C. R. Palevol 10 (2011) 1–10

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General palaeontology

Devonian radiolarian ribbon cherts from the Karakaya Complex, Northwest Turkey: Implications for the Paleo-Tethyan evolution

Cherts rubanés à radiolaires du Dévonien du complexe de Karakaya, Turquie nord-occidentale : implications pour l'évolution de la Paléo-Téthys

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ARTICLE INFO

Article history:
Received 29 August 2010
Accepted after revision 14 December 2010
Available online 1 February 2011

Presented by Phillipe Taquet

Keywords:
Devonian
Radiolaria
Chert
Karakaya Complex
Paleo-Tethys
Pontides
Turkey

Mots clés :
Dévonien
Radiolaires
Cherts
Complexe de Karakaya
Paléo-Téthys
Pontides
Turquie

ABSTRACT

Devonian radiolarian ribbon cherts are found as olistoliths and as a thin (<100 m) tectonic slice in pervasively deformed sandstone and shale in a Triassic subduction-accretion complex (Upper Karakaya Complex) in Northwest Turkey. The subduction-accretion complex also comprises exotic blocks of Lower Carboniferous and Upper Permian limestone. It lies tectonically over a thick metabasite series and is unconformably overlain by little deformed continental to shallow marine sedimentary rocks of Jurassic age. The Devonian radiolarian cherts, along with the earlier descriptions of Carboniferous and Permian radiolarian cherts from the Karakaya Complex suggest the subduction of a Late Paleozoic ocean, the Paleo-Tethys, along the southern margin of the Pontides.

RÉSUMÉ

Des cherts rubanés dévoniens à radiolaires ont été trouvés sous la forme d'olistolithes et de minces lames tectoniques (<100 m), dans des grès et argiles considérablement déformés d'un complexe de subduction-accrétion triasique (Complexe de Karakaya supérieur) de Turquie nord-occidentale, le complexe de subduction-accrétion comporte aussi des blocs exotiques de calcaire du Carbonifère inférieur et du Permien supérieur. Il repose tectoniquement sur une série épaisse de métabasite et est recouvert en discordance par des roches sédimentaires d'âge Jurassique peu déformées, d'origine continentale à marine peu profonde. Les cherts dévoniens à radiolaires, de même que les descriptions plus récentes de cherts à radiolaires carbonifères et permiens du complexe de Karakaya suggèrent la subduction d'un océan Paléozoïque tardif, la Paléo-Téthys, le long de la marge méridionale des Pontides.

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doi:10.1016/j.crpv.2010.12.002

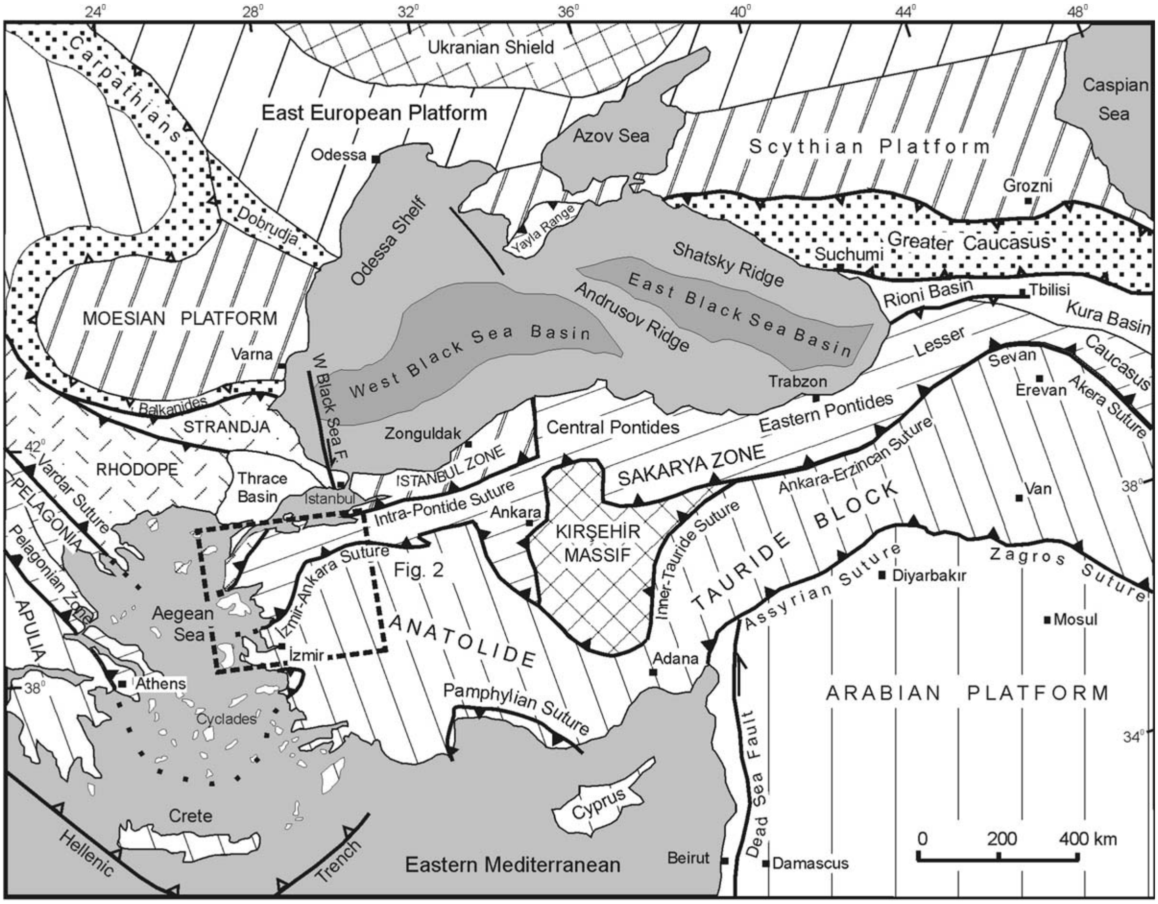

Fig. 1. Tectonic map of the eastern Mediterranean-Black Sea region (modified from Okay and Tüysüz, 1999). The Strandja, Istanbul and Sakarya zones make up the Pontides.

