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Main features of the pre-Variscan development in Turkey

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Abstract: The pre-Variscan development in Turkey ranges from a Caledonian-time complex in the Zonguldak Zone (accreted in the lowermost Devonian to Eurasia) to a peri-Gondwana shelf development above Panafrican basement in the southern part of the Tauride-Anatolide Composite Terrane and southeast Anatolian Autochthon. The Caledonian Zonguldak Terrane is a continuation of the Tornquist Sea, and the southwards adjacent Ordovician to Lower Devonian shallow-water shelf has an Ordovician ostracod and brachiopod fauna with close relations to Baltica and little relation to peri-Gondwana. A southward adjacent large Caledonian-time ocean (Karaburun-Bolkardağ Ocean) in the northern part of the Tauride-Anatolide Composite Terrane separated these warm-temperate faunas from Ordovician western peri-Gondwana cold-water associations in the southern part of the Tauride-Anatolide Composite Terrane.

INTRODUCTION

The Turkish orogenetic collage can be divided into a number of tectonostratigraphic units or terranes trending in E-W direction (Fig. 1). The last main orogenetic event, the Alpine orogeny, has controlled the present distribution of these terranes. However, the terranes have a complex tectonic history. Various tectonic settings, such as active and passive continental margins, arc and suture complexes, were generated as results of the opening and closure of different oceanic basins: Cadomian/Pan-African, Early Paleozoic ("Caledonian"), Variscan, Paleotethyan, and Neotethyan. With increasing age of the orogenetic events, their recognition becomes increasingly difficult because the tectonic setting is very complicated, obscured by younger tectonic events, and the stratigraphic data are scarce or missing. The present paper gives an overview about orogentic events and paleogeographic setting in Caledonian and Variscan times.

