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The Mississippian in the Central and Eastern Taurides (Turkey): constraints on the tectonic setting of the Tauride-Anatolide Platform

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Abstract: Data from the Mississippian tectono-stratigraphic units in the Tauride-Anatolide Platform, Central and Eastern Taurides, reveal that this region underwent incipient back-arc extension during the Variscan orogeny, but that rifting failed, leaving a basin floored with highly extended continental crust. The stratigraphy of several tectono-stratigraphic units, the Geyik Dağı, Aladağ, and Bolkar Dağı Units were studied in detail in the Sultan Dağı and Hadim areas in the Central and Eastern Taurides. In the Sultan Dağ area, the Geyik Dağı Unit contains shelf-type (shallow) marine clastics and carbonates of the Middle-Upper Mississippian Gökdere Member of the Harlak Formation, overlain by shales and basic volcanic/volcaniclastic rocks of the Kuz Member of the formation. The Mississippian age rocks in the Aladağ Unit around Hadim are characterized by quartzarenites and carbonates of coastal to shallow shelf environment. The Bolkar Dağı Unit in the Hadim area includes inner shelf-type recrystallized limestones, dolomites and oolitic limestones. To the north of Konya, however, Middle Mississippian formations of the Bolkar Dağı Unit include metamorphosed olistostromal deposits with Silurian–Upper Devonian olistoliths, which were generated in an extensional basin with back-arc type bimodal volcanism. In the Cataloturan Nappe of the Bolkar Dağı Unit, in the Eastern Taurides, the Mississippian is represented by a basin/slope-toe-type succession with an alternation of lithic tuffs, radiolarian cherts and pelagic limestones. It grades into Upper Mississippian shallow-marine carbonates. The data presented suggest the presence of a north-facing system with slope (Cataloturan) aborted rift basin (Konya-Bolkar Dağı) inner shelf (Hadim-Bolkar Dağı) coastal shelf (Hadim-Aladağ) and shallow-shelf (Sultan Dağı-Geyik Dağı) along the northern margin of the Tauride-Anatolide Platform during the Mississippian.

Key words: Mississippian, Taurides, southern Turkey, paleontology, stratigraphy, tectonic setting.

Introduction

The Tauride-Anatolide Platform is a continental microplate or terrane that was separated from Gondwana by the opening of the Southern Branch of Neotethys during the Late Permian-early Mesozoic (e.g. Göncüoğlu et al. 1997). It is considered to be a more or less stable platform (e.g. Sengör & Yılmaz 1981). The Alpine closure of the Neotethyan oceans and telescoping of their margins resulted in the reorganization of the Paleozoic–Mesozoic successions within numerous tectono-stratigraphic units in southern Turkey (Fig. 1). In the Central Taurides, six distinct tectono-stratigraphic units are recognized (Özgül 1976, 1984). From north to south, these are the Bozkir, Bolkar Dağı, Aladağ, Geyik Dağı, Antalya and Alanya Units (Fig. 1). The Geyik Dağı Unit is considered to be relatively autochthonous, located in the central part of the platform, and is characterized by a fairly complete Paleozoic succession in the Saimbeyli-Tufanbeyli, Geyik Dağı, Homa-Akdag and Sultan Dağ areas (Özgül 1976).

The Cambrian to Late Devonian period in the Taurides is characterized by more or less continuous deposition on a stable platform and platform margin (e.g. Özgül 1984; Göncüoğlu et al. 2004). Starting with the Mississippian, probably related to the Variscan events in the north of the Tauride Platform and the closure of a part of the Paleotethyan Ocean, a tectonically active episode is initiated, representing by bimodal volcanism and olistostromal deposits (Özcan et al. 1989; Göncüoğlu 1997; Kozur & Göncüoğlu 2000; Göncüoğlu et al. 2004). This event was interpreted as a result of back-arc rifting in the northern margin of the Tauride-Anatolide Platform (Özcan et al. 1990a,b), based on the characteristics of bimodal volcanism and depositional features indicating extensional tectonics.

A completely different tectonic setting has recently been proposed by Stampfli (2000), Stampfli et al. (2001) and most recently by Eren et al. (2004). In this model, during the Paleozoic, the Anatolides (including the metamorphic rocks of the Bolkar Dağı and Aladağ Units of Özgül

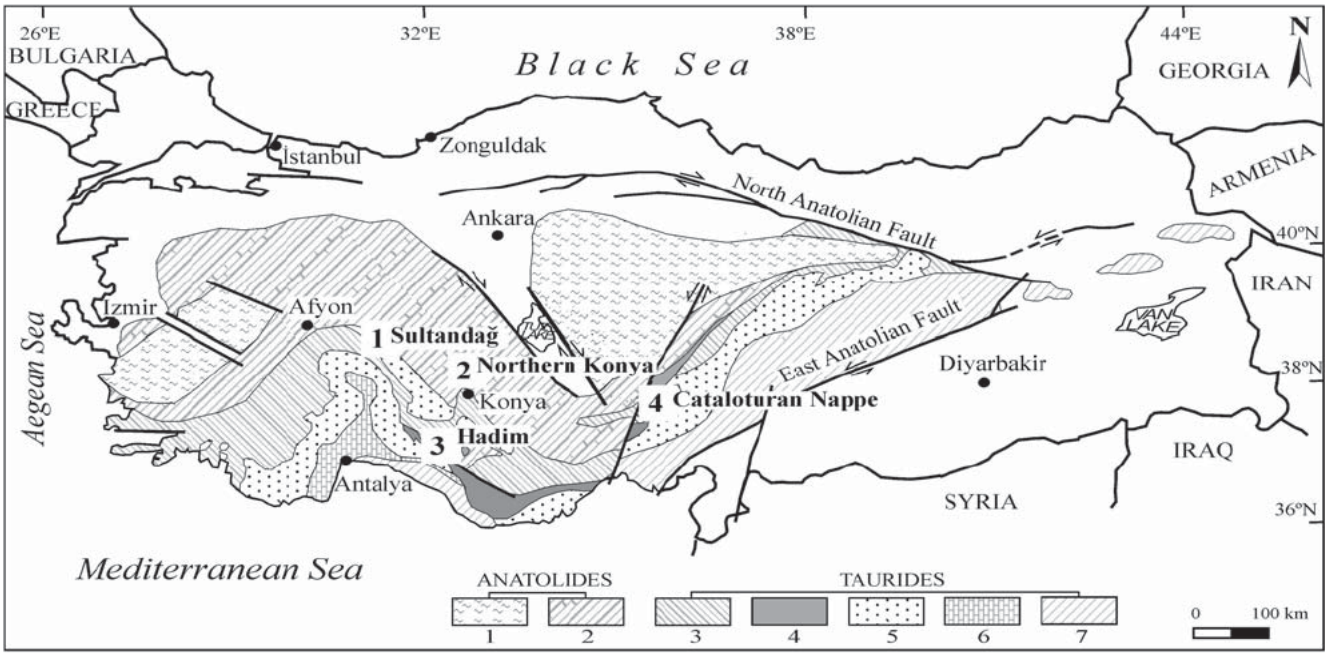

Fig. 1. Schematic map of the main tectonic units of southern Turkey (Taurides). **1** — Menderes and Kirsehir massifs, **2** — Bolkar Dağı Unit, **3** — Bozkir Unit, **4** — Aladağ Unit, **5** — Geyik Dağı Unit, **6** — Antalya Unit, **7** — Alanya Unit. (Modified from Özgül 1976; Göncüoğlu et al. 1997.)

(1976) in southern Central Anatolia) were located at the northern passive margin of the Paleotethys (sensu Stampfli 2000) that separated them from the rest of the Tauride-Anatolide Platform. The northward subduction of this ocean during the Carboniferous produced a magmatic arc/fore-arc complex within them. During the Late Triassic (Carnian), the passive margin sequences and the complex (Anatolides) were attached to the Menderes-Tauride Cimmerian block (the main bulk of the Tauride-Anatolide Platform) during the closure of the Paleotethys.

In the view of these contrasting ideas and for a better understanding of the Variscan-time events in the Taurides, the authors studied the Mississippian successions in the Central Taurides in the Sultan Dağ (Göncüoğlu et al. 2000) and Hadim areas (Özgül 1997), which were less-known compared to those in the Eastern Taurides (e.g. Özgül & Kozlu 2002; Göncüoğlu et al. 2004). The aim of this study is to elucidate the Mississippian tectonic events along the northern edge of the Tauride-Anatolide Platform through new data collected in the Central and Eastern Taurides. We present the new Mississippian ages of these units and correlate the Mississippian successions in different tectonic slices in the Geyik Dağı Unit (Sultan Dağ area), the Bolkar Dağı Unit (Konya and Hadim areas), the Aladağ Unit (Had m area) and the Cataloturan Nappe (Yahyali area). During the field-mapping in 1987–2000, the authors studied several more or less continuous sections, where the geological relations of the slightly metamorphosed Carboniferous rocks were relatively well-preserved. The conodonts, foraminifers and radiolarians from the carbonate dominated lower parts of these sections were determined by the second, fourth, sixth and the last authors.

Stratigraphy of the Geyik Dağı Unit in the Sultan Dağ area

Paleozoic rocks make up the main bulk of the Sultan Dağ Massif and occur within the NW–SE trending tectonic slices in the studied area that belong to the Bolkar Dağı/Aladağ and Geyik Dağı tectono-stratigraphic units of Özgül (1984). In the Sultan Dağ area, earlier studies (e.g. Haude 1968; Demirkol 1977, 1984; Öztürk et al. 1983, 1987) have contributed to the stratigraphy of the Paleozoic by some fossil findings. The presence of multiple tectono-stratigraphic units (Fig. 2A,B) has been introduced more recently especially near the towns of Akşehir (Konya Province of Central Anatolian Region) and Çay (Afyon Province of Aegean Region) by Eren (1990) and Özgül et al. (1991a,b). In particular, Özgül et al. (1991a) have verified the presence of Pennsylvanian carbonates in different tectonic slices.

