge basalt (MORB)-normalized trace element (b) patterns of Group I (light gray lines) and Group II (black lines) basalts associated with the dated chert samples from the Yüksekova Complex.

Fig. 4. Diagrammes des éléments traces normalisés par rapport au MORB (basalte de ride océanique) (a) et des terres rares normalisées par rapport au MORB (basalte de ride océanique) (b) des basaltes des groupe I (lignes gris clair) et II (lignes noires), associés aux échantillons de chert datés du complexe de Yüksekova.

Simplified after Ural et al., 2012, 2013.

in a chaotic mélange, displaying both tectonic (Fig. 3a) and depositionary (Fig. 3c–g) contacts. Individual chert and/or micritic limestone sequences within the volcanic-volcanoclastic units are up to 3 m thick, brick red–violet in color and may comprise decimeter-thick radiolarian cherts alternating with micritic limestones and green–red mudstones.

The most common block types are the pillow lavas (Figs. 3b–e, g) with intra-pillow radiolarian cherts and mudstones, which were sampled to study their geochemical characteristics. The pillow lavas are variably altered and cut by diabase dykes. They include calcite- and zeolite-filled vesicles at the rim of the pillows. Petrographically, they are mainly basaltic in composition, and show tholeiitic to tholeiitic calc-alkaline transitional character (Ural, 2012; Ural et al., 2013). The petrological evaluation of about seventy samples of the Yüksekova volcanic rocks reveal two different compositional groups (Fig. 4) with characteristic features of supra-subduction setting. The detailed evaluation of these compositional groups by trace and rare earth elements (REE) is published in another study (Ural et al., 2014). The evaluation suggests that the first compositional group (Group I) should be considered as product of a back-arc system and the second one (Group II) as representative of the arc-intra arc volcanism. Obviously, both types were developed above an intra-oceanic subduction within a convergent setting. From a large number of radiolarian cherts and mudstones collected from the Group I volcanic rocks of the Yüksekova Complex, only two samples (for sample locations see Fig. 2) yielded radiolarians with an age range of upper Cenomanian to Lower Turonian. The age of the radiolarians obtained from seven chert samples associated with pillow lavas of Group II, on the other hand, range between Lower Coniacian to Lower Maastrichtian.

3. Radiolarian assemblages from the Yüksekova Complex

From the Yüksekova Complex several rock samples obtained from different locations (see Fig. 2 and Table 1 for coordinates) are productive for radiolarians. Oldest radiolarian assemblage [*Patellula verteroensis* (Pessagno)] (Fig. 5.1), *Dactyliosphaera* sp. (Fig. 5.2), *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Fig. 5.3), *Pseudodictyomitra tiara* (Holmes) (Fig. 5.4), *Thanarla veneta* (Squinabol) (Fig. 5.5) and *Dictyomitra formosa* Squinabol (Fig. 5.6) have been determined from 09-SIV-5. Although many taxa have long ranges, the age of the sample is assigned as Upper Cenomanian (Fig. 6) based on the FAD of *Patellula verteroensis* at the base of Upper Cenomanian and LAD of *Thanarla veneta* at the top of Upper Cenomanian (Bragina, 2004; O'Dogherty, 1994; Pessagno, 1963, 1977).

Radiolarian assemblage of sample 09-SC-3 is very similar to those of obtained from sample 09-SIV-5 and

Table 1
Coordinates for localities discussed in text, given in Universal Transverse Mercator.
Tableau 1
Coordonnées des localités dont il est question dans le texte et données dans l'Universal Transverse Mercator.

Sample No	Coordinates	Age
09-SIV-5	4261287N/521117E	Upper Cenomanian
09-SC-3	4260155N/522960E	Upper Cenomanian to Lower Turonian
09-KV-4	4247585N/543520E	Lower Coniacian to Lower Maastrichtian
09-MDN-1	4256675N/554503E	Lower Coniacian to Lower Maastrichtian
09-MDN-2	4252543N/557077E	Lower Coniacian to Lower Maastrichtian
09-MDN-3	4248608N/559762E	Lower Coniacian to Lower Maastrichtian
09-SIV-9	4256605N/537744E	Lower Coniacian to Lower Maastrichtian
09-US-8	4251068N/488850E	Lower Coniacian to Lower Maastrichtian