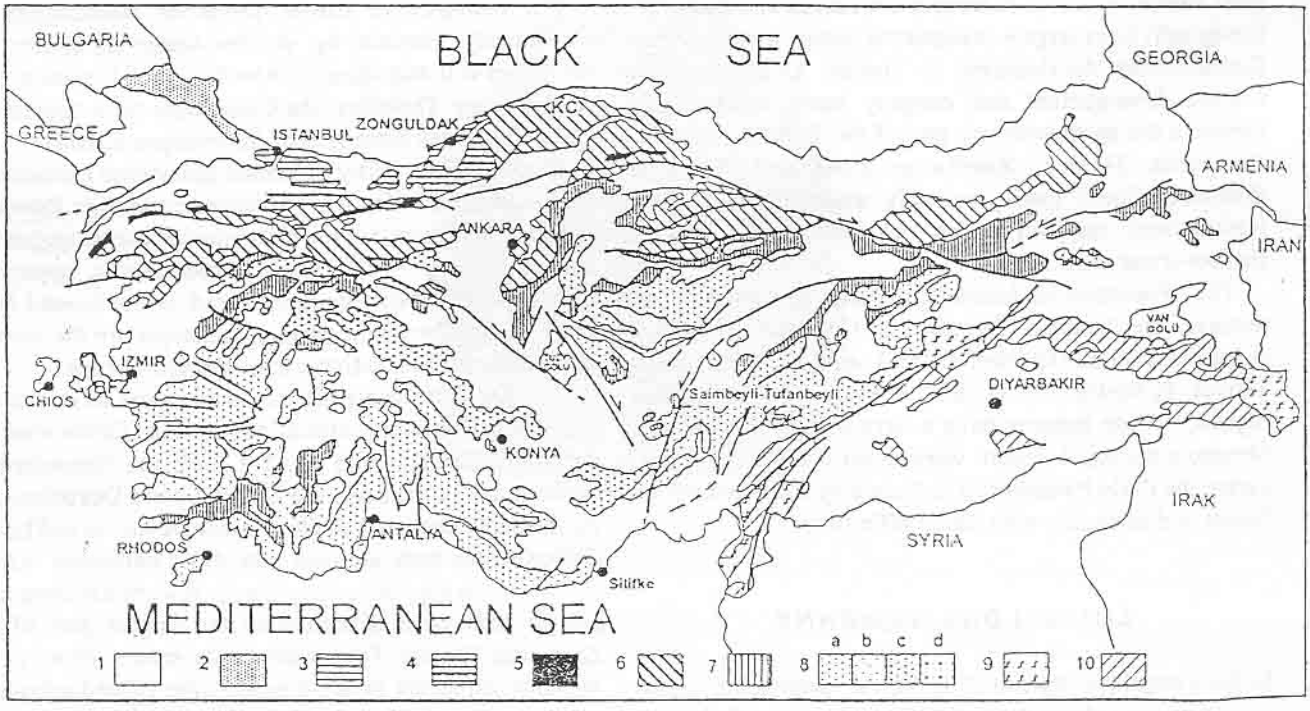

Fig. 1. Alpine tectonic units with studied Paleozoic rocks in Turkey. Modified after Göncüoglu, 1997). 1: Cenozoic cover. 2: Istranca Terrane. 3: Istanbul Zone s.s. 4: Zonguldak Zone. 5: Intrapontide Ophiolite Belt. 6: Sakarya Composite Terrane (including Küre Complex, KC). 7: Izmir-Ankara-Erzincan Ophiolitic Belt (Vardar Ocean suture zone) and ophiolites/ophiolitic melanges in nappe position that were derived probably from this suture zone, e.g. in the Lycian nappes. BFZ: Bornova Flysch Zone as southern marginal part of the Izmir-Ankara-Erzincan Ophiolitic Belt. 8: Tauride-Anatolide Composite Terrane (a: undivided, mainly Geyik Dagi Autochthon, b: Lycian-Bozkir nappes, c: Kütahya-Bolkardag Zone, d: Karaburun Zone). 9: Southeast Anatolian Ophiolite Belt and Kemer Ophiolite of the Antalya nappes. 10: Southeast Anatolian Autochthon.

Fossil-dated unmetamorphosed to very low-grade metamorphic pre-Carboniferous sequences in Turkey are found in the Zonguldak and Istanbul terranes and in the Tauride-Anatolide Composite Terrane (Fig. 1). In the Sakarya Composite Terrane, pre-Carboniferous rocks are either metamorphic and igneous rocks or consist of olistoliths and blocks of dated unmetamorphic to very low-grade metamorphic sediments and of undated metamorphics in the Upper Triassic turbidite-olistostrome unit of the Karakaya Complex. In the Izmir-Ankara-Erzincan Ophiolite Belt pre-Variscan rocks occur as blocks in uppermost Cretaceous to Paleocene flysch, especially in the Bornova Flysch Zone (Fig. 1) west of Izmir.

Before our micropaleontological investigations, dated pre-Carboniferous Paleozoic rocks were only known from the "Paleozoic of Istanbul" (dated Ordovician to Carboniferous), from the Bornova Flysch Zone (Upper Silurian to Lower Devonian limestone blocks in the Kalecik area of the Karaburun peninsula), from shelf deposits of the southern Tauride-Anatolide Composite Terrane and of the Southeast Anatolian Autochthon. Except for the Intrapontide Ophiolite Belt and the Southeast Anatolian Ophiolite Belt (pre-Variscan rocks probably not present), we have found and paleontologically dated (with conodonts, muellerisphaerids, ostracods and radiolarians) pre-Carboniferous rocks in all terranes and tectonic units of Turkey. Some of the investigated material contains also macrofossils (bivalves, brachiopods, cephalopods, crinoids, graptolites and trilobites). The pre-Permian metamorphics of the Menderes Massif have not yet been investigated; but also this unit has a complex tectonic history (e.g. Pan-African basement, Neotethyan metamorphism and nappe structure).