Fig. 1. Carte tectonique de la région Méditerranée orientale – Mer Noire (modifié d'après Okay et Tüysüz, 1999). Les zones de Strandja, Istanbul et Sakarya forment les Pontides.

1. Introduction

Late Paleozoic paleogeographic constructions show the presence of a large oceanic embayment in the region of the Middle East and eastern Mediterranean (e.g., Stämpfli and Borel, 2002; Torsvik and Cocks, 2004). However, evidence for this Paleo-Tethyan ocean in the geological record of the region has been meagre, with few descriptions of Paleozoic ophiolites, blueschists or subduction-accretion complexes. The scarcity of data has given rise to a series of different models regarding the location and evolution of the Paleozoic oceans (Robertson et al., 1996; Şengör et al., 1984; Stämpfli et al., 2002). Here we describe Devonian radiolaria from ribbon cherts in a Triassic subduction-accretion complex in northwest Turkey and discuss their significance in terms of the Paleo-Tethyan evolution.

2. Geological setting

The Pontides comprise the area between the Izmir-Ankara-Erzincan suture and the Black Sea (Fig. 1). Their geological record shows close affinity to that of Eurasia since the Early Paleozoic (Okay et al., 2006). One of the major tectonic units of the Pontides is the Sakarya Zone, which has a complex basement overlain by Jurassic and younger sedimentary strata. An important component of this basement is Permo-Triassic subduction-accretion complexes, collectively called as the Karakaya Complex (Okay et al., 1996; Pickett and Robertson, 1996; Tekeli, 1981). The Karakaya Complex is subdivided into two tectonostratigraphic units; the structurally lower unit consists of metabasite, phyllite and marble. Early and Middle Triassic conodont faunas have been described from the marbles of the Lower Karakaya Complex (Kaya and Mostler, 1992; Kozur et al., 2000). The metamorphism in the Lower Karakaya Complex is generally greenschist facies but it also includes tectonic slices of eclogites and blueschists with Late Triassic phengite Ar-Ar ages (Okay and Monié, 1997; Okay et al., 2002). In the eastern Pontides the metamorphism in the Lower Karakaya Complex is dated as Late Permian (ca. 260 Ma Rb-Sr and Ar-Ar mica ages, Topuz et al., 2004a) suggesting a long period of Late Permian-Triassic subduction. The Lower Karakaya Complex is interpreted as the upper parts of an oceanic plateau or a series of oceanic islands accreted to the southern margin of Eurasia during the Late Triassic (Okay, 2000; Pickett and Robertson,