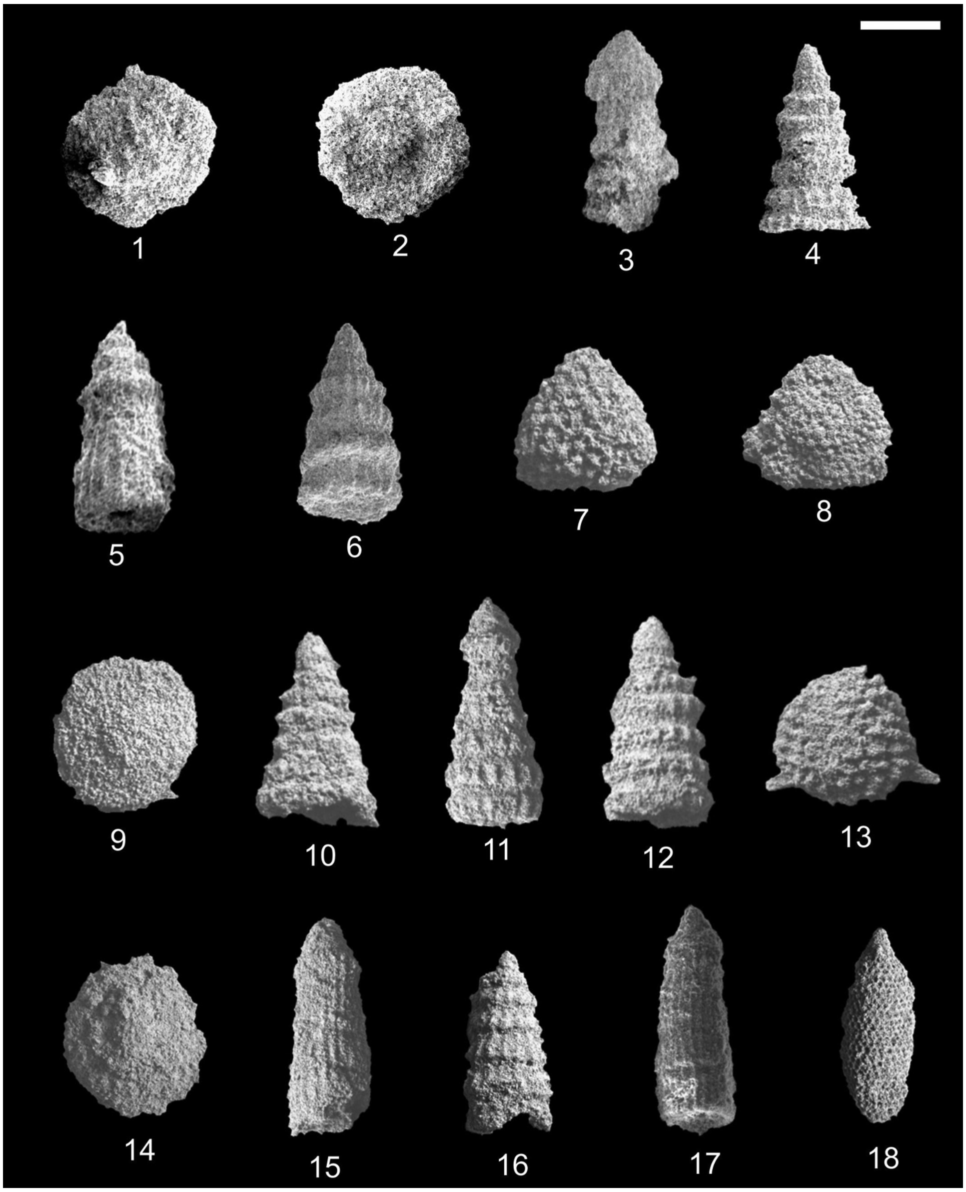

Fig. 5. Scanning electron micrographs of the Upper Cretaceous radiolarians from the Yüksekova Complex, eastern Turkey. Scale-number of microns for each figure: **1–6**. Upper Cenomanian radiolarians from the sample 09-SIV-5: **1**. *Patellula verteroensis* (Pessagno), scale bar: 130 μm; **2**. *Dactyliosphaera* sp., scale bar: 130 μm; **3**. *Pseudodictyomitra pseudomacrocephala* (Squinabol), scale bar: 100 μm; **4**. *Pseudodictyomitra tiara* (Holmes), scale bar: 90 μm; **5**. *Thanarla veneta* (Squinabol), scale bar: 75 μm; **6**. *Dictyomitra formosa* Squinabol, scale bar: 100 μm; **7–12**. Upper Cenomanian to lower Turonian radiolarians from the sample 09-SC-3: **7**. *Alievium* sp., scale bar: 70 μm; **8**. *Pseudoaulophacus* aff. *putahensis* Pessagno, scale bar: 120 μm; **9**. *Patellula verteroensis* (Pessagno), scale bar: 130 μm; **10**. *Crolanium* sp., scale bar: 100 μm; **11**. *Pseudodictyomitra pseudomacrocephala* (Squinabol), scale bar: 105 μm; **12**. *Pseudodictyomitra tiara* (Holmes), scale bar: 150 μm; **13–15**. Lower Coniacian to Lower Maastrichtian radiolarians from the sample 09-KV-4, **13**. *Alievium gallowayi* (White), scale bar: 110 μm; **14**. *Patellula verteroensis* (Pessagno), scale bar: 110 μm; **15**. *Dictyomitra koslovae* Foreman, scale bar: 150 μm; **16-18**. Lower Coniacian to Lower Maastrichtian radiolarians from the sample 09-MDN-1: **16**. *Dictyomitra formosa* Squinabol, scale bar: 110 μm; **17**. *Dictyomitra koslovae* Foreman, scale bar: 90 μm; **18**. *Stichomitra* sp., scale bar: 140 μm.

Fig. 5. Photos de microscopie électronique à balayage de radiolaires du Crétacé supérieur du complexe de Yüksekova, Turquie orientale. Échelle en microns pour chaque figure. **1–6**. Cenomanian superieur radiolaires de l'echantillon 09-SIV-5 : **1**. *Patellula verteroensis* (Pessagno), barre d'échelle : 130 μm; **2**. *Dactyliosphaera* sp., barre d'échelle : 130 μm ; **3**. *Pseudodictyomitra pseudomacrocephala* (Squinabol), barre d'échelle : 100 μm; **4**. *Pseudodictyomitra tiara* (Holmes), barre d'échelle : 90 μm; **5**. *Thanarla veneta* (Squinabol), barre d'échelle : 75 μm ; **6**. *Dictyomitra formosa* Squinabol, barre d'échelle : 100 μm; **7–12**. Cenomanian superieur radiolaires de l'échantillon Turonian inférieur radiolaires de l'échantillon 09-SC-3 : **7**. *Alievium* sp., barre d'échelle : 70 μm ; **8**. *Pseudoaulophacus* aff. *putahensis* Pessagno, barre d'échelle : 120 μm; **9**. *Patellula verteroensis* (Pessagno), barre d'échelle : 130 μm ; **10**. *Crolanium* sp., barre d'échelle : 100 μm; **11**. *Pseudodictyomitra pseudomacrocephala* (Squinabol), barre d'échelle : 105 μm ; **12**. *Pseudodictyomitra tiara* (Holmes), barre d'échelle : 150 μm ; **13–15**. Coniacien inférieur–Maastrichtien inférieur radiolaires de l'échantillon 09-KV-4, **13**. **Alievium gallowayi** (White), barre d'échelle : 110 μm ; **14**. *Patellula verteroensis* (Pessagno), barre d'échelle : 110 μm ; **15**. *Dictyomitra koslovae* Foreman, barre d'échelle : 150 μm; **16–18**. Coniacien inférieur–Maastrichtien inférieur radiolaires de l'échantillon 09-MDN-1 : **16**. *Dictyomitra formosa* Squinabol, barre d'échelle : 110 μm ; **17**. *Dictyomitra koslovae* Foreman, barre d'échelle : 90 μm; **18**. *Stichomitra* sp., barre d'échelle : 140 μm.