New stratigraphic results obtained by micropaleontological studies of Early Paleozoic sequences and protolith-stratigraphy have largely changed the former picture of pre-Carboniferous development in Turkey. Caledonian-time oceanic development and orogeny occur considerably further to the south (northern part of the Tauride-Anatolide Composite Terrane: Karaburun Zone and Kütahya-Bolkardag Zone) than previously assumed when these regions were assigned to the Paleozoic peri-Gondwana shallow-water shelf.

The "Paleozoic of Istanbul" belongs to two different terranes, the Istanbul Terrane s.s. (Paleozoic-Mesozoic sequence around Istanbul-Gebze) and the Zonguldak Terrane (Çamdag, Zonguldak, Amasra and Safranbolu regions). These terranes have a very different Paleozoic-Mesozoic history, but both were north of peri-Gondwana during the Early Paleozoic as indicated by their Ordovician faunas and acritarchs with Baltic affinities.

ZONGULDAK TERRANE

In the Zonguldak Terrane (Fig. 3), the Ordovician begins unconformably above Precambrian gneisses and Cadomian oceanic and island arc sequences (Ustaömer and Kipman 1997) with Tremadoc dark greenish-gray siltstones and dark-red sandstones (Bakacak Formation). Locally, an undated arkosic sandstone is present below the dated Tremadoc rocks. Five levels in the lower 15 m of the Bakacak Formation contain a cosmopolitan acritarch association (Dean *et al.* 1997) without any peri-Gondwana cold-water forms. The overlying light-gray to white quartzitic sandstones (Aydos Formation) have not yielded any fossil and were tentatively assigned to the upper Tremadoc or (and) lower Arenig by Dean *et al.* (1997). Dark-gray Arenig-lower Llanvirn mudstones and siltstones (Karadere Formation) with graptolites and trilobites of Welsh-European affinities indicate a rapid deepening of a basin in large parts of the Zonguldak Terrane. Only the Çamdag Zone remains an elevated area through most of the Ordovician and Silurian and will not be considered in the following discussion. Limestones and mudstones of the Ketencikdere Formation yielded Caradoc and Caradoc-Ashgill conodonts (CAI = 5-6), and cosmopolitan acritarchs. Very interesting is the occurrence of *Amorphognathus tvaerensis* Bergström, the index species of the Caradoc *A. tvaerensis* Zone that is only present in the warm-water faunas of Scandinavia, Estonia and North America, but absent from western peri-Gondwana cold-water faunas. The Silurian (Findikli Formation) consists mainly of black and gray graptolitic shales and mudstones with subordinate pelagic limestone intercalations (partly dolomitized). According to Dean *et al.* (1997) Wenlock rocks are unconformably overlain by Lower Devonian sandstones and quartzites. However, we found Silurian deep-water sediments (conodonts, paleopsychrospheric ostracods) of different ages below the unconformably overlying Lower Devonian siliciclastics. The youngest sample yielded Ludlowian to Přídolian conodonts. Up to this level all Silurian conodonts are distinctly thermally altered (CAI = 5).

The transgressive Lower Devonian siliciclastics are conformably overlain by shallow-water dolomites and limestones with conodonts (CAI = 2–2.5) of Emsian to Late Devonian age. Therefore, the Caledonian-time discordance of the Zonguldak Zone is post-Silurian/pre-Emsian.

Shallow-water, partly dolomitic limestones continued in the Lower Carboniferous. The youngest marine Paleozoic beds that we found, are lower Namurian conodont-bearing limestones (CAI = 1). Upper Carboniferous, uppermost Permian, and Triassic are represented by continental beds. In the Carboniferous the plant associations are the same as in the Donetz Basin, Middle and Western Europe.