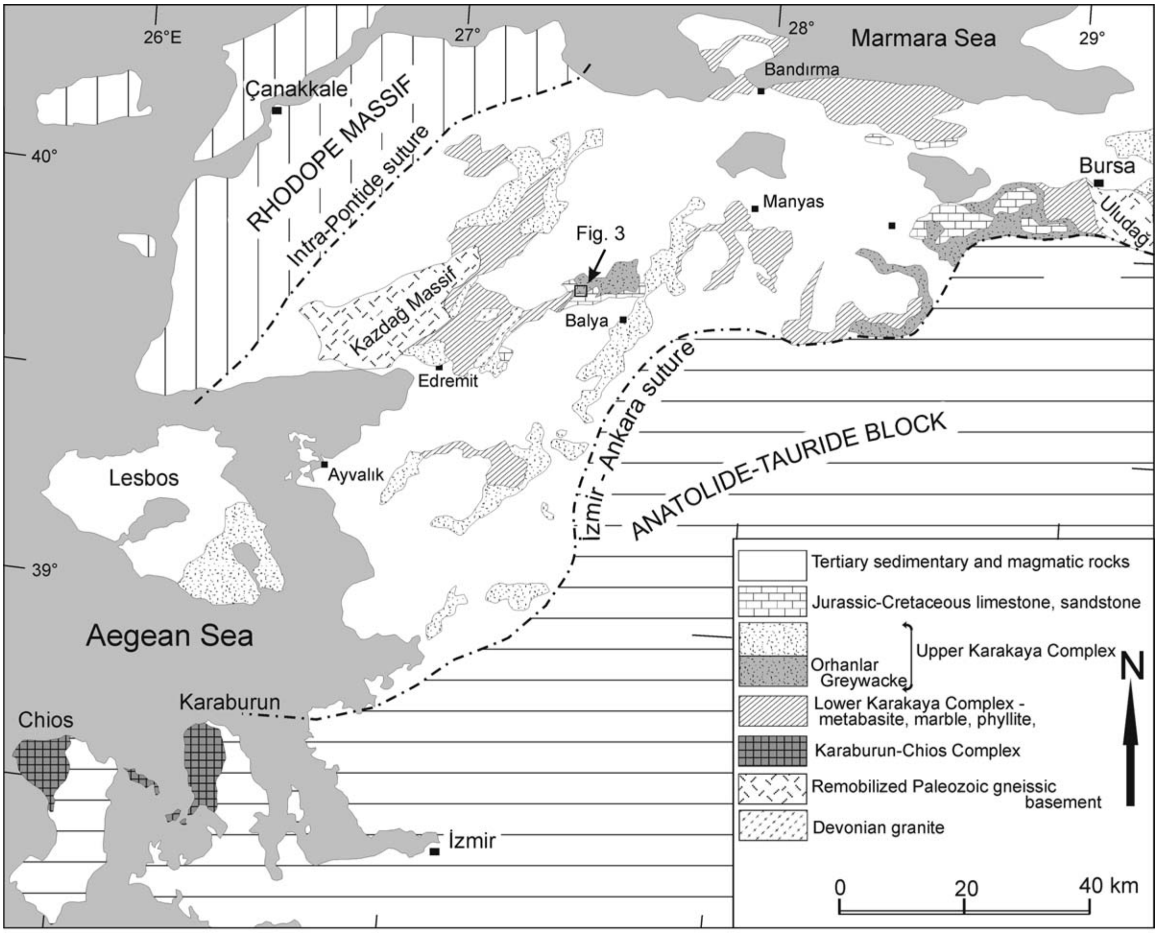

Fig. 2. Tectonic map of Northwest Turkey showing the outcrops of the Karakaya Complex. For location see Fig. 1.

Fig. 2. Carte tectonique de la Turquie nord-occidentale montrant les affleurements du complexe de Karakaya. Pour la localisation, voir la Fig. 1.

1996, 2004; Sayit et al., 2010). It is overlain by strongly deformed, unmetamorphosed to slightly metamorphosed sedimentary and volcano-sedimentary units, collectively called the Upper Karakaya Complex (Federici et al., 2010; Okay and Göncüoğlu, 2004). A characteristic feature of the Upper Karakaya Complex is widespread tectonized olistostromes with blocks of neritic Carboniferous and Permian limestone, pelagic Upper Permian and Triassic limestone, Carboniferous and Permian radiolarian ribbon chert and basalt (Kozur and Kaya, 1994; Okay and Mostler, 1994; Leven and Okay, 1996; Wiedmann et al., 1992).

The Upper Karakaya Complex is subdivided into several units, differentiated mainly on the basis of lithology (Okay et al., 1991, 1996; Okay and Göncüoğlu, 2004; Pickett and Robertson, 1996). The Devonian radiolarian cherts are found in the Orhanlar Greywacke, a thick (> 1000 m) series of strongly deformed sandstone, siltstone and shale with minor conglomerate (Figs. 2 and 3).

3. Orhanlar Greywacke

The sandstones in the Orhanlar Greywacke consist of poorly-sorted angular grains of quartz, feldspar and rock fragments in a clay-chlorite matrix. The lithic grains include chert, andesite, basalt, trachyte, tuff and shale. A study of clay minerals in the Orhanlar Greywacke has shown that it has undergone deep diagenetic to high anchizone–epizone conditions, corresponding to burial depths of 5 to 10 km (Federici et al., 2010).

The conglomerates make up a very minor part (< 1%) of the Orhanlar Greywacke and consist of angular to subrounded clasts, 1–20 cm across, in a sandy matrix. The clasts include black chert, andesite, basalt, dolerite, shale, siltstone, quartz and limestone. The Orhanlar Greywacke also comprises exotic blocks of shallow marine limestone and black radiolarian ribbon chert, which make up less than 1% of the series. The most common are the limestone blocks, which are of two types. The first type is black Lower Carboniferous limestone, up to a few meters across, rich in corals, brachiopods and Lower Carboniferous (Visean-Serpukhovian) foraminifera (Leven and Okay, 1996; Okay et al., 1991, 1996). The second type, found in the region southeast of Manyas, comprises up to several-hundred-metres large blocks of white to grey Upper Permian (Murgabian-Midian) limestones (Leven and Okay, 1996).