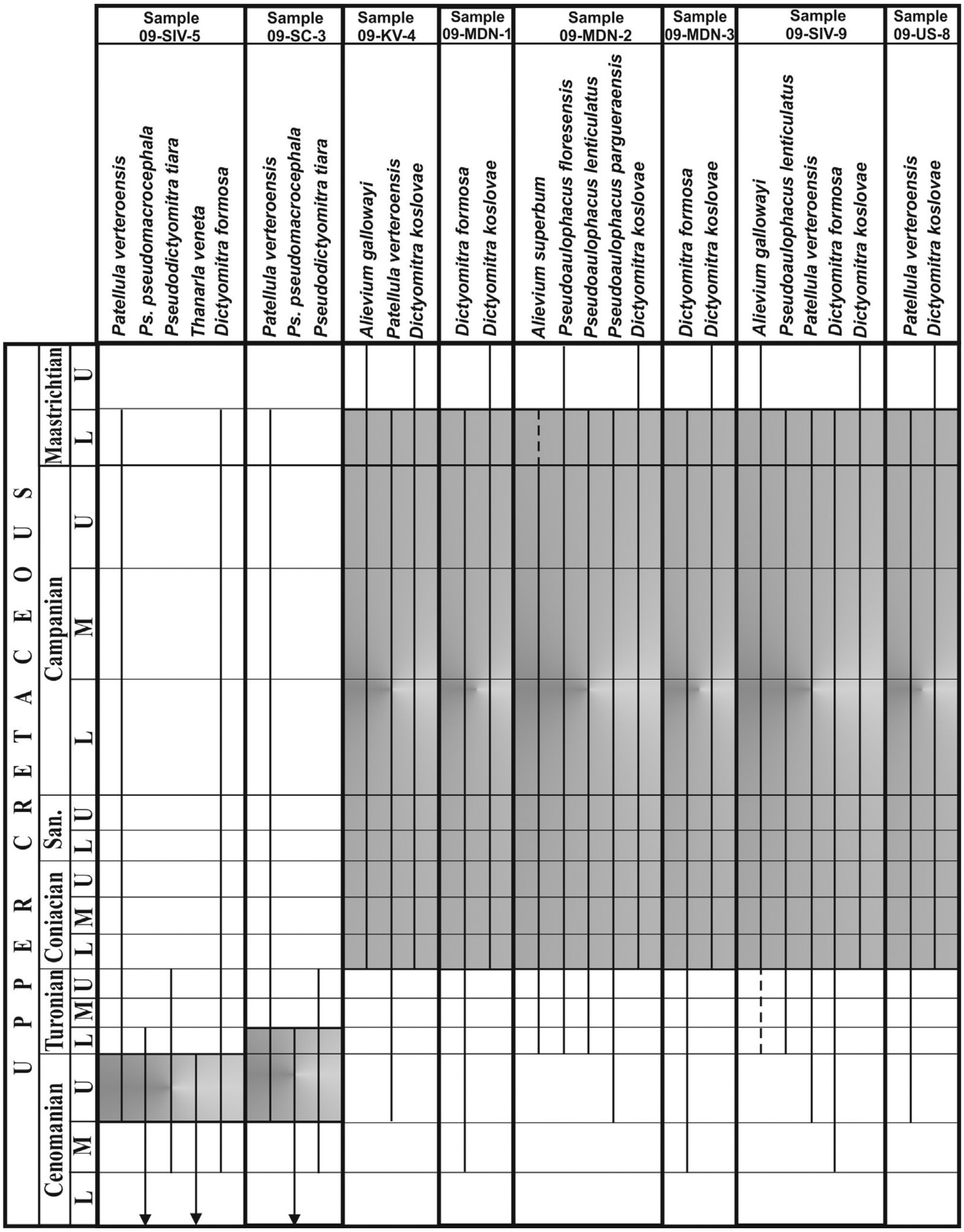

Fig. 6. Stratigraphic ranges of the selected Upper Cretaceous radiolarian taxa from samples of the Yüksekova Complex. Grey areas show the ages of radiolarian assemblages.

Fig. 6. Gammes stratigraphiques de taxons de radiolaires du Crétacé supérieur, sélectionnés dans les échantillons du complexe de Yüksekova. Les zones grises représentent les âges des assemblages de radiolaires.

characterized by *Alievium* sp. (Fig. 5.7), *Pseudoaulophacus* aff. *putahensis* Pessagno (Fig. 5.8), *Patellula verteroensis* (Pessagno) (Fig. 5.9), *Crolanium* sp. (Fig. 5.10), *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Fig. 5.11), *Ps. tiara* (Holmes) (Fig. 5.12). Based on the studies of Pessagno (1977), O'Dogherty (1994) and Bragina (2004), *Patellula verteroensis* appears for the first time at the base of Upper Cenomanian and *Pseudodictyomitra pseudomacrocephala* last appears at the top of Lower Turonian. Presence of these two taxa clearly reveals the Upper Cenomanian to Lower Turonian age for the sample 09-SC-3 (Fig. 6). These two samples (09-SIV-5 and 09-SC-3) are in primary relation with lavas that were geochemically incorporated into Group I (Fig. 4).