The Devonian to Permian successions of the Bolkar Dağı/Aladağ Unit occur in the uppermost tectonic slice that is known as the Çay Tectonic Unit (Özgül et al. 1991b). Here, the Upper Devonian-Carboniferous sequences (Degirmendere Formation) mainly comprise low-grade metamorphic quartzarenites with bands and lenses of conglomerates, recrystallized limestones/dolomites, metavolcanic rocks and violet-green slates. The upper part of the Çay Tectonic Unit is represented by an alternation of recrystallized sandy limestones and was named as the Elbis Dere Member. A limestone-band in the violet slates includes late Bashkirian (Early Pennsylvanian) foraminifers (e.g. *Profusulinella parva*, *Pseudostaffella* sp. determined by D. Altıner in Özgül et al. 1991b). The "Girvanella Limestones" above the Elbis Dere Member

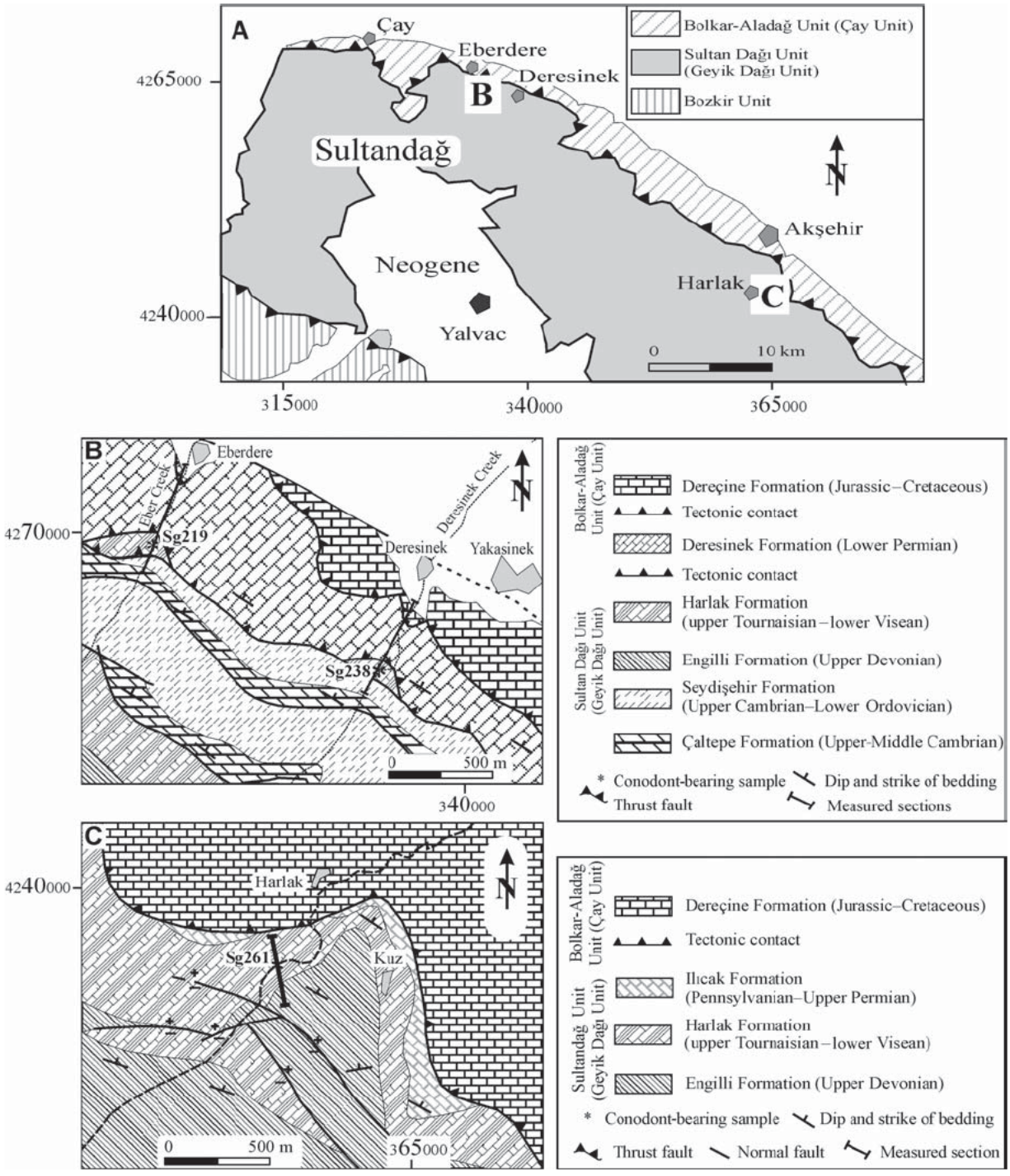

Fig. 2. A — Structural map of Sultan Dağ area. Geological map of **B** — Deresinek and Eberdere area (Çay), **C** — Harlak (Akşehir) area (modified from Özgül et al. 1991a).

mark the base of the Permian and represent a key horizon in the Aladağ Unit.

The Devonian to Permian successions of the Geyik Dağı Unit in the Sultan Dağ area are incorporated in the Çayözü Group, which is tectonically interleaved with rocks of the Çay Tectonic Unit (Özgül et al. 1991a). It is divided into three formations. In ascending order these are: Engilli, Harlak and Ilicak Formations (e.g. Özgül et al. 1991b). Engilli Formation disconformably overlies the Upper Cambrian-Lower Ordovician Seydişehir Formation and is mainly made up of quartzarenites and slate with crinoid-bearing limestone lenses. The sparsely fossiliferous limestone lenses in the upper part of the formation include *Dimitria seminoi*, *Camarotoechia* sp., *Schuchertella* cf. *umbracula*, *Cyrtospirifer* sp., *Peneckiella miner*, *Cyrtospirifer* ex gr. *grabaui*, *Alveolites* sp., *Disphyllum* sp.,

corals and brachiopods indicating a Frasnian (Late Devonian) age (Haude 1968; Özgül et al. 1991a,b). This succession is conformably overlain by the Gökdere and Kuz Members of the Harlak Formation and is transitional (Fig. 3) to the Pennsylvanian–Upper Permian Ilicak Formation (Özgül et al. 1991a).

Harlak Formation (Akşehir area). The Harlak Formation in Sultan Dağ area crops out along the NE edge of the massif within NW–SE trending slices and was studied at three localities, the type locality near Harlak village in the Konya Province of the Central Anatolian Region, and the Deresinek and Eber Dere sections in the southeast of the town of Çay in the Afyon Province of the Aegean Region.

The type-locality of the Harlak Formation is on the Akşehir-Yalvac road in the vicinity of Harlak village (Fig. 2A–C). It consists of a lower member (Gökdere Member) of recrystallized limestone with quartzarenite, sandstone and dark-coloured slate interlayers and an upper member (Kuz Member) including violet and green slates (Fig. 3). The Gökdere Member conformably overlies the Upper Devonian Engilli Formation. The member begins with an alternation of grey and green micaceous slates at the base and continues with laminated recrystallized limestones and slate bands (Fig. 4A). The limestones are light grey, medium- to thick-bedded, laminated and include crinoids. Bands and lenses of light grey dolomite occur within the limestones. While the slates are black–dark grey, mica-rich in the lower part they become carbonate-rich towards the middle part. The upper part of the member is composed of recrystallized limestone with a typical pink and white lamination and includes thin bands of pink slate. The conodonts are found in the middle part of the laminated recrystallized limestones of the member (Fig. 4A). Upwards, the amount of slates decrease and quartzarenites and sandstones dominate. The sandstones are beige, thick- and cross-bedded. The quartzarenites are grey, fine-grained and thick-bedded.

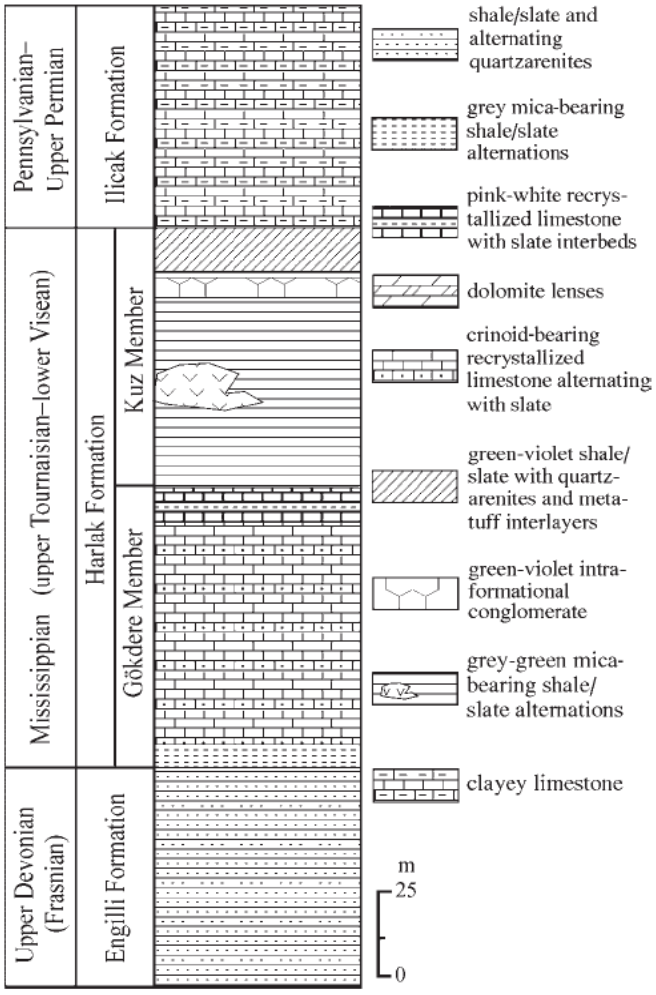

Fig. 3. Generalized columnar section of the Sultan Dağı Unit in Harlak village (Akşehir). (Modified from Özgül et al. 1991a.)

The Gökdere Member is transitional into the Kuz Member, which is comprised of grey-violet coloured slates with rare bands and lenses of chlorite-rich metatuffs and also basic lavas. In the upper part, up to 3 m-thick, bands of intra-formational conglomerate lenses are observed (Fig. 3). The variably rounded and deformed pebbles reach up to 7 cm in diameter and consist mainly of grey, white, pink and yellowish limestones and quartz. The conglomerates are generally lens-shaped and represent channel-fillings. The upper part of the member is made up of an alternation of green and grey coloured slates and grey sandstones (Fig. 4A). The Harlak Formation is conformably overlain by the Pennsylvanian–Upper Permian Ilicak Formation that is composed of recrystallized limestones, alternating with slates/calcschists. The Paleozoic succession in this area is tectonically overlain by the Lower Permian Deresinek Formation of the Bolkar Dağı/Aladağ Unit.

Deresinek section (Çay). Near the town of Çay in the Afyon Province, the Gökdere Member of the Harlak Formation crops out to the north of the Deresinek village (Fig. 2A,B). In this location, the upper part of the Gökdere Member tectonically rests on the Upper Cambrian–Lower Ordovician Seydişehir Formation and is tectonically overlain by the lower Lower Permian limestones of the Bolkar Dağı–Aladağ Unit (Fig. 4B). In this 20 m-thick section, the upper part of the Gökdere Member and the violet slates of the Kuz Member are absent. Conodonts were recovered from laminated recrystallized limestones interpreted to be the upper part of the Gökdere Member, close to the transition to the Kuz Member. These beds occur 2.5 m below recrystallized limestone beds with pink and white lamination, a lithology that typifies the upper part of the Gökdere Member in its type locality.