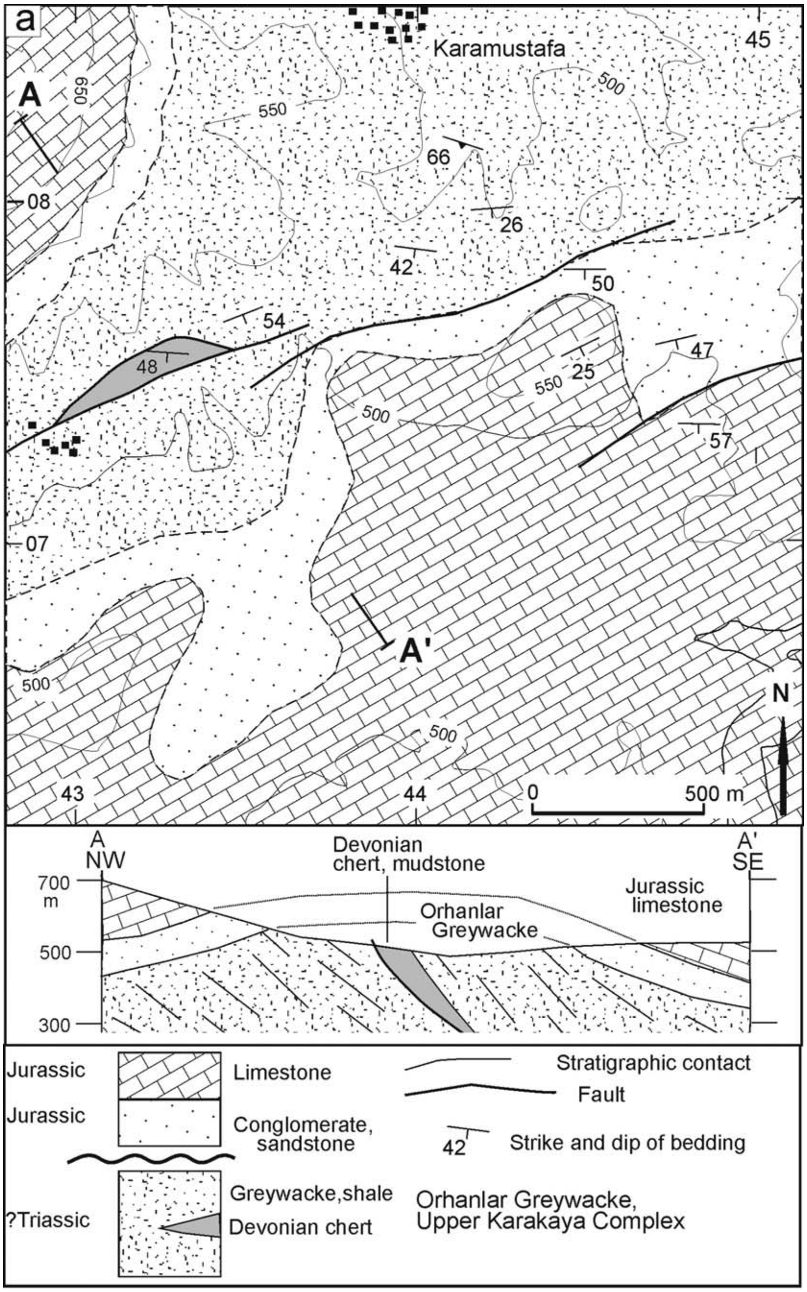

Fig. 3. Geological map and cross-section of the Balya region with the Devonian radiolarian cherts. For locations see Fig. 2. The coordinates are in UTM.

Fig. 3. Carte géologique et coupe de la région de Balya avec les cherts dévoniens à radiolaires. Pour les localisations, voir la Fig. 2. Les coordonnées sont en MTU.

Southwest of Bursa, the Orhanlar Greywacke lies with a tectonic contact over the metabasites of the Lower Karakaya Complex. It is unconformably overlain by little deformed, fluviatile to shallow marine Lower Jurassic sandstones and conglomerates, which pass up in to Upper Jurassic - Lower Cretaceous shallow marine limestones (Altıner et al., 1991). Stratigraphic relations constrain the age of deposition and deformation of the Orhanlar Greywacke as Triassic.

The deformation in the Orhanlar Greywacke is semi-brittle and pervasive so that undisturbed bedding is rarely observed. In most outcrops the Orhanlar Greywacke is cut by a large number of shear zones and faults, and forms a broken formation or mélange (Fig. 4a). The pervasive semi-brittle deformation of the Orhanlar Greywacke resembles that of the ancient subduction-accretion complexes, for example the Franciscan Complex in California (e.g., Cowan, 1974; Jayko and Blake, 1989) or the Shimanto Complex in

Fig. 4. (a) Typical outcrop of the Orhanlar Greywacke. Note the destruction of bedding through pervasive shear zones. (b) Devonian black radiolarian cherts from the Balya region.

Fig. 4. (a) Affleurement typique de la Grauwacke d'Orhanlar, noter la destruction du litage par des zones de cisaillement pénétratives. (b) Cherts à radiolaires noirs du Dévonian de la région de la Balya.

Japan (e.g., Kano et al., 1991). The present trench fan or trench axis sediments in the subduction zones also exhibit a similar pervasive semi-brittle deformation style (e.g., Thornburg and Kulm, 1987).

4. Devonian radiolarian cherts

Blocks of radiolarian ribbon cherts form a ubiquitous but very minor (< 0.1% of the outcrops) part of the Orhanlar Greywacke. They have two modes of occurrence. The most common are olistoliths of well-bedded black chert, a few metres across, in sheared sandstone. The black chert beds are 2–10 cm thick with millimetre-thick white to pale grey shale interlayers (Fig. 4b). In the second type, found only west of Balya, the radiolarian cherts occur in a tectonic slice with a preserved internal stratigraphy. The tectonic slice is ca. 60 m thick and 500 m long and is bounded above and below by the sandstones of the Orhanlar Greywacke. The stratigraphic sequence in the tectonic slice consists of two horizons of black, grey, thinly bedded (2–10 cm) radiolarian cherts separated by thicker horizons of laminated greyish blue, greenish brown shale with thin siltstone beds (Fig. 5). The radiolarian chert beds are characteristically separated by thin (1–3 mm) white, light grey laminated shale.