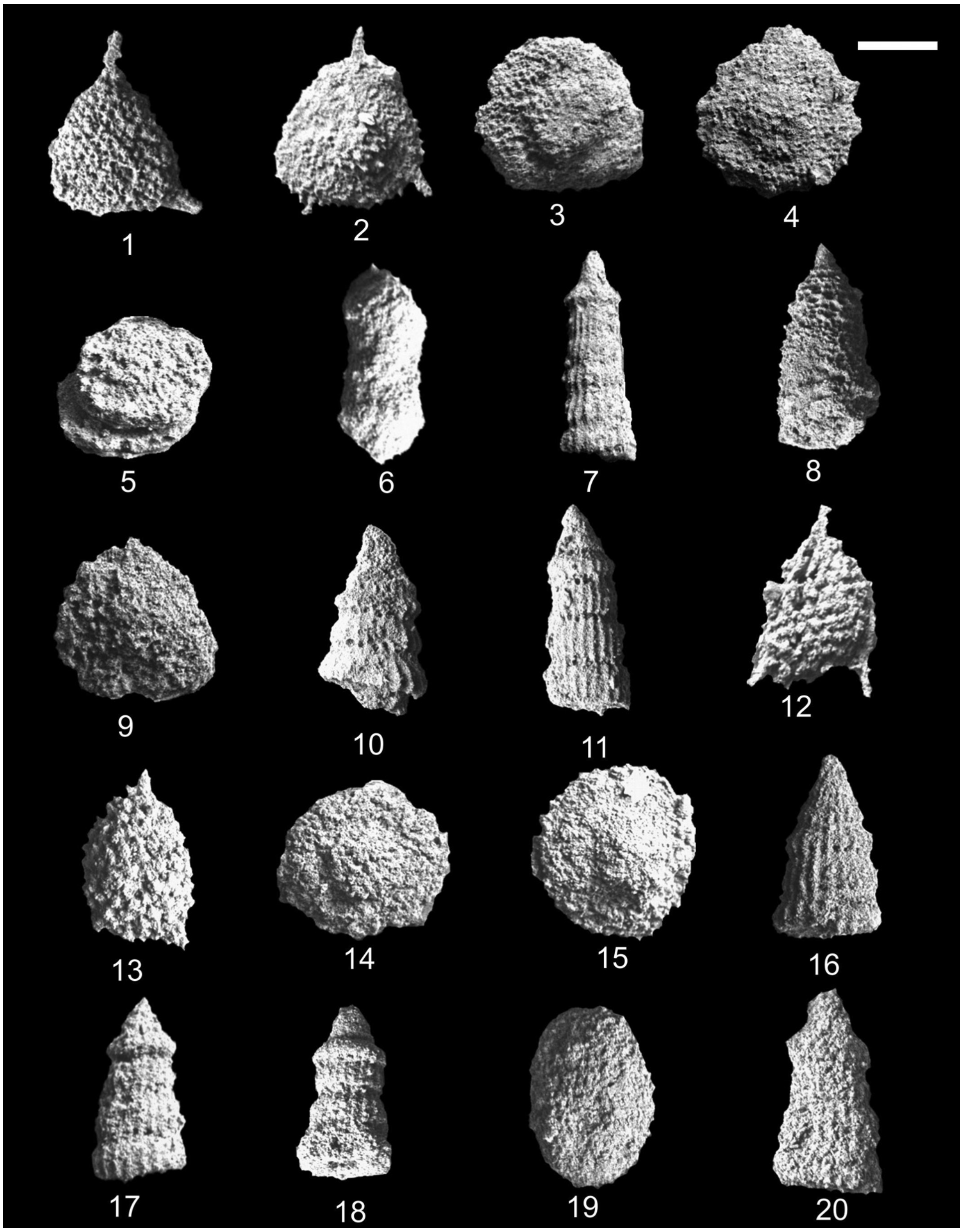

Fig. 7. Scanning electron micrographs of the Upper Cretaceous radiolarians from the Yüksekova Complex, eastern Turkey. Scale: number of microns for each figure: **1–8**. Lower Coniacian to Lower Maastrichtian radiolarians from the sample 09-MDN-2: **1**. *Alievium superbum* (Squinabol), scale bar: 75 μm; **2**. *Pseudoaulophacus floresensis* Pessagno, scale bar: 75 μm; **3**. *Pseudoaulophacus lenticulatus* (White), scale bar: 120 μm; **4**. *Pseudoaulophacus pargueraensis* Pessagno, scale bar: 130 μm; **5**. *Spongodiscus* aff. *multus* Kozlova, scale bar: 70 μm; **6**. *Archaeospongoprunum* cf. *bipartitum* Pessagno, scale bar: 80 μm; **7**. *Dictyomitra koslovae* Foreman, scale bar: 130 μm; **8**. *Spongocapsula* aff. *coronata* (Squinabol), scale bar: 170 μm; **9–11**. Lower Coniacian–Lower Maastrichtian radiolarians from the sample 09-MDN-3: **9**. *Pseudoaulophacus* sp., scale bar: 70 μm; **10**. *Dictyomitra formosa* Squinabol, scale bar: 140 μm; **11**. *Dictyomitra koslovae* Foreman scale bar: 100 μm; **12-18**. Lower Coniacian to Lower Maastrichtian radiolarians from the sample 09-SIV-9**: 12–13**. *Alievium gallowayi* (White), scale bar: 110 μm for both specimens; **14**. *Pseudoaulophacus lenticulatus* (White), scale bar: 100 μm; **15**. *Patellula verteroensis* (Pessagno), scale bar: 110 μm; **16**. *Dictyomitra formosa* Squinabol, scale bar: 100 μm; **17–18**. *Dictyomitra koslovae* Foreman, scale bar: 100 μm for both specimens; **19–20**. Lower Coniacian to Lower Maastrichtian radiolarians from the sample 09-US-8, **19**. *Patellula verteroensis* (Pessagno), scale bar: 90 μm; **20**. *Dictyomitra koslovae* Foreman, scale bar: 100 μm.

Fig. 7. Micrographies électroniques à balayage des radiolaires du Crétacé supérieur du complexe Yüksekova, Est de la Turquie. Échelle en microns pour chaque figure. **1–8**. Radiolaires Coniacien inférieur–Maastrichtien inférieur de l'échantillon 09-MDN-2:**1**. *Alievium superbum* (Squinabol), barre d'échelle : 75 μm ; **2**. *Pseudoaulophacus floresensis* Pessagno, barre d'échelle : 75 μm ; **3**. *Pseudoaulophacus lenticulatus* (White), barre d'échelle : 120 μm ; **4**. *Pseudoaulophacus pargueraensis* Pessagno, barre d'échelle : 130 μm ; **5**. *Spongodiscus* aff. *multus* Kozlova, barre d'échelle : 70 μm ; **6**. *Archaeospongoprunum* cf. *bipartitum* Pessagno, barre d'échelle : 80 μm; **7**. *Dictyomitra koslovae* Foreman, barre d'échelle : 130 μm ; **8**. *Spongocapsula* aff. *coronata* (Squinabol), barre d'échelle : 170 μm ; **9–11**. Radiolaires Coniacien inférieur–Maastrichtien inférieur de l'échantillon 09-MDN-3 : **9**. *Pseudoaulophacus* sp., barre d'échelle : 70 μm ; **10**. *Dictyomitra formosa* Squinabol, barre d'échelle : 140 μm ; **11**. *Dictyomitra koslovae* Foreman barre d'échelle : 100 μm ; **12–18**. Radiolaires Coniacien inférieur–Maastrichtien inférieur de l'échantillon 09-SIV-9 : **12-13**. *Alievium gallowayi* (White), barre d'échelle : 110 μm

Sample 09-KV-4 includes three important and characteristic radiolarian taxa [*Alievium gallowayi* (White)] (Fig. 5.13), *Patellula verteroensis* (Pessagno) (Fig. 5.14) and *Dictyomitra koslovae* Foreman (Fig. 5.15). According to Pessagno (1972, 1976), Foreman (1975), Taketani (1982), Sanfilippo and Riedel (1985) and Bandini et al. (2008), *Alievium gallowayi* first appears at the base of Coniacian and disappears at the end of Maastrichtian. Similar to this taxon, a range of the *Dictyomitra koslovae* has been reported as Lower Coniacian to Upper Maastrichtian by Foreman (1971, 1975), Nakaseko and Nishimura (1981), Sanfilippo and Riedel (1985) and Khokhlova et al. (1994). While considering ranges of these taxa and LAD of *Patelulla verteroensis* (Bandini et al., 2008; Ordoñez Alban, 2007; Pessagno, 1972, 1976), the age of the sample 09-KV-4 is Lower Coniacian to Lower Maastrichtian (Fig. 6).

Radiolarian assemblages are similar and not diverse in samples 09-MDN-1 (*Dictyomitra formosa* Squinabol (Fig. 5.16), *D. koslovae* Foreman (Fig. 5.17), *Stichomitra* sp. (Fig. 5.18)), 09-MDN-3 (*Pseudoaulophacus* sp. (Fig. 7.9), *Dictyomitra formosa* Squinabol (Fig. 7.10) and *Dictyomitra koslovae* Foreman (Fig. 7.11)) and 09-US-8 (*Patellula verteroensis* (Pessagno), Fig. 7.19), *Dictyomitra koslovae* Foreman (Fig. 7.20). *Dictyomitra formosa* is worldwide well-known taxa and has a range from Middle Cenomanian to Lower Maastrichtian (Bandini et al., 2008; O'Dogherty, 1994; Ordoñez Alban, 2007; Pessagno, 1976). While considering co-occurrence of this taxon together with *Dictyomitra koslovae*, Lower Coniacian to Lower Maastrichtian age could be assigned to sample 09-MDN-1 and 09-MDN-3 (Fig. 6). Furthermore, a same age could be also assigned to sample 09-US-8 based on the co-occurrence of *Patellula verteroensis* and *Dictyomitra koslovae* (Fig. 6).