Eberdere section (Çay). In the Eberdere section to the north of the ruins of Eberdere village (Fig. 2A,B), the Gökdere Member of the Harlak Formation occurs again as a tectonic sliver, sandwiched between the shales of the Cambrian-Ordovician Seydişehir Formation of the Geyik Dağı Unit and the recrystallized limestones of the Lower Permian Deresinek Formation of the Bolkar Dağı/Aladağ Unit. In this locality, the Gökdere Member is 65 m thick and composed of grey, recrystallized limestone, calcschists with green to grey coloured quartzarenite and slate interlayers (Fig. 4C). Conodonts were found in the lower part of the

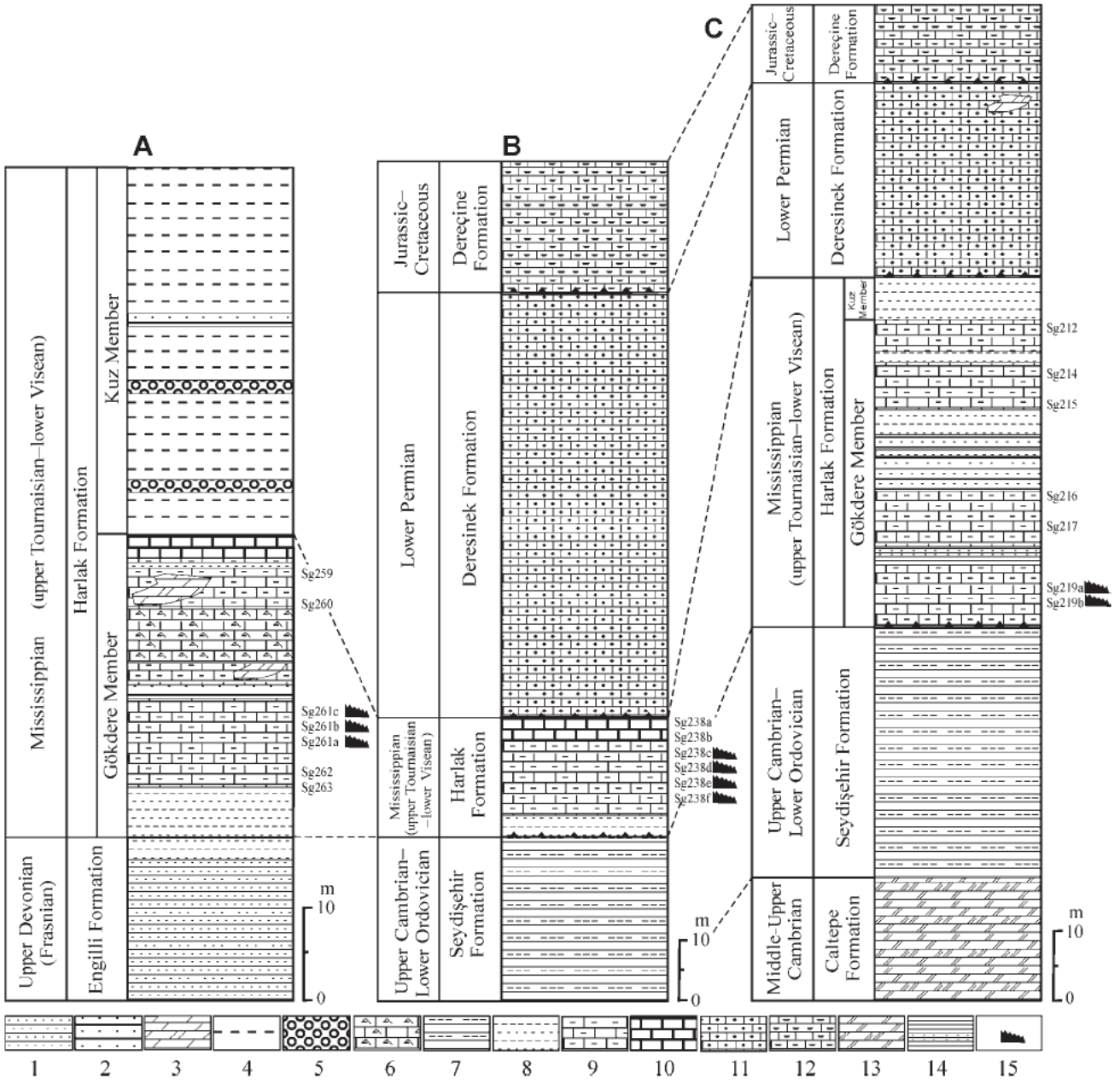

Fig. 4. Measured section of **A** — Harlak Formation near Akşehir, **B** — The Gökdere Member in old Deresinek village, **C** — The Gökdere Member in Eberdere village. **1** — pink-white, grey, brown quartzarenites; **2** — metasandstone lenses; **3** — dolomite lenses; **4** — grey-violet, green shales/slates; **5** — grey-green intra-formational pebblestone; **6** — grey, crinoid-bearing laminated, recrystallized limestone; **7** — green mica-bearing shales/slates; **8** — green shales/slates; **9** — grey-black laminated, recrystallized limestone with calcschist interlayers; **10** — pink-white-grey recrystallized limestone; **11** — grey-black–grey crinoid-bearing recrystallized limestone with calcschist interlayers; **12** — grey-black–grey cherty, recrystallized limestone; **13** — reddish-black–brown dolomite, dolomitic limestone; **14** — green-grey quartzarenites-bearing slate, **15** — conodont localities.

section. The rock units observed are interpreted as corresponding to the laminated limestones of the middle part of the Gökdere Member in its type locality. The structurally upper part of the Gökdere Member is made up of an alternation of grey-pink-white calcschists and laminated limestones with green-grey slates and sandstones.

Conodont data. The sections of the Gökdere Member described above were sampled in detail for conodonts. From a total of 56 limestone samples only three yielded conodonts. Sample Sg219 is from the Eberdere section, near the Elmasoynagi stream in Eberdere village (GPS location: $^{3}36^{050}:^{42}69^{200}$) and was taken from grey coloured recrystallized limestones alternating with calcschists in the middle part of the Gökdere Member (Fig. 2B). Sample Sg238 is from the Deresinek section from the Domuzalani brook (GPS location: $^{3}39^{100}:^{42}67^{575}$) to the N of the ruins of former Deresinek village (Fig. 2B) and was taken from the recrystallized laminated limestones that correspond to

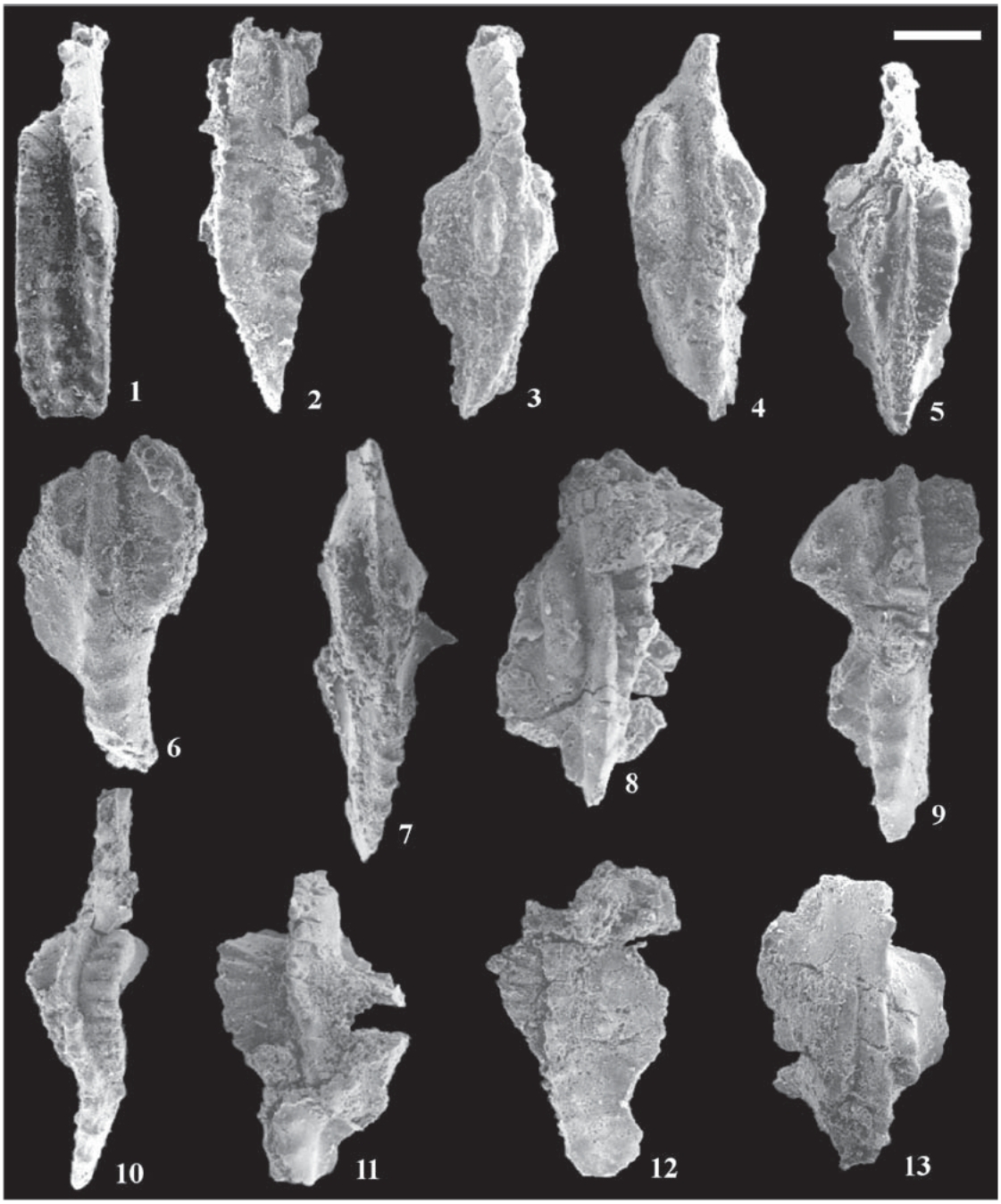

Fig. 5. Photomicrographs of the conodont faunas from the Gökdere Member of the Harlak Formation in the Sultan Dağ region. All are upper views of Pa elements. **1–2** — *Mestognathus praebeckmanni* Sandberg, Johnston, Orchard et Von Bitter. Both specimens are from sample Sg261, scale bar = 140 and 185 μm, respectively. **3–10** — *Gnathodus pseudosemiglaber* Thompson et Fellows 3, 4, 5, 6 and 7 are from sample Sg261 while 8, 9 and 10 are from sample Sg219. Scale bar = 220, 135, 140, 150, 150, 120, 180 and 175 μm, respectively. **11–13** — *Gnathodus semiglaber* Bischoff, 11 and 12 are from sample Sg219 while 13 is from sample Sg261. Scale bar = 160, 200 and 170 μm, respectively.

the upper part of the member. The third productive sample, Sg261 ($^{3}63^{675}$:$^{42}39^{300}$) was taken from the type locality of the Harlak Formation on the Akşehir–Yalvac road cuttings, 2 km to the south of Harlak village (Fig. 2C). The sample is from grey to dark grey coloured and laminated recrystallized limestones, 25 m above the base of the Gökdere Member of the Harlak Formation.