5. Radiolarian fauna and dating

Radiolarian fauna from the Balya region have been obtained from sample 6204 from the basal part of the sequence (Fig. 5). This black chert sample was etched with diluted (5–10%) hydrofluoric acid following the methods by Pessagno and Newport (1972). The fauna recovered is only moderately well preserved and contains abundant robust entactinarians identified as *Trilonche davidi* and *T. elegans* (Fig. 6), which are typical of Middle and Late Devonian radiolarian faunas (Atichison and Stratford, 1997). Unfortunately, no ceratoikiscids were recovered from the fauna and a more specific age cannot be assigned. Radiolarians of similar morphology occur in Carboniferous rocks, however, the fauna studied lacks younger elements, such as albaillellarians, pylomate entactinarians (eg. *Archocyrtium*, *Pylentonema*), and latentifistularians that characterize Carboniferous-Permian radiolarian assemblages. These taxa, particularly the pylomate entactinarians and latentifistularians, are robust and would not be absent due to preservational biases. Therefore, the lack of such species suggests that the radiolarian assemblage is Devonian.

6. Discussion

The presence of Devonian radiolarian cherts in a Triassic subduction-accretion complex implies the presence of a Late Paleozoic deep basin close to a trench. The Devonian radiolarian cherts have been incorporated into the Karakaya Complex by sedimentary and tectonic mechanisms. The olistoliths may have been derived from the accreted sediments on the trench wall and the tectonic slice could be a section of accreted sediment injected into the trench turbidites. However, the limited areal extent of the Devonian chert blocks and their sparsity do not allow a detailed characterization of the basin. Nevertheless, the main questions concern the location of this Devonian basin and its relation to the other Late Paleozoic and Triassic sedimentary rocks within the Karakaya Complex. The blocks in the Upper Karakaya Complex are dominated by the shallow marine Permian and Carboniferous limestones. Paleontological studies of the fusulinids in these limestones have shown the presence of most stages of Carboniferous and Permian (Fig. 7, e.g., Leven, 1995; Leven and Okay, 1996; Altıner et al., 2000; Okuyucu, 2007). This Permo-Carboniferous carbonate platform must have been deposited on a continental crust, however, the presence of such a depositional relationship has been a matter of debate. While some studies (e.g., Saner, 1978; Turhan et al.,

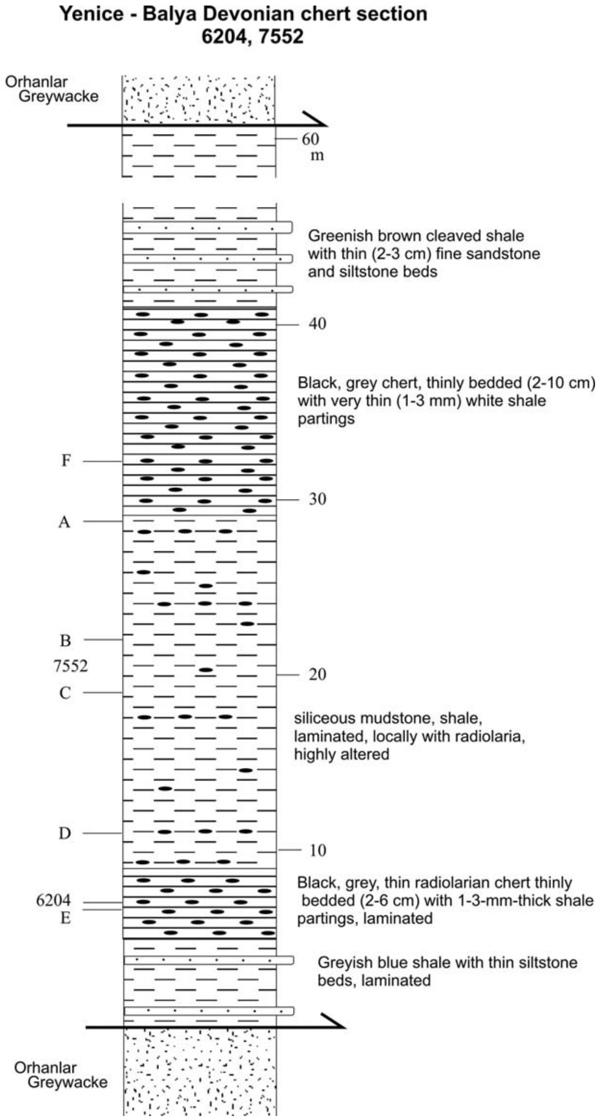

Fig. 5. Lithostratigraphic section of the Devonian radiolarian chert - mudstone from west of Balya.

Fig. 5. Section lithostratigraphique de boue-chert dévoniens à radiolaires, à l'ouest de Balya.

2004) have described an unconformity between Permian sediments and the metamorphic rocks, other field studies on the same locations argue for tectonic contacts (e.g., Robertson and Ustaömer, in press). The mid-Carboniferous metamorphic ages of the Variscan metamorphic massifs (Kazdağ and Pulur massifs) and mid-Carboniferous granitoids in the Sakarya Zone (Okay et al., 1996; Topuz et al., 2004b, 2010) indicate that these crystalline rocks cannot be a basement to the Early Carboniferous limestones. On the other hand, a possible pre-Carboniferous basement is represented by a tectonic slice of Early Devonian granitoid (397.5 ± 1.4 Ma zircon Pb-Pb ages) within the Triassic accretionary complex in northwest Turkey (Fig. 2, Okay et al., 2006).