Although slightly diverse radiolarian assemblage [*Alievium superbum* (Squinabol)] (Fig. 7.1), *Pseudoaulophacus floresensis* Pessagno (Fig. 7.2), *P. lenticulatus* (White) (Fig. 7.3), *P. pargueraensis* Pessagno (Fig. 7.4), *Spongodiscus* aff. *multus* Kozlova (Fig. 7.5), *Archaeospongoprunum* cf. *bipartitum* Pessagno (Fig. 7.6), *Dictyomitra koslovae* Foreman (Fig. 7.7) and *Spongocapsula* aff. *coronata* (Squinabol) (Fig. 7.8) have been obtained from sample 09-MDN-2, many of taxa (e.g., *Alievium superbum*, *Pseudoaulophacus floresensis* and *P. lenticulatus*) have longer ranges from Lower Turonian to Lower and Upper Maastrichtian (Bandini et al., 2008; Bragina, 2004; Koslova and Gorbovets, 1966; O'Dogherty, 1994; Pessagno, 1972, 1976; Sanfilippo and Riedel, 1985). On the other hand, *Pseudoaulophacus pargueraensis* is well-known taxon with range from Upper Cenomanian to Lower Maastrichtian (Bandini et al., 2008; Bragina, 2004; Foreman, 1975; Ordoñez Alban, 2007; Pessagno, 1963, 1972; Riedel and Sanfilippo, 1974; Sanfilippo and Riedel, 1985). Co-occurrence of *Pseudoaulophacus pargueraensis* and *Dictyomitra koslovae* clearly reveals the Lower Coniacian to Lower Maastrichtian age for the sample 09-MDN-2 (Fig. 6).

Diverse radiolarians [*Alievium gallowayi* (White)] (Fig. 7.12–13), *Pseudoaulophacus lenticulatus* (White) (Fig. 7.14), *Patellula verteroensis* (Pessagno) (Fig. 7.15), *Dictyomitra formosa* Squinabol (Fig. 7.16) and *Dictyomitra koslovae* Foreman (Fig. 7.17–18) have been encountered from sample 09-SIV-9. As FAD of *Dictyomitra koslovae* is at the base of Coniacian and LAD of the *Pseudoaulophacus lenticulatus*, *Patellula verteroensis* and *Dictyomitra formosa* are at the top of Lower Maastrichtian (Bandini et al., 2008; Bragina, 2004; Foreman, 1975; O'Dhogerty, 1994; Ordoñez Alban, 2007; Pessagno, 1963, 1972, 1976; Sanfilippo and Riedel, 1985), Lower Coniacian to Lower Maastrichtian age is assigned for the sample 09-SIV-9 (Fig. 6). All these fossiliferous samples (09-KV-4, 09-MDN-1, 09-MDN-2, 09-MDN-3, 09-SIV-9 and 09-US-8) are found in primary depositional contact with volcanic rocks geochemically assigned to Group II (Fig. 4).

4. Regional geological constraints

The available data on the age of the opening as well as closure ages of the southern Branch of Neotethys to the North of the Bitlis–Pütürge Massifs are only limited to a few findings. The first set of indirect data comes from radiometric ages from mantle rocks, represented by the Kömürhan and Ispendere ophiolites. Together with a group of other mantle rocks towards the east (e.g., Çolakoğlu et al., 2013), the radiometric ages indicate formation of a supra-subduction-type oceanic lithosphere during the Upper Cretaceous (85 to 105 Ma).

The second set of age data is derived from the crustal rocks of the Southern Neotethys. In this group, blocks of oceanic sediments within the mélanges were sampled and their pelagic foraminifers were dated (e.g., Hempton, 1985; Perinçek, 1979, 1980). This conventional approach of dating mélange blocks has provided some valuable information on the maximum and minimum ages of the oceanic basin evolution, but has not helped to decipher the details of the oceanic crust formation. To overcome this shortage the authors tried to combine geochemical methods to interpret the tectonomagmatic settings of the volcanic rocks in mélange complexes and radiolarian biostratigraphy to date the associated sediments in different areas (e.g., Bortolotti et al., 2013; Bragin and Tekin, 1996; Göncüoğlu et al., 2006, 2010; Tekin and Göncüoğlu, 2009;Tekin et al., 2002, 2012a in Izmir-Ankara Suture zone of Northern Neotethys; Göncüoğlu et al., 2008, 2012, 2014, Tekin et al., 2012b in Intra-Pontide Suture Belt; Uzunçimen et al., 2011; Varol et al., 2011 in the volcano-sedimentary rocks belonging to the Koçali Complex to the South of Bitlis–Pütürge massifs).

First of all, the new age data obtained from the radiolarian proved that a considerable part of pelagic rocks in association with basalts in the tectonic slices in Elazığ-Maden area (Fig. 2), previously included into the Eocene Maden Group (e.g., Herece et al., 1992), are actually Upper

pour les deux spécimens ; **14**. *Pseudoaulophacus lenticulatus* (White), barre d'échelle : 100 μm ; **15**. *Patellula verteroensis* (Pessagno), barre d'échelle : 110 μm ; **16**. *Dictyomitra formosa* Squinabol, barre d'échelle : 100 μm ; **17–18**. *Dictyomitra koslovae* Foreman, barre d'échelle : 100 μm pour les deux spécimens ; **19–20**. Radiolaires Coniacien inférieur–Maastrichtien inférieur de l'échantillon 09-US-8 ; **19**. *Patellula verteroensis* (Pessagno), barre d'échelle : 90 μm ; **20**. *Dictyomitra koslovae* Foreman, barre d'échelle : 100 μm.

Cretaceous in age and should be considered as members of the Yüksekova Complex. This finding is important for recognizing the thin-skinned imbrication of Upper Cretaceous mélanges and their post-accretionary Eocene cover that include similar lithologies.

Secondly, it was already reported from different parts of the Southern Neotethyan suture that the oceanic crust generation within this oceanic strand had continued into lower Upper Cretaceous. The geochemical character of the Upper Cretaceous basalts from a number of localities from Cyprus to Oman suggested a supra-subduction setting (e.g., Blome and Irwin, 1985; Çolakoğlu et al., 2012; Pearce, 1980; Robertson, 2002), generated by the northward subduction of the southern Neotethyan oceanic lithosphere (e.g., Göncüoğlu and Turhan, 1984). Our new data confirms the presence of an "ensimatic arc" (e.g., Yazgan et al., 1983) and hence, the intra-oceanic subduction within the southern Branch of Neotethys. Moreover, the new data provides a more comprehensible picture on the subduction related events during this process. Based upon the Upper Cenomanian–Lower Turonian radiolarian ages obtained from arc related volcanic rocks it is obvious that the generation of an island arc was realized during this time interval. Yet, this is the only reliable finding where paleontological age data is combined with petrogenetic evaluation and contrasts with suggestions (e.g., Perinçek and Özkaya, 1981) that the chert deposition in association with basaltic volcanism commenced not earlier than the Upper Turonian. It is important to note that no evidence for older or younger cherts in association with basalts was encountered during our sampling campaign.

Likewise, the finding of Lower Coniacian–Lower Maastrichian radiolarian cherts within the back-arc type basalts has important constraints on the closing history of the Southern Neotethys. In previous studies, either no distinction was made for different volcanisms of the supra-subduction setting (e.g., Beyarslan and Bingöl, 2000), or an approximate Campanian to Maastrichtian time interval was suggested for back-arc spreading (e.g., Robertson et al., 2007). For a part of the back-arc basalts in Zagros belt in Iran (e.g., Moghadam et al., 2009), a similar age range is suggested. Our new ages, however, suggest that the back-arc spreading has commenced earlier then in Iran, i.e. during Early Coniacian to Early Maastrichtian as proven by the radiolarian assemblages in association with back-arc-type basalt blocks in the Yüksekova Complex. Taking into account the recent finding of pelagic limestones within Back-arc basalts (Çolakoğlu et al., 2013), the spreading in this basin continued during the Upper Maastrichtian. Simultaneously, huge accretionary complexes were formed all along the closing southern Neotethys from Cyprus to Oman (e.g., Robertson et al., 2012). The basaltic blocks, including the studied arc and back-arc rocks that were generated in different tectonomagmatic settings were incorporated during this time interval into the Yüksekova-type mélange complexes.