The conodont fauna in the Gökdere Member of the Harlak Formation consists of the species of *Gnathodus* and *Mestognathus*. The specimens are mostly broken and deformed, as a result of tectonic deformation. Sample Sg261 (Figs. 2C, 4A) yielded *Gnathodus pseudosemiglaber* Thompson et Fellows (Fig. 5.3–7), *Gnathodus semiglaber* Bischoff (Fig. 5.13), and *Mestognathus praebeckmanni*

Sandberg, Johnston, Orchard et von Bitter (Fig. 5.1–2). The most short-ranging taxon in this fauna is *Mestognathus praebeckmanni* Sandberg, Johnston, Orchard et von Bitter, that occurs in the Upper *typicus* Zone to the *anchoralis-latus* Zone, and may extend into the lower part of the *texanus* Zone (von Bitter et al. 1986, text-fig. 5, p. 35). This occurrence restricts the age of the sample 261 to the late Tournaisian to the earliest Visean interval. Samples Sg238 (Figs. 2B, 4B) and Sg219 (Figs. 2B, 4C) produced *Gnathodus pseudosemiglaber* Thompson et Fellows (Fig. 5.8–10) and *Gnathodus semiglaber* Bischoff (Fig. 5.11–12). *Gnathodus pseudosemiglaber* Thompson et Fellows ranges from near the base of the Lower *typicus* Zone into the *bilineatus* Zone, and *Gnathodus semiglaber* Bischoff from within the *isosticha*-Upper *crenulata* Zone to the end of the *praebilineatus* Zone (Sweet 1988; Blanco-Ferrera et al. 2005, fig. 5). The joint range of these two taxa defines a late Tournaisian to early Visean age.

Stratigraphy of Bolkar Dağı Unit in Hadim and Konya areas

In the Central Taurides, in the Had m area of the Konya Province, Mississippian successions crop out in the Bolkar Dağı and Aladağ Units but were eroded prior to deposition of Dogger in the Geyik Dağı Unit. Variably metamorphosed Mississippian rocks in the Central Taurides that were attributed to the Bolkar Dağı Unit have been reported in the Hadim (Özgül 1997; Altiner & Özgül 2001) and northern Konya area (Özcan et al. 1990b).

The Northern Konya area. In the Konya area (Fig. 6A), Mississippian rock units are found within a highly deformed, very low to low-grade metamorphic Paleozoic succession (Özcan et al. 1990a,b; Eren 1993; Göncüoğlu & Kozur 1998). The lowermost rock unit in this area is represented by distal turbiditic siliciclastic rocks, black ribbon-cherts, and knockers of pelagic limestones and metadiabases. The pelagic limestones yielded rich Silurian conodont faunas dominated by simple cone conodonts (Göncüoğlu et al. 2001). The upper part of this siliciclastic unit contains some thin-bedded, brown to black limestone beds with late Ludlow conodonts. The conformably overlying Bozdag Limestone (BL) is about 800 m thick and starts with late Lochkovian (*A. delta* Zone) pink to black nodular limestones (Göncüoğlu et al. 2001) followed by grey-white, barren medium–thin-bedded dolomites (Fig. 6B). The overlying nautiloid limestone includes a late Lochkovian to Pragian conodont fauna. The nautiloid limestone is overlain by medium–thick-bedded limestones and dolomites with occasional solitary corals and bands of "Amphipora Limestones", a Upper Devonian marker horizon of the Taurides. The upper part of the BL is represented by massive limestones.

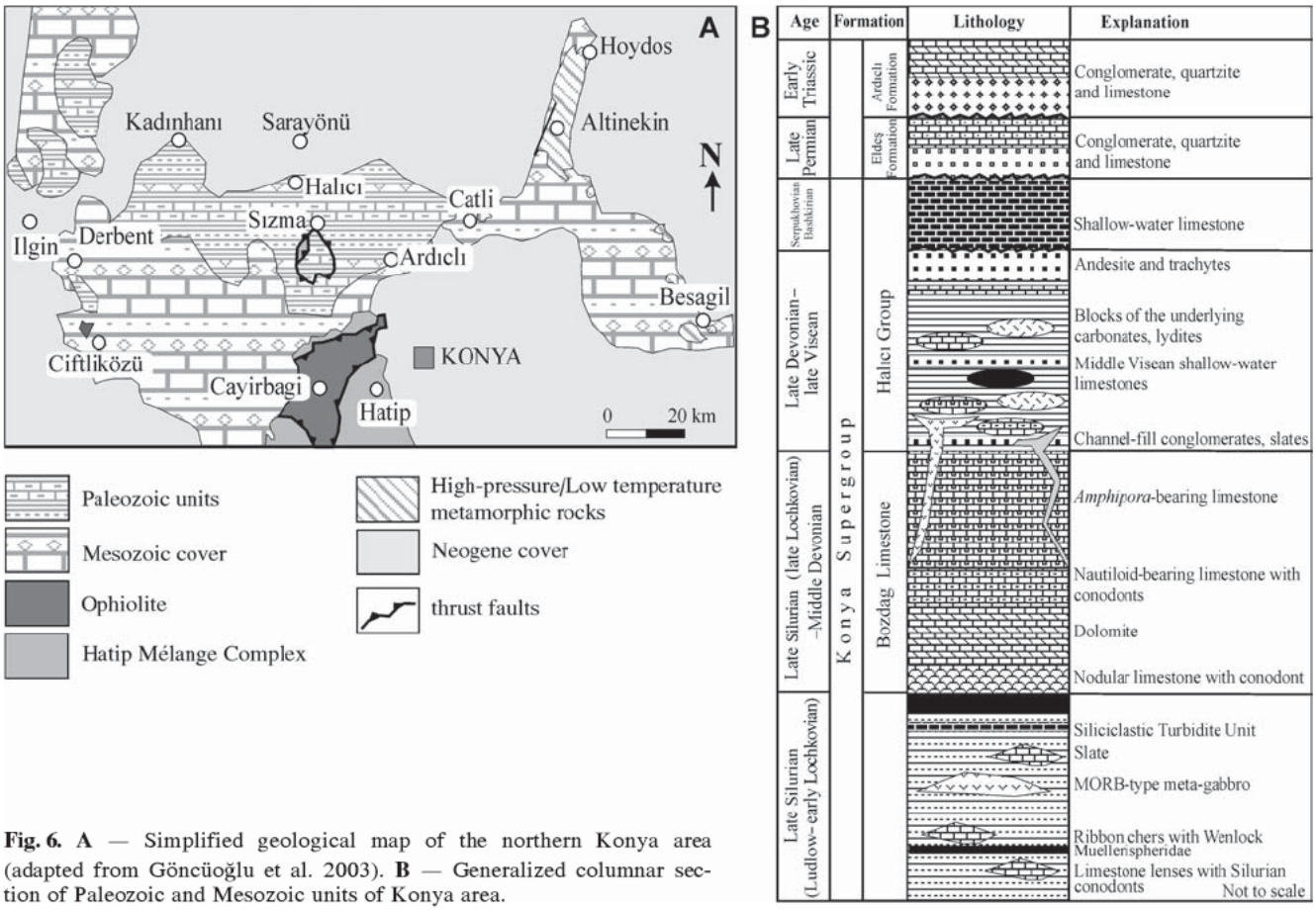

Fig. 6. **A** — Simplified geological map of the northern Konya area (adapted from Göncüoğlu et al. 2003). **B** — Generalized columnar section of Paleozoic and Mesozoic units of Konya area.

The BL is unconformably overlain by an olistostromal unit (Halıcı Group sensu Özcan et al. 1990a,b) with channel-fill conglomerates changing in the upper part into sandstones and conglomerates. The unit contains olistoliths of neritic and pelagic limestones together with dikes, lava flows (Kurt 1996) and trachyte domes alternating with greywackes.

The olistoliths are mainly derived from the underlying lower Paleozoic rock-units and include middle-Silurian and Late Silurian-Early Devonian conodonts (Göncüoğlu et al. 2000). They also include syn-sedimentary shallow-water limestones with fossils (Fig. 7.1–4) belonging to three genera of foraminifers (*Bradyina*, *Cribrospira* and *Eostaffella*) and one of algae (*Koninckopora*). The foraminiferal fauna and algae contain common, widespread and important species and genera recorded in the Mississippian standard and reference regions, such as the Dinant Basin in Belgium, Russian Platform, southwestern Spain and Ireland. The most characteristic and prolific form of the foraminiferal fauna is the genus *Bradyina*. One species of the genus was identified from the studied material as *Bradyina* ex gr. *rotula* (D'Eichwald), which is typical of the upper part of the Asbian (=Cf6γ) and first occurs in the highest Asbian, but is also recorded in Brigantian (=Cf6δ) rocks (Mamet 1974; Vachard 1977; Cózar & Somerville 2004). The base of the Aleksinsky Horizon (=Cf6γ) can be defined by the first appearances of *Bradyina* ex gr. *rotula* (D'Eichwald) in the Russian Platform and Urals (Kulagina et al. 2003). It also occurs in the second part of the Cf6γ (late Asbian) biozone in Aladağ Mountains (Cataloturan Nappe) (Okuyucu & Vachard 2006). *Cribrospira* ex gr. *panderi* (von Moeller) is one of the guide foraminiferal genera for the late Asbian and its first appearance defines the base of the Cf6γ biozone (Gallagher & Somerville 2003; Cózar 2004) in southwestern Spain and southern Ireland. It disappears at the Asbian-Brigantian boundary in southern Ireland (Gallagher & Somerville 2003). The genus *Eostaffella* ex gr. *mosquensis* Vissarionova has a rather long stratigraphic range from the middle Visean to early Bashkirian, and is fairly abundant in the late Visean (Vachard 1977; Brenckle & Milkina 2003; Cózar 2004; Okuyucu & Vachard 2006). *Koninckopora* ex gr. *inflata* (de Koninck) is very abundant in late Asbian rocks, but it dramatically declines in numbers in the uppermost Asbian to lowermost Brigantian (Cózar 2004; Cózar & Somerville 2004; Okuyucu & Vachard 2006; for an accurate discussion). Only one specimen, *Koninckopora* ex gr. *inflata* (de Koninck), was recovered from the studied material. This finding suggests that the age of the deposition can be assigned to the latest Asbian–early Brigantian (=middle part of the late Visean).