The Arenig to latest Silurian deep-water development, the distinct thermal alteration of the Ordovician to uppermost Silurian beds (CAI = 5-6), the disconformity between the Silurian and the higher Lower Devonian, and the thermally unaltered shallow-water Devonian and Lower Carboniferous beds indicate that: (1) Continuous Middle Ordovician to uppermost Silurian (or lowermost Devonian) pelagic beds were deposited in the largest part of the Zonguldak Terrane. They were partly eroded down to the Wenlock sediments in pre-Emsian time (Caledonian-time discordance). (2) There were distinct Caledonian-time movements and thermal alteration. (3) The Zonguldak Terrane may be part of a non-oceanic Tornquist Sea or a marginal part of an oceanic Tornquist Sea. (4) The

Zonguldak Terrane does not belong to the Variscan chain, but was in Variscan time a stable shallow-water shelf attached to the southern margin of Eurasia.

The Paleozoic development of the Zonguldak Terrane is very similar to that of the Moesian Platform. The entirely continental Triassic of the Zonguldak Terrane indicates a slightly more northern position of the Zonguldak Terrane compared with the Moesian Platform.

ISTANBUL TERRANE s.s.

The oldest rocks in the Istanbul Terrane s.s. (Haas 1968; Kaya 1973) are Ordovician siliciclastic deposits. Upper Caradoc-Ashgill ostracods and brachiopods (Sayar and Schallreuter 1989) include *Piretella*, a typical Baltoscandian genus, *Klimphores* (very common in Baltica, but it occurs also in peri-Gondwana Europe and Saudi Arabia) and *Eochilina* (outside Turkey only known from Siberia and Michigan). The brachiopods show connections to Baltica, Bohemia and the Appalachians. Thus, the Ordovician had apparently a warm-temperate fauna with close connections to North Europe and Siberia/North America (warm-water), but also with few connections to peri-Gondwana (cold-water). The clastic shallow-water deposits continued in the Llandovery, whereas in the Wenlock and Ludlow shallow-water limestones were deposited (Fig. 2). Despite a slight deepening in the Přídolí, shallow-water limestones and clastics were deposited during the Early Devonian up to the lower Emsian. The upper Emsian to Upper Devonian succession consists of pelagic rocks, predominantly limestones. In the Tournaisian

Fig. 2. Paleozoic to Mesozoic succession and events in the Istanbul Terrane s. s.

lydites are common, and in the Viséan Culm flysch was deposited. The youngest marine Paleozoic deposits yielded lower Bashkirian fossils. The Lower Triassic rests unconformably on Bashkirian or older beds. Middle Triassic condensed deep-water deposits and Upper Triassic flyschoid siliciclastic turbidites and olistostromes are very similar to those of the adjacent northern part of the Karakaya Ocean, but also to the northern Dobrogea, where, however, the Paleozoic development is distinctly different.

Lower Carboniferous flysch and Variscan thermal alteration of the conodonts (Devonian CAI = 4; Gedik 1988) indicate that the Istanbul Terrane s.s. belongs to the Variscan Belt. Shallow-water Ordovician to Lower Devonian deposition without hiatus between the Silurian and Devonian indicates that there were no Caledonian movements.

SAKARYA COMPOSITE TERRANE

In the Sakarya Composite Terrane, the pre-Bashkirian rocks are either metamorphosed and unfossiliferous (Sakarya continent) or consist of unmetamorphic or metamorphic olistoliths and blocks in the Upper Triassic turbidite-olistostrome unit of the Karakaya Complex. The metamorphism was related to the Variscan orogeny. The oldest rocks of the unmetamorphosed olistoliths and blocks are upper Silurian pelagic radiolarian-bearing limestones (Kozur and Kaya in prep.). The pre-Variscan development cannot be reconstructed in detail.

IZMIR-ANKARA BELT

The latest Cretaceous to Paleocene flysch of the Izmir-Ankara-Erzincan Ophiolitic Belt (continuation of the Vardar Zone) contain some olistoliths, in the Bornova Flysch Zone also large blocks of Upper Silurian and Lower Devonian rocks. They are best dated from the Kalecik area in northeastern Karaburun Peninsula (Kozur 1998). There, Upper Silurian pelagic nautiloid limestones and micritic radiolarian limestones, crinoidal slope limestones and coral-rich reef limestones of Ludlow-Lower Devonian age are known (Kalecik Limestone). The Upper Silurian part is well dated by conodonts, mainly *Dapsilodus obliquicostatus* (Branson et Mehl), *Oulodus elegans detorta* (Walliser) and *Panderodus* spp. It contains low-temperature hydrothermal mercury ores. As post-Lower Devonian limestones of the same area never contain hydrothermal mercury ores, the hydrothermal activity is probably related to the Caledonian orogeny.