The most clear-cut tectonic scenario that may comply with these findings is as following:

- the northward intra-oceanic subduction of the Southern Neotethyan oceanic lithosphere generated at least during the Upper Cenomanian to Lower Turonian an island arc;
- the roll-back of the oceanic lithosphere during ongoing subduction was responsible for the formation of an extensional back-arc basin within the overriding block, where the Back-arc basalts were erupted during the Lower Coniacian to Lower Maastrichtian interval.

This scenario is in accordance with the tectonic models proposed by several authors (for a review see Robertson et al., 2007) for the closing Neotethys between the Tauride–Anatolide and the Arabian platforms. Its importance, however, is that it provides the first reliable age constraints of the arc and back-arc systems by dating the radiolarian bearing sediments.

5. Conclusions

The systematic sampling of radiolarian cherts of the oceanic sediments in association with basalt blocks within the Yüksekova Complex in SE Turkey and the geochemical fingerprinting of the these pillow basalts has resulted in identification of an arc–back-arc pair.

The studied arc basalts were very probably formed during the Upper Cenomanian to Lower Turonian interval by northward intra-oceanic subduction of Southern Neotethys. The arc generation was then followed without a considerable break by the back-arc spreading above the subducting slab during the Lower Coniacian to Lower Maastrichtian period. Regional data suggests that the ongoing compression between the Tauride–Anatolide and the Arabian plates gave way to the formation of the Yüksekova-type subduction–accretion complexes, where all kinds of oceanic lithologies were accommodated to form mélanges along the Amanos–Elazığ-Van Suture Belt in southern Turkey.

Acknowledgements

We thank Turkish Scientific Council (Project No: 108Y201) and Fırat University Scientific Research Fund (FUBAP-1632) for providing financial support for this research. Authors also wish to thank Luis O'Dogherty for reviewing the manuscript.

References

Aktaş, G., Robertson, A.H.F., 1984. The Maden Complex, SE Turkey: Evolution of a Neo-Tethyan active margin. In: Dixon, J.E., Robertson, A.H.F. (Eds.), The Geological Evolution of the Eastern Mediterranean. Blackwell Scientific Publications, Oxford, pp. 375–402.

Bağcı, U., Parlak, O., Höck, V., 2005. Whole rock and mineral chemistry of cumulates from the Kızıldağ (Hatay) ophiolite (Turkey): clues for multiple magma generation during crustal accretion in the sourhern Neotethyan Ocean. Min. Mag. 69, 53–76.

Bandini, A.N., Flores, K., Baumgartner, P.O., Jackett, S.J., Denyer, P., 2008. Late Cretaceous and Paleogene Radiolaria from the Nicoya Peninsula,Costa Rica: a tectonostratigraphic application. Stratigraphy 5 (1), 3–21.

Beyarslan, M., 2005. The Upper Cretaceous ophiolites and magmatic arc rocks in the eastern Taurus, Turkey. Geol. Soc. of India 66, 323–333.

Beyarslan, M., Bingöl, A.F., 2000. Petrology of a supra-subduction zone ophiolite (Kömürhan-Elazığ-Turkey). Can. J. Earth Sci. 37, 1411–1424.

Bingöl, A.F., Beyarslan, M., 1996. Geochemistry and petrology of the Elazığ Magmatics. In: Korkmaz, S., Akçay, M. (Eds.), Proceedings of