In the upper part of the formation channel-conglomerates and coarse sandstones dominate and the succession is regressive with shallowing-upwards sequences. After a gap from the Late Pennsylvanian to Middle Permian, uppermost Middle-Upper Permian shallow-water sediments and Werfen-type (lowermost Triassic) continental clastics disconformably overlay older units.

To the northeast of Konya, in a separate tectonic slice the Ludlow siliciclastic rocks with lydites are paraconformably overlain by shallow-water limestones that yielded foraminifers of Serpukhovian–Bashkirian age (determined by D. Altıner).

The Mississippian rock-units in the Konya Province are interpreted as products of an extensional basin on the N edge of the Gondwanan Tauride-Anatolide Platform, where deposition of olistostromes and olistoliths is accompanied by bimodal volcanism (Özcan et al. 1990a,b; Göncüoğlu et al. 2000). It did not develop into a deep (oceanic?) basin but remained as an aborted one, as deduced by the shallowing upward sequences (Göncüoğlu et al. 2000).

Volcanism. The metamorphic volcanic rocks in the northern Konya area occur either as dikes cross-cutting the Devonian platformal limestones or as olistoliths within the Mississippian greywackes of the Halıcı Group. Less frequently, they occur as domes within the olistostromes in the Halıcı Group. Petrographical and preliminary geochemical investigation of metaigneous rocks of the Halıcı Group indicate three compositional groups on Zr/TiO_2-SiO_2 diagrams of Winchester & Floyd (1977) as trachyandesites, rhyolites

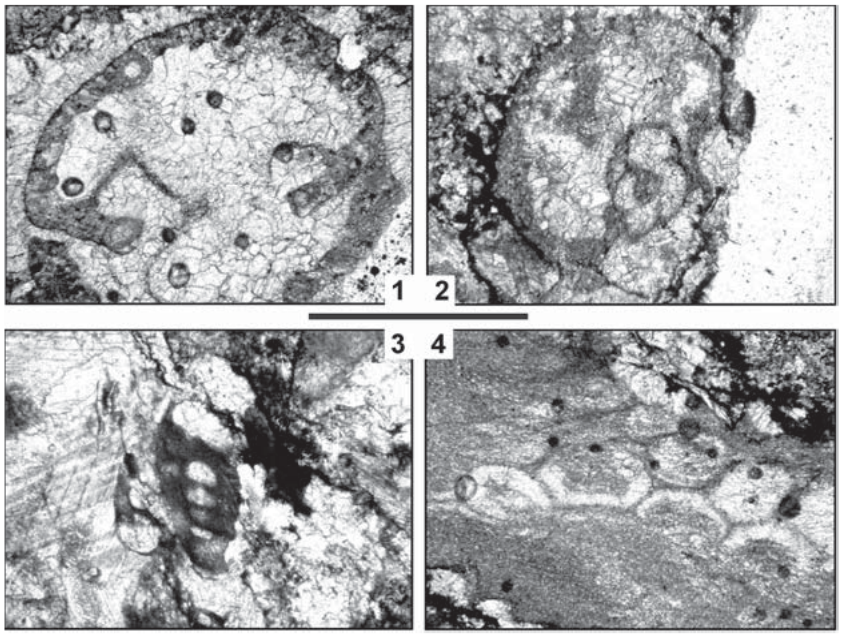

Fig. 7. Characteristic foraminifers and algae from the Mississippian Halıcı Group (Sample KC-16) in the Bolkar Dağı Unit in the Konya area. Scale bar represent 0.5 mm. All specimens are from sample C-16. **1** — *Bradyina* ex gr. *rotula* (D'Eichwald), subaxial section. **2** — *Cribrospira* ex gr. *panderi* (von Moeller), sagittal section. **3** — *Eostaffella* ex gr. *mosquensis* Vissarionova, axial section. **4** — *Koninckopora* ex gr. *inflata* (de Koninck), oblique section.

and subalkaline basalts (Fig. 8A). All of them are transitional to tholeiitic affinity on Y/Nb diagrams (Fig. 8B) of Pearce & Cann (1973). The N-MORB normalized trace and REE elements patterns of all the metaigneous rocks in the Halıcı Group show sharp negative Nb, Zr and Ti anomalies relative to Th, La, Ce implying a subduction related chemistry (Fig. 8C). Considering the N-MORB normalized REE patterns, the first group (metadiabase dikes near Kadınhanı area) displays relatively flat LREE to HREE pattern close to N-MORB (Fig. 8D). The second group is made up of HP-LT metamorphosed basalts in Karatepe. The basalts are characterized as relative enrichment of LREE with strong depletion of HREE with respect to N-MORB. The third group represented by metadiabase dikes in Karamadazi Dağı (Yahyali area) also display relative enrichment in LILE to the HFSE compared to N-MORB. The fourth group (metarhyolites in Talas creek in Yükselen village), with characteristic features of subalkaline signature, displays a higher degree of enrichment LREE relative to HREE with a sharp Eu anomaly (Fig. 8D). The last group, represented by HP-LT trachyandesites in Kadınhanı and Sızma areas, show clearly greater enrichment in LREE and sharp-strong depletion of HREE with a very weak Eu anomaly (Fig. 8D). On the Th/Yb-Ta/Yb diagrams of Pearce (1983), the metavolcanic rocks (diabases, rhyolites and basalts) show signatures of subduction enrichment. The trachyandesites in the Kadınhanı and Sızma areas are displaced to higher Th/Yb ratios with a sub-parallel trend to mantle array which may reflect partial melting, fractional crystallization and AFC (crustal contamination) on mantle-derived magmas with subduction component (Fig. 8E). Additionally on the La/Nb-Y diagrams of Floyd et al. (1991) they plot in the area of back-arc basin basalts rather than IAT (island arc tholeiites). However, the Karatepe basalts in this diagram display a fore-arc platform basalt signature (Fig. 8F).

The preliminary geochemical data suggest that all metavolcanic rocks in the Halıcı Group are relatively enriched in LILE, LREE and depleted in HREE with negative Nb, Zr and Ti anomalies. These indicate that these metaigneous rocks have a typical back-arc geochemical signature and can be interpreted as reflections of back-arc extension on a continental margin (the Tauride-Anatolide Platform) that has been subjected to lithospheric thinning producing the back-arc basin magmatic rocks.

Hadim area. To the south of Hadim, slightly metamorphic rocks of Carboniferous age are included in the Kongul Formation (Özgül 1997). The Kongul Formation conformably overlies Upper Devonian slates and includes an alternation of dark coloured shales, mudstones, dark grey biostromal limestones (Fig. 9A) rich in crinoids and brachiopods and quartzite interlayers in its lower part (Zidancik Member). The upper member (Mantar Beleni Member) is made up, from bottom to top, of limestones (wackestones and grainstones) and dolomites, respectively. While the limestone bands of the Zindancik Member include Visean foraminifers, the overlying limestones

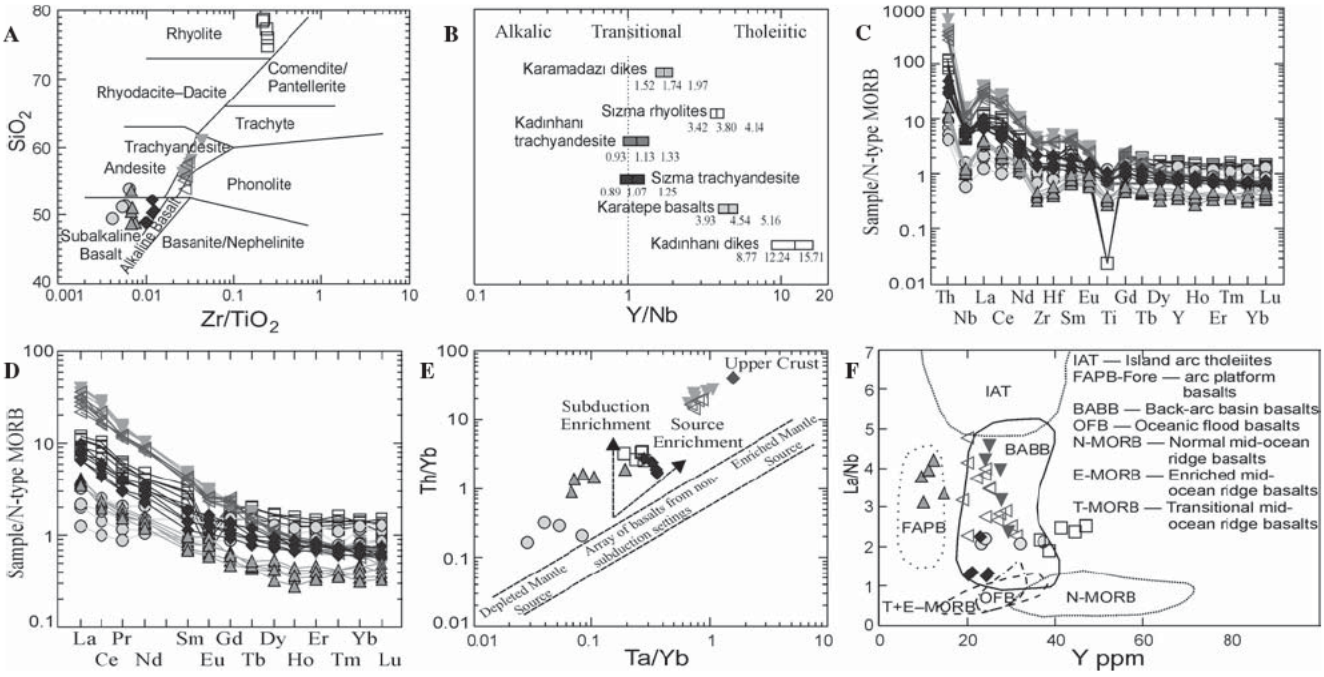

Fig. 8. A — Classification of the metamagmatic rocks of the Halıcı Group. **B** — Y/Nb discrimination diagrams of Pearce & Cann (1973). **C,D** — N-MORB normalized multivariation and REE diagrams (normalization values from Sun & McDonough 1989); Tectonic discrimination diagrams of metamagmatic rocks of Halıcı Group. **E** — Th/Yb-Ta/Yb diagram (Pearce 1983). **F** — La/Nb-Y diagram (Floyd et al. 1991). Closed circle — metadiabase dikes near the Kadınhanı area, closed triangle — Karatepe basalts, closed diamond — Karamadazı Dağ metadiabase dikes (near Yahyali), open triangle — trachyandesite in Kadınhanı village, reversed closed triangle — trachyandesite in Sızma village, open square — metarhyolite in Talas creek near Yükselen village.

contain characteristic foraminiferal assemblages of Visean–Serpukhovian and Bashkirian–Moscovian. In an isolated outcrop, Ekmekci & Kozur (2001) described an incomplete succession of the formation with Moscovian conodonts.