TAURIDE-ANATOLIDE COMPOSITE TERRANE AND SOUTHEAST ANATOLIAN AUTOCHTHON

Early Paleozoic rocks are widely distributed south of the Izmir-Ankara-Erzincan Ophiolitic Belt, within the Tauride-Anatolide Composite Terrane. They occur in the Taurides.

in the Alanya and Antalya nappes of the southern Tethyan branch, and in SE Turkey (SE Anatolia) on the margin of the Arabian Platform (Southeast Anatolian Autochthon). The Taurides consist of the Geyik Dağı Autochthon, tectonically overlain in the western Taurides by the Lycian nappes, and in the central Taurides by the Aladağ, Kütahya-Bolkardağ and Bozkır units. The highest units (Lycian nappes and Bozkır Unit) were originally situated in a northernmost position, adjacent to the Izmir-Ankara-Erzincan Ophiolitic Belt. In a tectonic position between the Bolkardağ Unit and the Bozkır Unit lies the Karaburun Unit of Karaburun Peninsula and Chios.

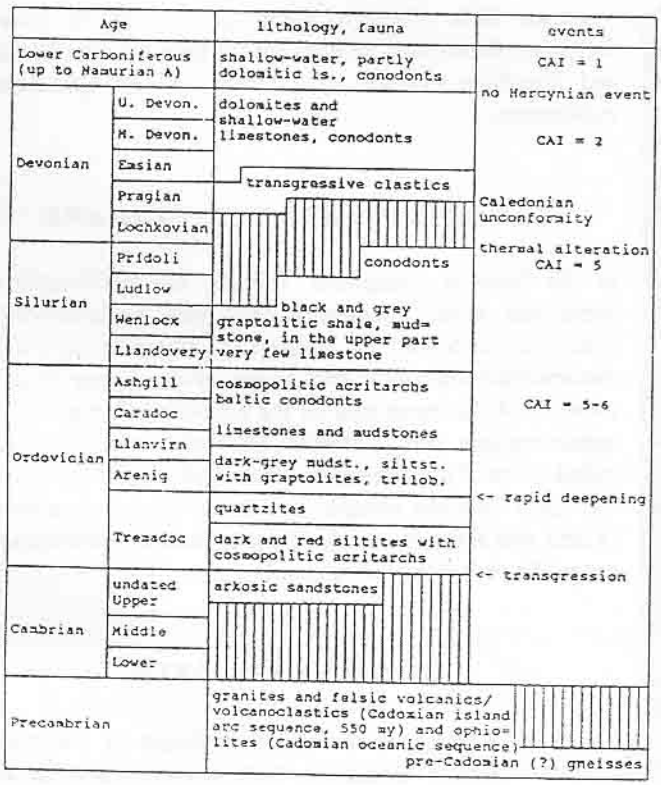

Fig. 3. Paleozoic succession in the Zonguldak Terrane (without Çamdağ Zone).

In the northern part of the Tauride-Anatolide Composite Terrane (Karaburun Unit and Kütahya-Bolkardağ Unit), remnants of a large Caledonian ocean (Karaburun-Bolkardağ Ocean) were discovered (Kozur 1997a, 1997b, 1998; Göncüoğlu and Kozur in prep.). This ocean separated the peri-Gondwanan shelf of the southern Tauride-Anatolide Composite Terrane with Ordovician cold-water fossil associations (see below) from an Ordovician-Silurian shelf area with predominantly Baltoscandian faunal elements (best known from the Istanbul Terrane s.s., but in blocks and olistoliths also known from the Sakarya Composite Terrane and the Izmir-Ankara-Erzincan Ophiolitic Belt (see above).