30th Annual Symposium. Karadeniz Technical University, Trabzon, pp. 208–227 (in Turkish).
Blome, C.D., Irwin, W.P., 1985. Equivalent radiolarian ages from ophiolitic terranes of Cyprus and Oman. Geology 13, 401–404.
Bortolotti, V., Chiari, M., Göncüoğlu, M.C., Marcucci, M., Principi, G., Tekin, U.K., Saccani, E., Tassinari, R., 2013. Age and geochemistry of basalt-chert associations in the ophiolites of the Izmir-Ankara Mélange east of Ankara, Turkey: preliminary data. Ofioliti 38 (2), 157–173.
Bragin, N.Y., Tekin, U.K., 1996. Age of radiolarian-chert blocks from the Senonian Ophiolitic Melange (Ankara, Turkey). Island Arc 5, 114–122.
Bragina, L.G., 2004. Cenomanian-Turonian radiolarians of northern Turkey and Crimean Mountains. Paleontol. J. 38 (4), 325–456.
Çolakoğlu, A.R., Sayit, K., Günay, K., Göncüoğlu, M.C., 2012. Geochemistry of mafic dykes from the Southeast Anatolian ophiolites, Turkey: implications for an intra-oceanic arc-basin system. Lithos, 113–126.
Çolakoğlu, A.R., Göncüoğlu, M.C., Günay, K., Çakır, Ü., 2013. Geology of the mélange complexes in Van-Özalp area and their setting within the SE Anatolian Suture Belts. In: 19th Int. Petrol. and Nat. Gas Cong., Abstracts, pp. 339–340.
Foreman, H.P., 1971. Cretaceous Radiolaria Leg 7. DSDP. In: Winterer, E.L., Riedel, W.R. (Eds.), Initial Rep. of the Deep Sea Dril. Project, 7. U.S. Govern. Print. Office, Washington D.C., pp. 1673–1693.
Foreman, H.P., 1975. Radiolaria from the North Pacific, DSDP, Leg, 32. In: Larson, R.L. (Ed.), Initial Rep. of the Deep Sea Dril. Project, Covering Leg 32 of the Crises of the Drilling Vessel Glomar Challenger, 32. U.S. Govern. Print. Office, Washington D.C., pp. 579–676.
Göncüoğlu, M.C., 2010. Introduction to the geology of Turkey: Geodynamic evolution of the Pre-Alpine and Alpine Terranes. MTA Monographs Series (ISBN 978-605-4075-74, in Turkish).
Göncüoğlu, M.C., Turhan, N., 1984. Geology of the Bitlis Metamorphic Belt. In: Tekeli, O., Göncüoğlu, M.C. (Eds.), Geology of the Taurus Belt, Proc. of Int. Symp., Publ. of Min. Res. and Expl. Inst. of Turkey, Ankara, pp. 237–244.
Göncüoğlu, M.C., Dirik, K., Kozlu, H., 1997. General characteristics of pre-Alpine and Alpine Terranes in Turkey: explanatory notes to the terrane map of Turkey: Ann. Géol. Pays Hellen. Geol. Soc. Greece 37, 515–536.
Göncüoğlu, M.C., Sayit, K., Tekin, U.K., 2010. Oceanization of the northern neotethys: geochemical evidence from ophiolitic mélange basalts within the Izmir-Ankara suture belt, NW Turkey. Lithos 116, 175–187.
Göncüoğlu, M.C., Yalınız, K., Tekin, U.K., 2006. Geochemistry, tectono-magmatic discrimination and radiolarian ages of basic extrusives within the Izmir-Ankara Suture Belt (NW Turkey): time constraints for the Neotethyan evolution. Ofioliti 31, 25–38.
Göncüoğlu, M.C., Gürsu, S., Tekin, U.K., Köksal, S., 2008. New data on the evolution of the Neotethyan oceanic branches in Turkey: Late Jurassic ridge spreading in the Intra-Pontide branch. Ofioliti 33, 153–164.
Göncüoğlu, M.C., Marroni, M., Sayit, K., Tekin, U.K., Ottria, G., Pandolfi, L., Ellero, A., 2012. The Aylı Dağ ophiolite sequence (central-northern Turkey): a fragment of Middle Jurassic oceanic lithosphere within the Intra-Pontide Suture Zone. Ofioliti 37, 77–91.
Göncüoğlu, M.C., Marroni, M., Pandolfi, L., Ellero, A., Ottria, G., Catanzariti, R., Tekin, U.K., Sayit, K., 2014. The Arkot Dağ Melange in Araç area, central Turkey: evidence of its origin within the geodynamic evolution of the Intra-Pontide Suture Zone. J. Asian Earth Sci. 85, 117–139.
Hempton, M., 1984. Results of detailed mapping near Lake Hazar, eastern Taurus mountains. In: Tekeli, O., Göncüoğlu, M.C. (Eds.), Geology of the Taurus Belt, Proceedings of International Symposium, Publ. of Min. Res. and Expl. Inst. of Turkey, Ankara, pp. 223–228.
Hempton, M., 1985. Structure and deformation history of the Bitlis suture near Lake Hazar, SE Turkey. Geol. Soc. Am. Bull. 96, 223–243.
Herece, E., Akay, E., Küçümen, Ö., Sarıaslan, M., 1992. Geology of Elazığ-Sivrice- Palu region. Gen. Direc. of Min. Res. and Expl. Report No: 9634, Ankara (unpublished, in Turkish).
Karaoğlan, F., Parlak, O., Klötzli, U., Thöni, M., Koller, F., 2012. U–Pb and Sm–Nd geochronology of the ophiolites from the SE Turkey: implications for the Neotethyan evolution. Geodinamica Acta 25 (3–4), 146–161.
Khokhlova, I.E., Bragina, L.G., Krasheninnikov, V.A., 1994. Zonal stratigraphy of the Upper Cretaceous and Paleogene deposits of the Key Perapedhi section (Southern Cyprus) by means of radiolarians and correlation with the foreminiferal zones. In: Krashininokov, V.A., Hall, J.K. (Eds.), Geological Structure of the northwestern Mediterranean, Jaruselam, pp. 219–250.
Koslova, G.E., Gorbovets, A.N., 1966. Radiolarians of the Upper Cretaceous and Upper Eocene deposits of the West Siberian lowlands, 248. Trudy VNIGRI, Leningrad.
Michard, A., Whitechurch, H., Ricou, L.E., Montigny, R., Yazgan, E., 1985. Tauric subduction (Malatya–Elazığ province) and its bearing on the tectonics of the Tethyan realm in Turkey. In: Dixon, J.E., Robertson, A.H.F. (Eds.), The Geological Evolution of the eastern Mediterranean. Geol. Soc. Spec. Publ., London, pp. 361–373.
Moghadam, H.S., Whitechurch, H., Rahgoshay, M., Monsef, I., 2009. Significance of Nain-Baft ophiolitic belt (Iran): Short-lived, transtensional Cretaceous back-arc oceanic basins over the Tethyan subduction zone. C. R. Geoscience 341 (12), 1016–1028.
MTA, 2002. Geological Map of Turkey, 1:500.000 scale the Erzurum Quadrangale. Gen. Direc. of Min. Res. and Expl., Ankara, Turkey.
Nakaseko, K., Nishimura, A., 1981. Upper Jurassic and Cretaceous radiolaria from the Shimato Group in Southwest Japan. Sci. Rep. Col. Gen. Educ., Osaka Univ. 30 (2), 133–203.
O'Dogherty, L., 1994. Biochronology and paleontology of Mid-Cretaceous radiolarians from northern Apennines (Italy) and Betic Cordillera (Spain). Mém. Géol. (Lausanne) 21.
Ordoñez Alban, M., 2007. Asociaciones de radiolarios de la Cordillera Chongón Colonche, Ecuador (Coniaciano–Eoceno). In: Díaz-Martínez, E., e Rábano, I. (Eds.), 4th European Meeting on the Palaeontology and Stratigraphy of Latin America. Cuadernos del Museo Geominero, nº 8. Inst. Geol. y Min. de España, Madrid, pp. 291–299.
Parlak, O., Höck, V., Kozlu, H., Delaloye, M., 2004. Oceanic crust generation in an island arc tectonic setting, SE Anatolian Orogenic Belt (Turkey). Geol. Mag. 141, 583–603.
Parlak, O., Rızaoğlu, T., Bağcı, U., Karaoğlan, F., Höck, V., 2009. Tectonic significance of the geochemistry and petrology of ophiolites in Southeast Anatolia, Turkey. Tectonophysics 473, 173–187.
Pearce, J.A., 1980. Geochemical evidence for the genesis and eruptive setting of lavas from Tethyan ophiolites. In: Panayiotou, A. (Ed.), Ophiolites: Proc. of the Inter. Ophiolite Symp., Cyprus, pp. 261–272.
Perinçek, D., 1979. The geology of Hazro-Korudağ-Çüngüş-Maden-Ergani-Hazar-Elazığ- Malatya Area, Guide Book. The Geol. Soc. Turkey.
Perinçek, D., 1980. Sedimentation on the Arabian shelf under the control of tectonic activity in Taurid Belt. Proc. of Fifth Petr. Congr. of Turkey, Ankara, 77–93 (in Turkish with English Abstract).
Perinçek, D., Özkaya, I., 1981. Tectonic evolution of the northern margin of the Arabian Plate. Yerbilimleri 8, 91–101 (in Turkish with English abstract).
Pessagno Jr., E.A., 1963. Upper Cretaceous Radiolaria from Puerto Rico. Micropaleontology 9 (2), 197–214.
Pessagno Jr., E.A., 1972. Cretaceous radiolaria, Part I, The Phaseliformidae, a new family and other Spongoniscacea from the Upper Cretaceous portion of the Great Valley Sequence, Part II, Pseudoaulophacidae Riedel from the Cretaceous of California and the Blake Bahama Basin (Joides leg I). Bull. Am. Pal. 61 (270), 269–328.
Pessagno Jr., E.A., 1976. Radiolarian zonation and stratigraphy of the Upper Cretaceous portion of the Great Valley Sequence, California Coast Ranges. Spec. Publ. Micropaleontol. 2, 1–95.
Pessagno Jr., E.A., 1977. Lower Cretaceous radiolarian biostratigraphy of the Great Valley Sequence and Franciscan Complex, California Coast Ranges. Cushman Foundation for Foraminiferal Research. Spec. Publ. 15, 1–87.
Rızaoğlu, T., Parlak, O., Höck, V., Işler, F., 2006. Nature and significance of Late Cretaceous ophiolitic rocks and their relation to the Baskil granitoid in Elazığ region, SE Turkey. Geol. Soc. of London Spec. Publ. 260, 327–350.
Rızaoğlu, T., Parlak, O., Höck, V., Koller, F., Hames, W.E., Billor, Z., 2009. Andean type active margin formation in the eastern Taurides: Geochemical and geochronological evidence from the Baskil Granitoid, SE Turkey. Tectonophysics 473, 188–207.
Riedel, W.R., Sanfilippo, A., 1974. Radiolaria from the southern Indian Ocean DSDP leg 26. In: Davis, T.A., Luyendyke, B.P. (Eds.), Rep. of the Deep Sea Drill, 26. Project, U.S., Gover. Print. Office, Washington, pp. 771–783.
Robertson, A.H.F., 2002. Overview of the genesis and emplacement of Mesozoic ophiolites in the eastern Mediterranean Tethyan region. Lithos 65, 1–67.
Robertson, A.H.F., 2004. Development of concepts concerning the genesis and emplacement of Tethyan ophiolites in the eastern Mediterranean and Oman regions. Earth Sci. Rev. 66, 331–387.
Robertson, A.H.F., Parlak, O., Ustaömer, T., 2012. Overview of the Palaeozoic-Neogene evolution of Neotethys in the eastern Mediterranean region (Southern Turkey, Cyprus, Syria). Petrol. Geos. 18, 381–404.
Robertson, A.H.F., Parlak, O., Rızaoğlu, T., Ünlügenç, U.C., Inan, N., Taslı, K., Ustaömer, T., 2007. Tectonic evolution of the South Tethyan ocean: evidence from the eastern Taurus Mountains (Elazığ region, SE Turkey). In: Ries, A.C., Butler, R.W.H., Graham, R.H. (Eds.), Deformation of the Continental Crust: The Legacy of Mike Coward, Geol. Soc. London Spec. Publ., 272, pp. 231–270.