In contrast to the olistostromal Mississippian in the Konya Province, the coeval rocks in the Hadim area are characterized by inner-shelf deposits.

Stratigraphy of the Aladağ Unit in the Hadim area

The limestone and quartzite dominated Carboniferous succession (Fig. 9B) to the south of Hadim consist of the Yaricak Formation (Özgül 1997). This formation rests conformably on Devonian coarse clastics and includes in its lower part (Cityayla Member) typical black shales, siltstones and sandy limestones with Tournaisian macro-fossils. The lower part of the upper member (Mantar Tepe Member) consists of fossiliferous limestones. The middle part is mainly composed of quartzites with bioclastic limestone intercalations, whereas the upper part comprises limestones with sandstone and quartzarenites. In this area Özgül (1997) and Altıner & Özgül (2001) have reported a continuous succession that covers the complete Tournaisian–Moscovian time-span with several characteristic biozones. The Tournaisian Stage could not be zoned because of its rare foraminiferal content, but nine biostratigraphic zones for Visean, three for Serpukhovian, five for Bashkirian and five for Moscovian were recognized by the previous authors (Altıner & Özgül 2001). All the described zones have been correlated with their equivalents in Western Europe, the Eastern European Platform and Russian Platform. However, one stratigraphic gap between two zones of Moscovian (MT1 and MT2) and one probable correlation for the last zone of Bashkirian was also realized. The Pennsylvanian is at least partly present but not yet studied in detail.

The depositional environment of the Yaricak Formation is coastal to shallow shelf and may include short intervals of erosion and continental deposits during Tournaisian–Visean and Visean–Bashkirian times (Özgül 1997). Conglomerates with limestone dominated pebbles and bauxite patched conglomerate lenses in the succession correspond to the indicated depositional environments of the sequence.

The Pennsylvanian is at least partly present but not yet studied in detail.

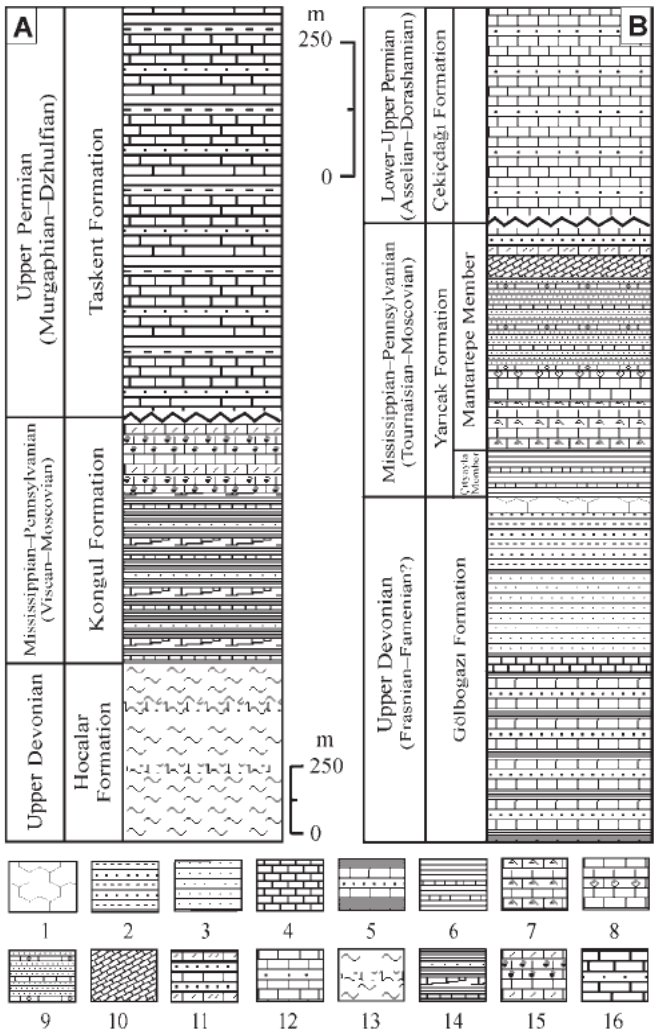

Fig. 9. Generalized columnar section of **A** — The Kongul Formation of the Bolkar Dağı Unit, **B** — Yaricak Formation of the Aladağ Unit in the Hadim area. **1** — conglomerate; **2** — quartzarenite–shale alternation; **3** — quartzarenites; **4** — limestone; **5** — limestone, shale and sandstone alternation; **6** — shale with sandy limestone interlayers; **7** — limestone with gastropods, crinoids and algae; **8** — oolitic limestone with quartzarenite interlayers; **9** — quartzarenites with foraminifers-bearing limestone interlayers; **10** — foraminifers and algae-bearing limestone; **11** — quartzarenite–limestone alternations; **12** — limestone-clayey limestone-shale alternation with quartzarenite interlayers; **13** — slate-quartzarenite recrystallized limestone alternation; **14** — shale–limestone alternation; **15** — crinoid-, brachiopod-, foraminifers-bearing oolitic limestone with rare shale interlayers; **16** — foraminifers-, algae-bearing limestone with rare quartzarenites and shale interlayers. (After Özgül 1997.)

Stratigraphy of Cataloturan Nappe in the Yahyali area (Eastern Taurides)

The Cataloturan Nappe is a distinct tectonic unit in the northern Aladağ Mountains at the western end of the Eastern Taurides (Fig. 1) that was recognized in the pioneering work of Blumenthal (1952). It is an exotic nappe, imbricated with ophiolites and other Paleozoic-Mesozoic nappes during their Late Cretaceous emplacement on the Tauride-Anatolide Platform (Tekeli et al. 1984).

The Cataloturan Nappe is characterized by the Mississippian deep-water (basinal-lower slope) facies in its base and shallow-water (shelf edge) facies in its upper parts (Aksay 1980; Isik 1981; Okuyucu & Vachard 2006). In the Nohutluk Tepe section, Isik (1981) established 12 biozones ranging from Tournaisian to Bashkirian, but the recent study of Okuyucu & Vachard (2006) have demonstrated that the latest age of the Nohutluk Tepe section is late Visean. The unit exhibits deformation and low grade metamorphism and correlated (Tekeli et al. 1984; Ayhan

& Lengeranli 1986) with the Bolkar Dağı Unit of Özgül (1976). We aimed to study the basal part of the nappe, where cherts and volcanic/volcaniclastic rocks dominate, using conodonts and radiolarians in our recent work. The Cataloturan Nappe rests with a thrust contact on the Alpine ophiolites (Fig. 10), and the pre-Carboniferous units are truncated. At the NE bank of the Dereyurdu Kapısı creek at 1.5 km southeast of Teknelikösk (at Kozan M34b1 quadrangle sheet, between coordinates $^{42}00^{420}$ N:$^{7}03^{430}$ E and $^{42}00^{700}$ N:$^{7}03^{850}$ E) the authors measured a section (Fig. 11). The basal part of the sequence (approximately 0–25 meters) consists of graphite-rich black shales with dark-grey sandstones, which are very typical of the Devonian-Carboniferous transition beds in the Eastern Taurides ("D-C boundary anoxic event" in Göncüoğlu et al. 2004). An alternation of thin-bedded dark grey limestones and dark green volcaniclastic sandstones and tuffs that reach up to 0.8 m in thickness continues upwards. The volcaniclastic sandstones include a chloritized matrix and angular fragments of plagioclase, less frequently quartz, dacite and glass shards. The tuffaceous material is lighter green in colour and occurs as thin, carbonaceous and radiolaria-bearing bands and lamellae. Towards the top, the tuffaceous intercalations are reduced and light green siliceous bands alternate with dark grey limestones. The measured section starts in the eastern side of the creek with the cherty limestones. Between samples 00CO1 and 00CO36, the sequence is mainly characterized by alternations of limestones, cherts and mudstones (Fig. 11).

The limestones are black to grey-beige in colour, thin- to medium-bedded and rich in organic matter and pyrite. The cherts are black in colour, thin-bedded, mainly nodular sometimes band-like. Towards the top, the thickness of the chert bands gradually decreases and they become more nodular. The interbedded mudstones are mainly thin-bedded and their colour changes from yellow-dark grey to green due to their volcanic constituents. The upper part of the section (approximately 100–160 m from sample 00CO37 to sample 00 CO 41; Fig. 11) is represented by the alternations of dark grey to black in colour, thin- to medium-bedded limestones and dark grey mudstones. The limestones are partly dolomitic with some black chert nodules. The measured part of the section is rich in radiolarians and conodonts (Fig. 12.1–14). The first benthic foraminifers were detected at sample 00CO42 together with crinoids and they become more abundant upwardly. From this point to the end of the section, the common lithology is limestone with mudstone interbeds and has been recently published by Okuyucu & Vachard (2006). A thick late Visean succession with eighty taxa of algae, foraminifers and calcareous microproblematica has been defined from 00CO42 to the end of the section (00CO98) and this interval subdivided into three informal assemblage biozones by this authors as *Howchinia bradyana–Lituotubella magna–Koktjubina* (?) sp. biozone, *Bradyina rotula–Euxinita tauridiana* biozone, *Janischewskina typica* and *Biseriella* aff. *parva* biozone. According to Okuyucu & Vachard (2006) the assemblages of the studied section in the Cataloturan Nappe is typically Northwestern Paleotethyan and based on the occurrence and biogeographical distribution of the *Euxinita*, the Anatolides-Taurides and Pontides blocks were paleogeographically linked and located near the northwestern border of the Paleotethys.