A synthetic stratigraphy based on the age and lithology of the blocks in the Upper Karakaya Complex would suggest a Devonian crystalline basement overlain by a Carboniferous-Permian carbonate platform, which subsided in the Latest Permian and was followed by pelagic carbonate sedimentation during the Triassic (Fig. 7). The Devonian and mid-Carboniferous (Bashkirian) radiolarian cherts from the Upper Karakaya Complex (Okay and Mostler, 1994; Kozur and Kaya, 1994, this study) most likely represent continental slope to ocean basin sediments north of this enigmatic Balya terrane. The Balya terrane was dismembered in a subduction zone during the Late Triassic and pieces were accreted to the active Eurasian margin. No intact remains of the Balya terrane are recognized in Anatolia, suggesting that it was a narrow continental sliver within the Tethyan ocean, similar to the Cimmerian continent of Şengör et al. (1984).

The recent recognition of Devonian granitoids from the northern margin of the Anatolide-Tauride Block (Akal et al., 2008) suggests that the Balya terrane rifted off from the northern margin of Gondwana probably in the Latest Permian to Early Triassic associated with the worldwide mafic magmatism, which also produced the Lower Karakaya Complex (Fig. 8). The earliest determined radiolarian cherts associated with basalts from the northern branch of the Neo-Tethys (the Izmir-Ankara ocean) are early Late Carnian age (Tekin et al., 2002) supporting a Triassic or earlier rifting. The paleogeographical affinities of the fusulinids in the Permo-Carboniferous limestone blocks in the Upper Karakaya Complex are not clear with suggestions of deposition both on the northern (Leven and Okay, 1996; Leven and Özkan, 2004) and on the southern margin (Altıner et al., 2000) of the Paleo-Tethys.

An Upper Paleozoic accretionary complex crops out in the Karaburun peninsula and on the island of Chios (Fig. 2, Papanikolaou and Sideris, 1983). This Karaburun-Chios melange includes blocks of pelagic limestone and radiolarian chert of Silurian and Lower Devonian ages in a clastic matrix (Kozur, 1998; Larghi et al., 2005), the matrix is probably of mid-Carboniferous age based on the age of the detrital zircons (Meinhold et al., 2008) and fossils from the sandstones (Groves et al., 2003). The Chios mélange is overlain unconformably by a carbonate-dominated Mesozoic sequence starting with Lower Triassic pelagic carbonates (Robertson and Pickett, 2000; Zanchi et al., 2003). The Mesozoic carbonates show strong similarities to those of the Anatolide-Tauride Block (Erdoğan et al., 1990) and hence both the Karaburun peninsula and Chios are placed south of the Izmir-Ankara suture (Fig. 2). The Chios mélange is generally regarded as a Hercynian subduction-accretion complex (Groves et al., 2003; Zanchi et al., 2003) and the Karakaya Complex as a Paleo-Tethyan one. However, the presence of Devonian radiolarian cherts in both accretion complexes indicates subduction of oceanic crust of similar ages. The relation between the two accretionary complexes, which apparently record different periods of subduction (Carboniferous versus Triassic), may be explained by a diachronic termination of subduction, whereby the inactive sections of the subduction-accretion complex is overlain by Mesozoic carbonates (Fig. 8).