Sanfilippo, A., Riedel, W.R., 1985. In: Bolli, H.M., Saunders, J.B., Perch-Nielson, K. (Eds.), Cretaceous Radiolaria. Cambridge University Press, pp. 573–630.

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

Taketani, Y., 1982. Cretaceous radiolarian biostratigraphy of the Urakawa and Obira Areas, Hokkaido. Tohoku Univ., Sci. Report Second Ser. (Geology) 52, 1–76.

Tekin, U.K., Göncüoğlu, M.C., 2009. Late Middle Jurassic (Late Bathonian-Early Callovian) radiolarian cherts from the Neotethyan Bornova Flysch Zone, Spil Mountains, western Turkey. Strat. and Geol. Correlation 17 (3), 298–308.

Tekin, U.K., Göncüoğlu, M.C., Turhan, N., 2002. First evidence of Late Carnian radiolarian fauna from the Izmir-Ankara Suture Complex, central Sakarya, Turkey: Implications for the opening age of the Izmir-Ankara branch of Neotethys. Geobios 35, 127–135.

Tekin, U.K., Göncüoğlu, M.C., Uzunçimen, S., 2012a. Radiolarian assemblages from an olistolith with Middle - Late Jurassic to early Late Cretaceous pelagic deposition within the Bornova Flysch Zone in western Turkey. Bull. Soc. geol. France 183 (4), 307–318.

Tekin, U.K., Göncüoğlu, M.C., Pandolfi, L., Marroni, M., 2012b. Middle-Late Triassic radiolarian cherts from the Arkotdağ mélange in northern Turkey: implications for the life span of the northern Neotethyan branch. Geodinamica Acta 25 (3–4), 305–319.

Turan, M., Bingöl, A.F., 1991. Tectono-stratigraphic characteristics of the region between *Kovancılar-Baskil*, Elazığ, Turkey. In: Yetiş, C. (Ed.), Proc. of Ahmet Acar Geol. Symp., Adana, pp. 211–226 (in Turkish).

Ural, M., 2012. Petrochemistry, petrology and age of the basic volcanites of the Yuksekova Complex around Elazığ and Malatya. (Ph. D. Thesis). Fırat University, Graduate Schools of Science, Engineering and Technology, Elazığ (in Turkish with English abstract, unpublished).

Ural, M., Göncüoğlu, M.C., Tekin, U.K., Arslan, M., 2013. Geology and geodynamic interpretation of the volcanic rocks of the Yüksekova Complex in Elazığ and surroundings. In: 19th Int. Petroleum and Natural Gas Congress Proceedings, pp. 317–319.

Ural, M., Kürüm, S., Arslan, M., Göncüoğlu, M.C., Tekin, U.K., 2010. Petrographical and petrochemical features of Upper Cretaceous pillow lavas from Elazığ and Malatya areas, SE Turkey. Geophys. Res. Abstracts 12, EGU2010–EGU11662.

Ural, M., Kürüm, S., Tekin, U.K., Arslan, M., Göncüoğlu, M.C., 2012. Late Cretaceous arc-back arc system within the closing Troodos–Bitlis–Zagros branch of Neotethys in eastern Turkey: Geochemical indications. In: P06D/49/Mo. Goldschmidt Conference.

Ural, M., Göncüoglu, M.C., Arsan, M., Tekin, U.K., Kürüm, S., 2014. Petrological and paleontological evidence for generation of an arc–backarc system within the closing southern branch of Neotethys during Late Cretaceous. In: Proceedings XX Congress of the Carpathian Balkan Geological Association, pp. 1–5.

Uzunçimen, S., Tekin, U.K., Bedi, Y., Perincek, D., Varol, E., Soycan, H., 2011. Discovery of the Late Triassic (Middle Carnian–Rhaetian) radiolarians in the volcano-sedimentary sequences of the Koçali Complex, SE Turkey: correlation with the other Tauride units. J. Asian Earth Sci. 40, 180–200.

Varol, E., Bedi, Y., Tekin, U.K., Uzunçimen, S., 2011. Geochemical and petrological characteristics of Late Triassic basic volcanic rocks from the Koçali Complex, SE Turkey: implications for the Triassic evolution of southern Tethys. Ofioliti 36 (1), 99–133.

Yazgan, E., 1984. Geodynamic evolution of the eastern Taurus Region (Malatya-Elazığ area, Turkey). In: Tekeli, O., Göncüoğlu, M.C. (Eds.), Geology of the Taurus Belt, Proc. of Int. Sym., Publ. of Min. Res. and Expl. Inst. of Turkey, Ankara, pp. 199–208.

Yazgan, E., Michard, A., Whitechurch, H., Montigny, R., 1983. Le Taurus de Malatya (Turquie orientale) élément de la suture sud-téthysienne. Bull. Soc. geol. France 25 (1), 59–69.

Yılmaz, Y., 1993. New evidence and model evolution of the Southeast Anatolian Orogeny. Geol. Soc. of Am. Bull. 105, 251–271.