Although abundant radiolarians were detected from thin sections, very few of them were extracted from limestones (only from sample 00CO6) because of extensive calcification. Better radiolarians were recovered from the chert beds in sample 00CO10. Although relatively abundant conodont elements were extracted from sample 00CO4 to 00CO18, very rare elements of conodonts (sample 00CO35) were obtained from the upper part of the section.

The samples studied mainly include Pa elements of *Gnathodus pseudosemiglaber* Thompson et Fellows (Fig. 12.1–4). This species ranges from near the base of the Lower *typicus* Zone into the *bilineatus* Zone (Sweet 1988; Blanco-Ferrera et al. 2005) (Fig. 5), and defines the late Tournaisian to early Visean interval (Mississippian). In the conodont biofacies model for the Early Mississippian *anchoralis-latus* Zone of Sandberg et Gutschick (1984) the genus *Gnathodus* occurs within the gnathodid-pseudopolygnathid biofacies of the foreslope environment. *Gnathodus* and *Pseudopolygnathus* were nectobenthic slope dwellers, whose living environment diminishes towards the dysaerobic levels (Sandberg & Gutschick 1984).

The radiolarians include the *Albaillella paradoxa* group Deflandre, 1952 (Fig. 12.5), *Belowea variabilis* Won, 1983 (Fig. 12.6–11), *Entactinia* sp. (Fig. 12.12–13) and *Archocyrtium* sp. (Fig. 12.14).

On the basis of the radiolarian fauna, the assemblage is assigned to a late Tournaisian

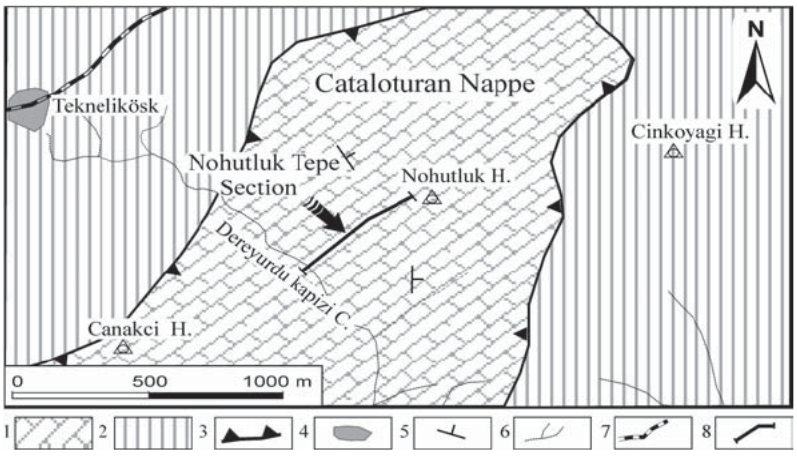

Fig. 10. Geological map of the area around Nohutluk Tepe section in Cataloturan Nappe. **1** — Carboniferous rock units; **2** — Senonian ophiolitic mélange; **3** — thrust fault; **4** — settlement; **5** — dip and strike of bedding; **6** — drainage systems; **7** — main roads; **8** — location of the Nohutluk Tepe section. (Modified from Aksay 1980.)

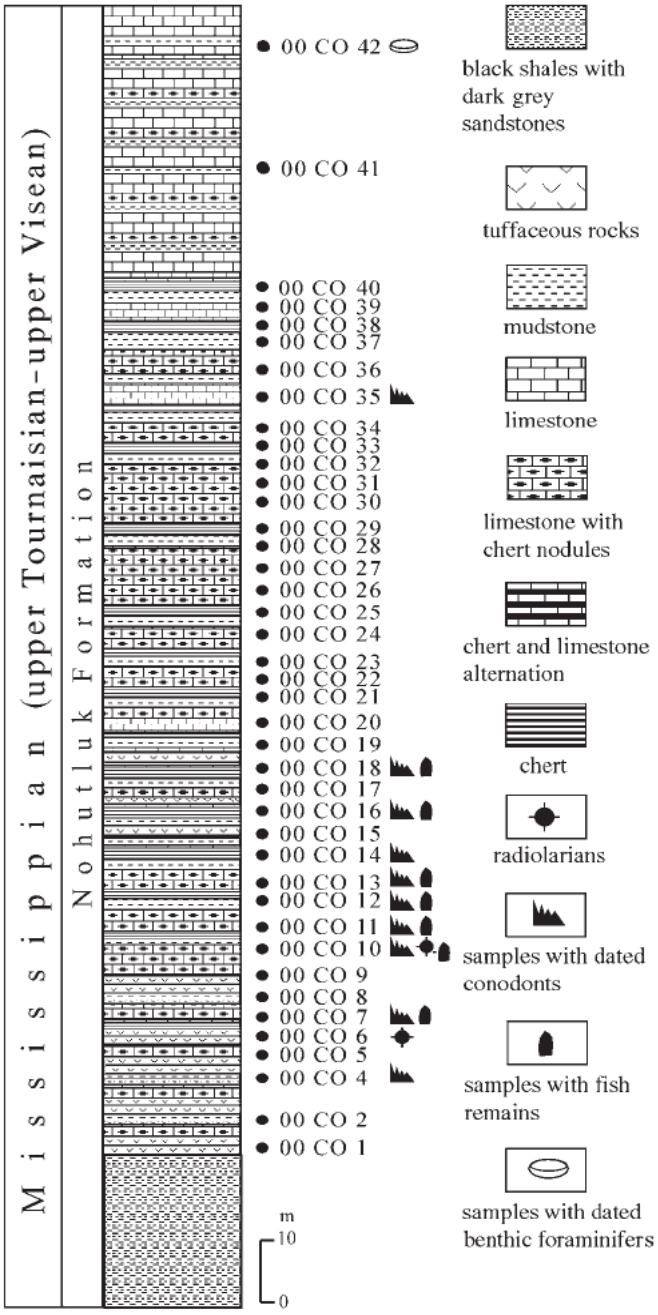

Fig. 11. Basal part of the Nohutluk Tepe section from the Nohutluk Formation in the Cataloturan Nappe.

through Visean age. The *Albaillella paradoxa* group taxa are known from the early Tournaisian (Tn2) through the early Visean in both Europe and North America (Holdsworth & Jones 1980; Braun 1990). In Germany, where the radiolarian strata are fairly well constrained by goniatites and conodonts, the range of *A. paradoxa* corresponds to the *Pericyclus princeps* through *P. kochi* Zones (Braun 1990). *Belowea variabilis* Won is also restricted to the late Tournaisian–early Visean, by making its first appearance slightly above *A. paradoxa* in the *Pericyclus plicatilis-corpulentum* Zone in Germany, and in terms of conodont zones, this interval correlates to the *typicus* through *texanus* Zones (Braun & Schmidt-Effing 1993).

Discussion and conclusions

Disregarding some models inconsistent with local geology (e.g. Stampfli et al. 2001; Eren et al. 2004), since Sengör & Yılmaz (1981) there has been overall agreement that the Tauride-Anatolide Platform remained mainly as a single tectonic unit (Sengör 1984; Göncüoğlu et al. 1997, 2000, 2003; Okay & Tüysüz 1999) until its disintegration during the Late Permian-early Mesozoic by the opening of the Neotethyan oceanic branches. It is also commonly accepted that this platform was deformed by thrusting and nappe-emplacement during the Alpine closure of the above-mentioned oceans. These compressional tectonics caused a thrust-stacking of the Paleozoic-Mesozoic successions. As briefly mentioned above, Özgül (1976, 1984) proposed a restoration of the northern platform margin, by which the Aladağ and Bolkar Dağı tectono-stratigraphic units were positioned to the north of the Geyik Dağı Unit. Both of them are "distinguished and differentiated from each other by their stratigraphic position, character of metamorphism, and their present structural position (Özgül 1976)". For the Bolkar Dağı Unit for example, the main criteria are the metamorphism and the Late Permian unconformity, which are lacking in the Aladağ and Geyik Dağı Units. Aladağ Unit, on the other hand, shows a continuous deposition throughout the Devonian–end Paleozoic period and includes very typical local key horizons and facies in Carboniferous (*Siphonophyllia* Zone), and Permian (Girvanella Limestones facies (*Calcaires à Girvanellas* Güvenç, 1965) and *Pseudoschwagerina* Zone).

Even if this overall approach is applicable to the main tectonic units, several tectonic slices in the Central Taurides cannot be easily affiliated to one of them, when the stratigraphic intervals do not include the characteristic features such as unconformities or typical bio- and lithofacies. Moreover, successions of Aladağ- and/or Geyik Dağı type lithostratigraphic units may show metamorphism. This is especially the case in the northern Sultan Dağı, Konya and Hadim areas, as reported in this paper. In the Sultan Dağı area, both the Çayözü Group of Geyik Dağı Unit as well as the Çay Tectonic Unit of the Aladağ/Bolkar Dağı Unit are metamorphic and rarely include fossils. Moreover, recrystallized carbonates of different tectono-stratigraphic units are intensively interleaved. Hence, interpretations based on the physical resemblance of lithostratigraphic units or their state of metamorphism without biostratigraphic data may lead to confusion (e.g. Uguz et al. (1996) in Deresinek area; Ekmekci & Kozur (2001) in Had m area and Eren et al. (2004) in Konya area).