Previously, these beds were either included in the "Scythian-Anisian Karaeis Fm." of the Karaburun Unit (Erdogan *et al.* 1995) or regarded as a Variscan complex in the Kütahya-Bolkardağ Zone (Özcan *et al.* 1990). In the Karaburun Unit (Fig. 4) the Early Paleozoic complex consists of more than 2000 m of very low-grade metamorphic pre-Silurian siliciclastic deposits, overlain by a Silurian oceanic sequence with shales, lydites and basic volcanics. The Upper Silurian to lower Pragian rocks consist of siliciclastic turbidites with distal turbiditic lydites and olistostromes. The contemporaneous northern carbonate platform is represented by the Kalecik Limestone (see above). In the Bolkardağ Unit an identical Silurian to Lower Devonian part of the oceanic sequence, and a contemporaneous carbonate platform (Bozdağ Limestone) are known. The Upper Silurian to lower Pragian turbidite-olistostrome unit contains many felsic and intermediate volcanics (?subduction-related). The Bozdağ Limestone contains low-temperature hydrothermal mercury ores, like the Kalecik Limestone of the Bornova Flysch Zone. By the Caledonian time subduction, the Bolkardağ Unit was attached to the peri-Gondwana shelf, and the Devonian to Permian succession is characterized by shallow-water, largely carbonatic shelf sediments with sedimentary gaps. In the Karaburun Zone, a Variscan oceanic complex is known with closure in the latest Viséan. However, this Variscan complex may have been attached by Alpine movements.

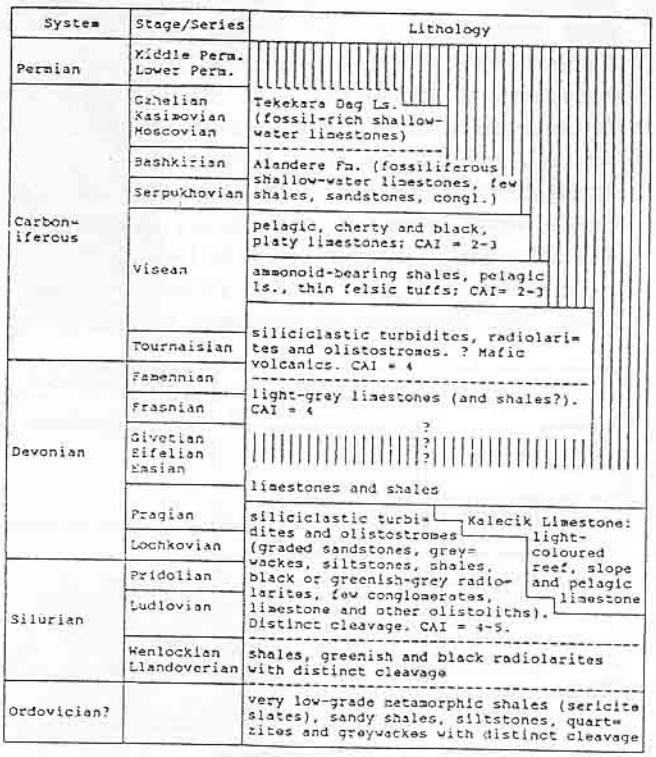

Fig. 4. Paleozoic of the Karaburun peninsula: Karaburun Zone and Bornova Flysch Zone (only Kalecik Limestone).