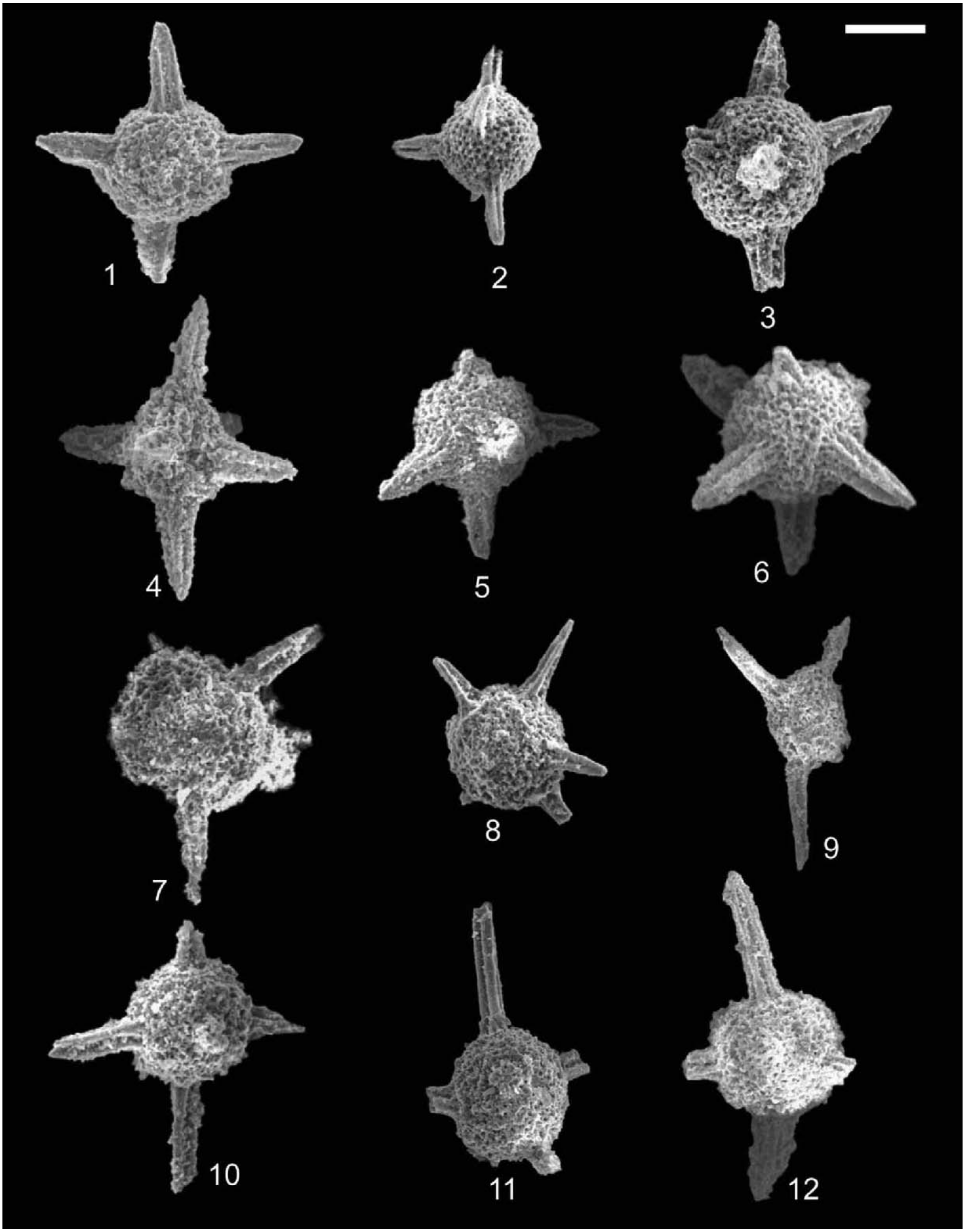

Fig. 6. Scanning electron photomicrographs of Devonian radiolarians from sample 6204, Balya region. 1-6. *Trilonche davidi* (HINDE), scale bar = 75 μm, 7-9. *Trilonche elegans* HINDE, scale bar = 75 μm, 10-12. *Trilonche* sp., scale bar = 85 μm.

Fig. 6. Microphotographies au microscope électronique à balayage de radiolaires dévoniennes de l'échantillon 6204, région de Balya. 1-6. *Trilonche davidi* (HINDE), barre d'échelle = 75 μm, 7-9. *Trilonche elegans* HINDE, barre d'échelle = 75 μm, 10-12. *Trilonche* sp., barre d'échelle = 85 μm.

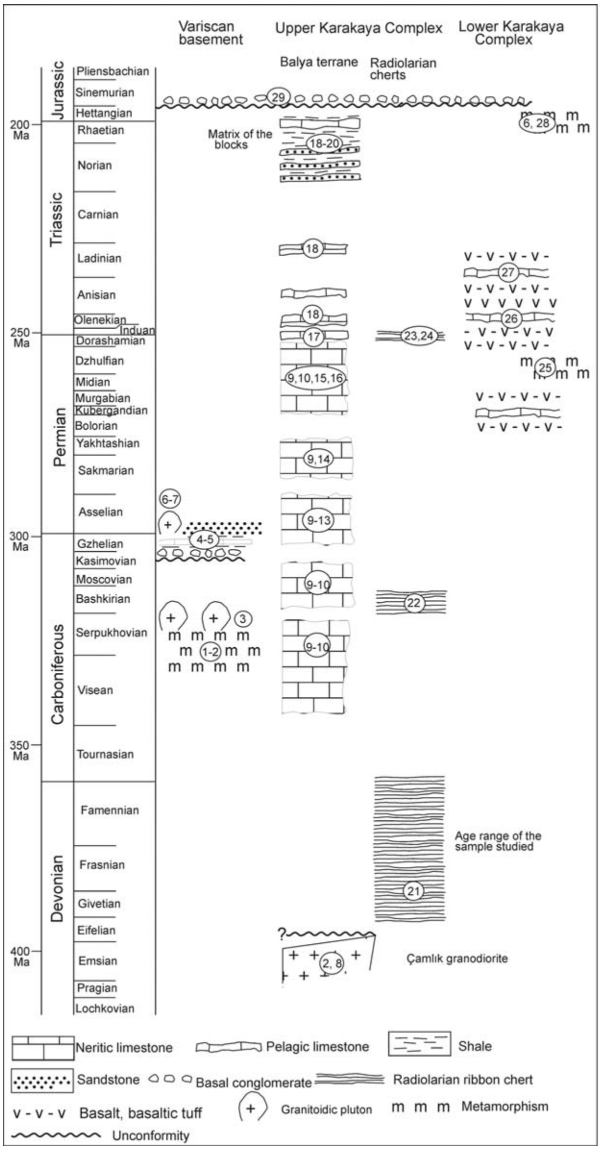

Fig. 7. Stratigraphy of the pre-Jurassic basement of the Sakarya Zone. The stratigraphy of the Balya terrane is based on the age and lithology of the exotic blocks in the Karakaya Complex. The primary data sources are: 1. Topuz et al., 2004a, 2. Okay et al., 1996, 3. Topuz et al., 2010, 4. Okay and Leven, 1996, 5. Çapkınoğlu, 2003, 6. Okay et al., 2002, 7. Delaloye and Bingöl, 2000, 8. Okay et al. 2006, 9. Leven and Okay, 1996, 10. Altıner et al., 2000, 11. Bozkurt, 1990, 12. Okuyucu and Göncüoğlu, 2010, 13. Leven, 1995, 14. Leven and Özkan, 2004, 15. Turhan et al., 2004, 16. Okuyucu, 2007, 17. Kozur and Kaya, 1994, 18. Wiedmann et al., 1992, 19. Okay et al., 1991, 20. Okay and Altıner, 2004, 21. This study, 22. Okay and Mostler, 1994, 23. Kozur, 1997; 24. Göncüoğlu et al., 2004, 25. Topuz et al., 2004a, 26. Kozur et al., 2000, 27. Kaya and Mostler, 1992, 28. Okay and Monié, 1997, 29. Altıner et al., 1991.