Considering the depositional features within the late Tournaisian to early Serpukhovian interval of the Bolkar Dağı, Aladağ, and Geyik Dağı Units in several sections in the Central and Eastern Taurides a palinspastic reconstruction of the Tauride-Anatolide Platform is proposed in

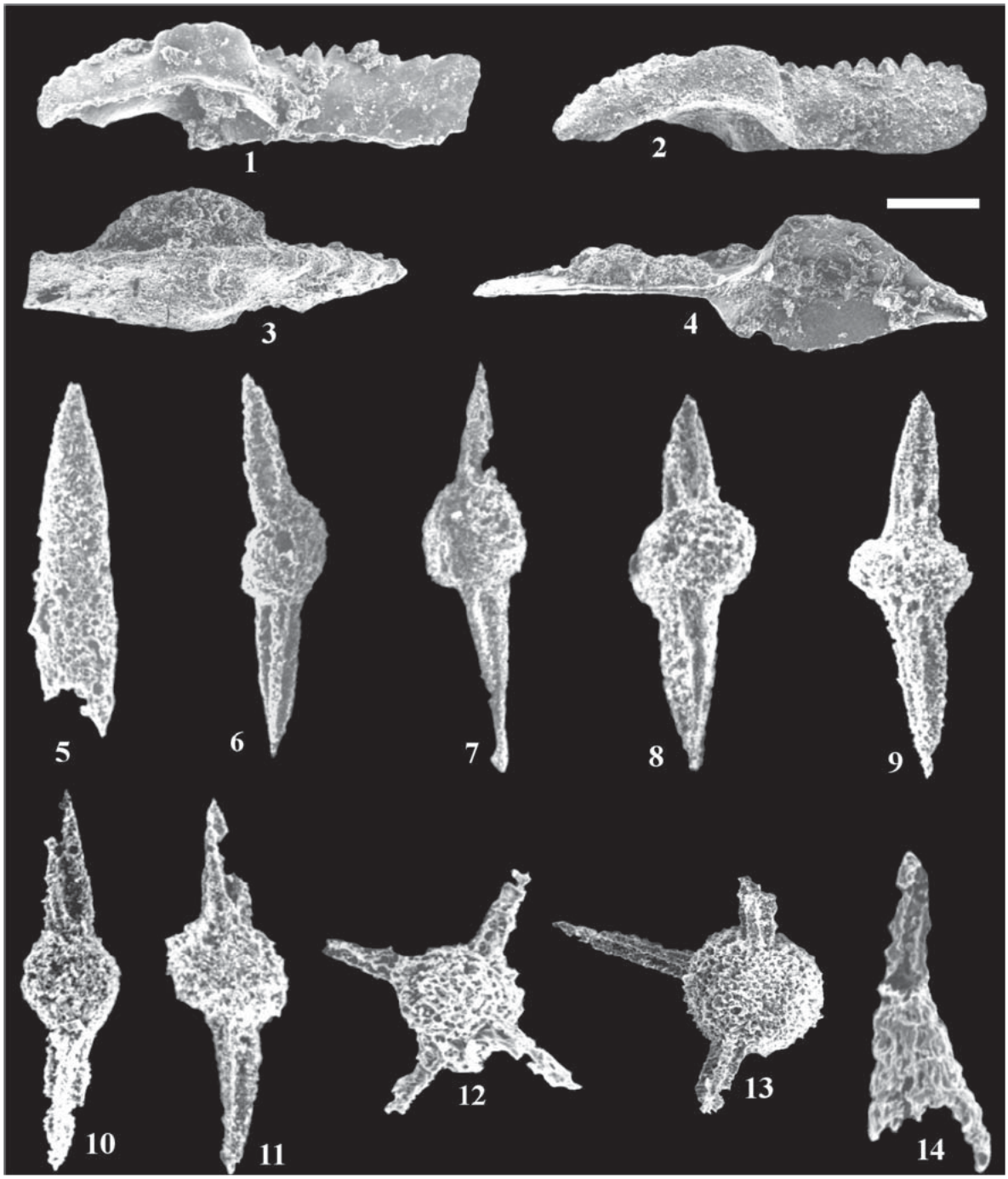

Fig. 12. Photomicrographs of the conodont and radiolarian faunas from the Cataloturan Nappe in Yahyali area. Figures 1–4 are from conodont fauna and figures 5–14 are from radiolarian faunas. **1–4** — Pa elements of *Gnathodus pseudosemiglaber* Thompson et Fellows. 1 is from sample 00CO11, 2–3 are from sample 00CO12 and 4 is from sample 00CO16, scale bar = 260, 280, 220 and 190 μm, respectively. **5** — *Albaillella paradoxa* group Deflandre, sample 00CO10, scale bar = 260 μm. **6–11** — *Belowea variabilis* Won, all specimens are from sample 00CO10, scale bar = 110, 105, 85, 95, 90 and 90 μm, respectively. **12–13** — *Entactinia* sp., both specimens are from sample 00CO10, scale bar = 90 and 120 μm. **14** — *Archocyrtium* sp. Sample 00 CO 6, scale bar = 70 μm.

Fig. 13. It concerns the northern edge of the Gondwana margin, facing toward a Paleozoic ocean. The slope to basin-toe-type Wenlock to late Lochkovian turbidites and ribbon-cherts with pelagic conodonts in the Konya area (Göncüoğlu & Kozur 1998) indicate that this ocean was already open in the early Paleozoic and may correspond to a southern part of Paleotethys (sensu Sengör 1984) or alternatively the Paleotethys (e.g. sensu Stampfli 2000).

Starting with the early Lochkovian, an extensive carbonate platform was developed in this Gondwana margin, as indicated by the very thick shelf-type limestones and dolomites all along the Taurides (Göncüoğlu et al. 2004).

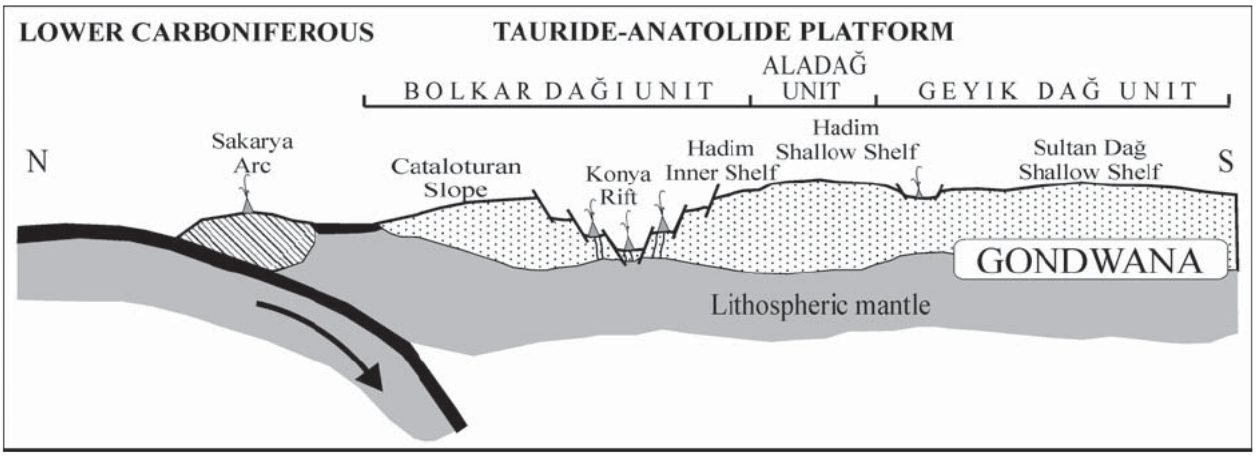

Fig. 13. Schematic reconstruction of the Tauride-Anatolide Platform for Mississippian.

The first indications of an extensional period on this platform are recorded in the Middle Devonian unconformities and volcanism in the Geyik Dağı Unit, interpreted as products of block-faulting.

The Devonian/Carboniferous (D/C) transition is characterized in Geyik Dağı, Aladağ and Cataloturan-Bolkar Dağı Units by the very typical black shales, indicative for the D/C anoxic event (Göncüoğlu et al. 2004). Starting with the late Tournaisian, the extension in the northern edge of the platform in the Konya area has resulted in the formation of the Bolkar Dağ Unit as a marginal basin deposition with olistostromes and olistoliths sourced from the underlying Silurian-Devonian platform carbonates. A distinct bimodal volcanic activity with within-plate-type alkaline lavas and domes together with calc-alkaline felsic intrusive rocks (Kurt 1996; Eren & Kurt 1998; Eren et al. 2004) were generated in this basin.

The basin was very probably not extremely deep, as only shallow-marine Mississippian carbonates but no basinal facies strata were identified (e.g. cherts or oceanic shales). Moreover, no mid-ocean ridge basalts or any other volcanic rocks related to an oceanic lithosphere of late Paleozoic age are reported. By this, it is suggested that this basin was not floored with oceanic crust. The fact that the upper part of this olistostromal unit is regressive, or upwards shallowing, is suggestive for a failed (aborted) rift. Özcan et al. (1990b) and Göncüoğlu et al. (2003) initially proposed that this rifting on the northern edge of Gondwana was in a back-arc setting, above the southward subducting Paleozoic oceanic lithosphere to the south of the Sakarya arc (Fig. 13). Whether the extensional volcanism is the product of the melting of this subducting slab or was formed by the mantle uplifting cannot be deduced from the available geochemical data of Kurt (1996). However, the new data presented above indicate that they may have been erupted in a back-arc basin setting above the northern Gondwana continental margin.

The late Tournaisian–Visean interval in the Cataloturan-Bolkar Dağı Unit is characterized by the presence of reworked basic volcanic material and tephra alternating with radiolarian cherts and pelagic limestones. The carbonate petrographic features (Aksay 1980) as well as its faunal content are indicative for a slope to basin-toe-type setting. We therefore place it in the most internal part with regard to the Paleozoic ocean to the north of Konya-Bolkar Unit. The Hadim-Bolkar Dağı Unit on the other hand must be located to the south of the Konya-Bolkar Dağı Unit, as it is mainly represented by inner shelf deposits. The Aladağ Unit in the same time-interval mainly includes shallow-marine to coastal deposits with indications of erosional events (Özgül 1997). By this, the most appropriate position of this unit is a paleo-ridge between the Bolkar Dağı and Geyik Dağı type successions, as initially proposed by Özgül (1976). The Geyik Dağı Unit also represents a shallow platform in the period concerned. However, it also includes Mississippian basic volcanic rocks, which were also known from Konya-Bolkar (Özcan et al. 1990b) and from the Cataloturan-Bolkar (Aksay 1980; Tekeli et al. 1984) areas. The presence of these volcanic rocks within the Kuz Member just above the conodont-dated Göktepe Member indicates that the volcanic activity has affected the inner parts of the platform.

With the sole exception of the Cataloturan Nappe, all the Bolkar Dağı-related units include the earliest Late Permian angular unconformity, marking the closure of the Carboniferous basin along the Tauride-Anatolide Platform. Closure is ascribed to the marginal affect of the Variscan events in the north (Göncüoğlu 1989).

To conclude, the reconstruction of the Alpine Tauride-Anatolide tectono-stratigraphic units in the Central and Eastern Taurides for the Mississippian time reveals the formation of an aborted rift basin in a back-arc setting, above a southward subducting Paleozoic oceanic plate along the northern margin of Gondwana. The rifting did not result in the formation of an oceanic crust. Instead, rifting failed and the basin was progressively filled with a regressive sequence. The regressive sequence was then deformed, and unconformably overlain by lowermost Upper Permian strata.

Our field data indicate an absence of a late Paleozoic–early Mesozoic suture within the Taurides. Models suggesting a "Paleotethyan suture" within the Taurides and

advocating a northern "Paleotethyan passive margin position" (e.g. Stampfli et al. 2001; Eren et al. 2004) for the metamorphic units (Anatolides) of the Tauride-Anatolide Platform are not supported.

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