North of the Caledonian accreted part of the peri-Gondwana shelf, an ocean remained open or new Variscan oceanic basins opened on the adjacent shelves (NW-Anatolian Ocean). In these areas pelagic Upper Devonian is followed by uppermost Devonian and Lower Carboniferous turbidites and olistostromes, often with felsic and intermediate volcanics. These Variscan units are known from the Karaburun Unit, where the Variscan flysch and transition series (with felsic tuffs) to the overlying Serpukhovian-Bashkirian shallow-water carbonates and clastics were formerly assigned also to the "Scythian-Anisian Karaeis Fm." as the Caledonian complex (Erdogan

et al. 1995; for age revision see Kozur 1997a, 1997b), from the Tavas Nappe of the Lycian nappes (Lower Carboniferous lydites, shales, turbidites and olistostromes, formerly assigned to the Permian, Kozur *et al.* in press), Çataloturan Nappe of the Aladağ (Nohutluk Fm.: Lower Carboniferous turbidites, lydites, cherty limestones, felsic to intermediate tuffs, changing, as in the Karaburun Unit, in the Serpukhovian-Bashkirian to shallow-water carbonates and clastics, Tekeli *et al.* 1984), and at the northern margin of the Variscan ocean the Culm flysch of the Istanbul Zone s.s.

A transitional series between the Caledonian-time Karaburun-Bolkardağ Ocean to the southwards adjacent peri-Gondwana shelf is known from the eastern Taurides, in the Saimbeyli-Tufanbeyli area. There, the Upper Cambrian to Arenig Seydişehir Formation (shales) is slightly metamorphosed (Göncüoğlu and Kozur in press) indicated also by a very high conodont alteration index (CAI = 7). Thus, the Sardian movements have caused in this area both a post-Arenig unconformity as in the entire southern part of the Taurides (peri-Gondwana shelf), and a distinct thermal alteration. This thermal alteration is contemporaneous with a thermal event in the Alps (von Raumer, lecture on the International Geological Conference: Pre-Variscan Terrane analysis of "Gondwanan Europe", Dresden 1998). The Seydişehir Formation is overlain unconformably by a coarse, lower Silurian quartz conglomerate, followed by cross-laminated sandstones and violet-gray, silty shales that are overlain by black graptolite shale with some radiolarites in the lower part. Graptolites indicate a middle and late Llandovery age. The overlying nodular nautiloid limestone yielded at its base conodonts of the *P. amorphognathoides* Zone (upper Llandovery to basal Wenlock), and at its top conodonts of the *O. bohemica* Zone (upper Wenlock). These conodonts are accompanied by paleopsychrospheric deep water ostracods that indicate that this sequence was deposited at the margin of an ocean with cold bottom-water currents (Göncüoğlu and Kozur in press). The deep water conditions continued in the Upper Silurian with black shales, dark siltstones and thin-bedded limestone. All Silurian conodonts have CAI = 5. As the Upper Devonian and younger conodonts from the same area are thermally unaltered, a distinct Caledonian-time thermal alteration is present. The thermal alteration in connection with the Caledonian-time orogeny was as strong as in the Karaburun and Bolkardağ units. On the other hand, the Cambrian and Ordovician has the typical peri-Gondwana sequence with Lower Cambrian sandstones (Feke Formation), upper Lower to Middle Cambrian carbonates (Çaltepe Formation) with typical Middle Cambrian reddish nodular limestone, the deep-water siltstones and shales with very subordinate thin limestone intercalations of the Seydişehir Formation, and the post-Arenig long gap before the deposition of the Silurian. However, this sequence became twice metamorphosed during the post-Arenig Sardic movements (CAI = 7 up to the Arenig) and during the Caledonian orogeny (see above).