Fig. 7. Stratigraphie du socle pré-Jurassique de la zone de Sakarya. La stratigraphie de la terrasse de Balya est fondée sur l'âge et la lithologie de blocs exotiques dans le complexe de Karakaya. Les principales sources de données sont: 1. Topuz et al., 2004a, 2. Okay et al., 1996, 3. Topuz et al., 2010, 4. Okay et Leven 1996, 5. Çapkınoğlu, 2003, 6. Okay et al., 2002, 7. Delaloye et Bingöl, 2000, 8. Okay et al. 2006, 9. Leven et Okay, 1996, 10. Altıner et al., 2000, 11. Bozkurt, 1990, 12. Okuyucu et Göncüoğlu, 2010, 13. Leven, 1995, 14. Leven et Özkan, 2004, 15. Turhan et al., 2004, 16. Okuyucu, 2007, 17. Kozur et Kaya, 1994, 18. Wiedmann et al., 1992, 19. Okay et al., 1991, 20. Okay et Altıner, 2004, 21. Cette étude 22. Okay et Mostler, 1994, 23. Kozur, 1997; 24. Göncüoglu et al., 2004, 25. Topuz et al., 2004a, 26. Kozur et al., 2000, 27. Kaya et Mostler, 1992, 28. Okay et Monié, 1997, 29. Altıner et al., 1991.

7. Conclusions

Devonian radiolarian ribbon cherts are found as olistoliths and as a tectonic slice in sheared sandstones and shales of a Triassic subduction-accretion complex (Upper Karakaya Complex) in Northwest Turkey. The Upper Karakaya Complex is located directly north of the Neo-Tethyan Izmir-Ankara suture (Fig. 2). The Devonian radiolarian cherts, as well as earlier descriptions of Carboniferous and Permian radiolarian cherts (Okay and Mostler, 1994, Kozur, 1997; Göncüoğlu et al., 2004) from the Upper Karakaya Complex indicate subduction of a Late Paleozoic ocean along the Izmir-Ankara suture. In the Late Triassic the Karakaya Complex was accreted to the southern active margin of Eurasia, in a similar manner as the accretion of the Franciscan Complex to the continental North America.

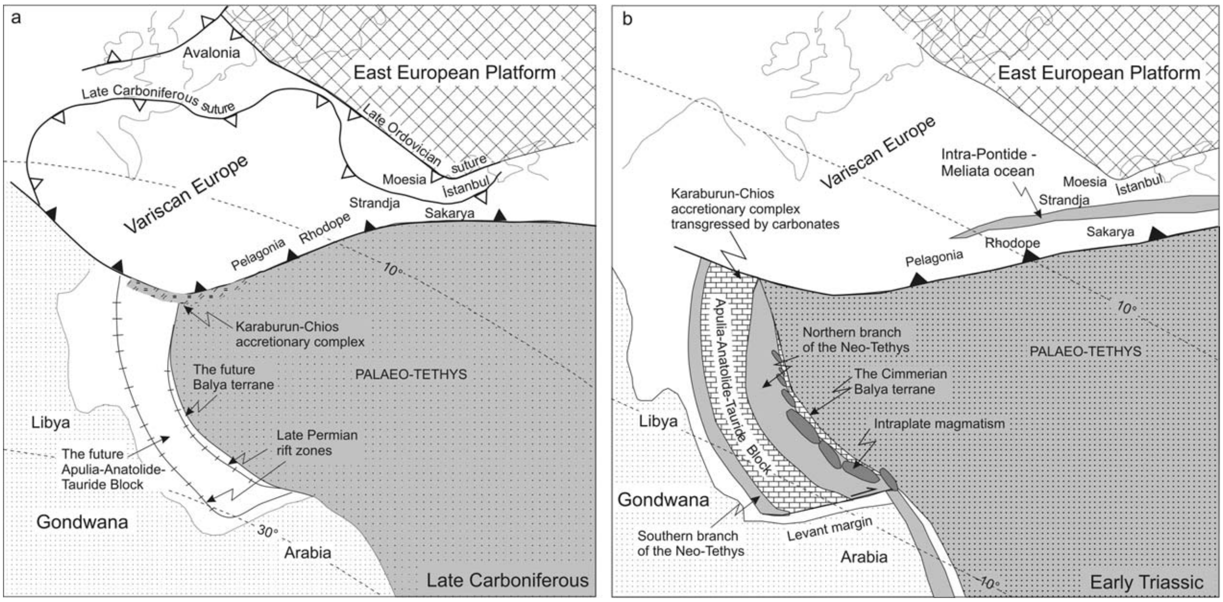

Fig. 8. Paleogeographic constructions of the western Tethyan realm for the Late Carboniferous (a) and Early Triassic (b). The general paleogeographical framework is from Stämpfli et al. (2001) (modified from Okay et al., 2006).

Fig. 8. Reconstructions paléogéographiques du domaine Ouest-Téthysien pour le Carbonifère tardif (a) et le Trias précoce (b). La trame paléogéographique générale est issue de Stämpfli et al. (2001) (modifié d'après Okay et al., 2006).

Acknowledgements

We thank Mehmet Duru and Şükrü Pehlivan of the Geological Survey of Turkey (MTA) for help in the field work. Aral Okay thanks Turkish Academy of Sciences for support.

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