The Geyik Dagi Autochthon belongs to the peri-Gondwana shelf and has a very similar development throughout the Taurides, and a similar lithologic succession is also present in SE Turkey. The low-grade metamorphic Infra-Cambrian of the Taurides (Emirgazi Fm. and equivalents), of SE Turkey (Meryemuşagi Fm.) and of the lower Mahmutlar Nappe (Alanya nappes) consists of shallow-water siliciclastics, with stromatolitic and cherty limestones in the middle part. In the lower and middle part mafic to intermediate volcanics and tuffs are often present. The slight metamorphic overprint and the discordance against the overlaying Lower Cambrian indicates youngest Panafrican movements in the entire area. The Cambrian begins with unmetamorphic Lower Cambrian quartzites. They are overlain in ascending order by dolomites, black and light-gray limestones, and red nodular limestones (Çaltepe Fm.). The Lower-Middle Cambrian boundary lies within these carbonates. In the Sultandağ, the lower part of the Çaltepe Fm. contains numerous Lower Cambrian archaeocyathids discovered during an excursion. The nodular limestone indicates a deepening that begins generally later towards the SE. Further deepening is indicated by the deposition of the upper Middle Cambrian to Arenig fine-grained siliciclastic rocks (Seydişehir Fm.). In the upper Arenig a shallowing occur and limestone intercalations appear. The Seydişehir Fm. is also known from the Antalya nappes. After a long Middle Ordovician gap in few places of the Taurides and in SE Turkey, upper Caradoc to Ashgill clastics were deposited. The Ordovician acritarchs of the Taurides show clear peri-Gondwana cold-water character (*Stelliferidium trifidum*, *Vavrdovella*, *Coryphidium elegans*, C. *bohemicum*, *Arbusculidium filamentosum*, *Arkonia*, *Aureotesta clathrata*, *Striatotheca principalis* parva (Dean and Martin 1992; Martin 1996). Trilobites consist both of European peri-Gondwana species and of Asian species; in the Arenig trilobites and conodonts with Baltic affinities are also present. In SE Turkey, situated on the same peri-Gondwana shelf, the faunistic connections are different. Connections to the peri-Gondwana cold-water associations are mainly indicated by the acritarch *Vavrdovella-Coryphidium* group. Tremadoc trilobites indicate affinities to warm-temperate and warm-water faunas of Iran, Afghanistan, China and Australia (Dean and Martin 1992). Caradoc trilobites have distinct peri-Gondwana affinities, whereas Ashgill trilobites have again Asian and Baltic affinities.

The irregularly distributed Silurian of the Geyik Dagi Autochthonous and of the Antalya nappes is everywhere discordant on mainly Lower Ordovician beds. It begins with coarse clastics followed by graptolitic shales and nautiloid limestone, indicating a deepening. Some volcanic activities are also known. A general uplift can be observed in the Upper Silurian and Lower Devonian (connected with southward-directed subduction of the big Caledonian Karaburun-Bolkardağ Ocean), causing shallowing upwards sequences and an important unconformity close to the Silurian-Devonian boundary. Shallow water, mainly carbonatic Devonian shelf deposits lie unconformably on Silurian. In SE Turkey the Middle and (?) Upper Devonian dolomites contain evaporites.

The Upper Silurian-Lower Devonian uplift is related to the subduction and closure of the large Karaburun ocean that separated the peri-Gondwana Tauride shelf (with

Ordovician peri-Gondwana cold-water faunas) from the Istanbul and Zonguldak Terranes (with faunistic relations to Baltica and Siberia).

CONCLUSIONS

(1) In the northernmost unit of Turkey, the Zonguldak Terrane of the Middle Pontides, there was a Caledonian Arenig to uppermost Silurian deep water trough in continuation with the Tornquist Sea. After the closing of this trough, this area was attached to the East-European Platform and Emsian to lower Namurian shallow-water shelf carbonates were deposited. The closure caused thermal alteration and an angular unconformity between Silurian rocks and Emsian (or upper Pragian) transgressive clastics.

(2) South of this area, there was an Ordovician to Silurian shelf (NW-Anatolian shelf) that was not part of the peri-Gondwana shelf. The Istanbul Zone s.s., the Sakarya Composite Terrane and Izmir-Ankara-Erzincan Ophiolitic Belt belonged to this shelf. The Ordovician fossils have close connections to Baltica and the Siberian Platform and few connections to the peri-Gondwana shelf. The NW-Anatolian shelf was broken up during the Late Silurian to Emsian interval, and a Variscan ocean (NW-Anatolian Ocean) developed that closed in the Late Viséan to Bashkirian interval.

(3) South of the NW-Anatolian shelf, in the northern part of the Tauride-Anatolide Composite Terrane a Caledonian-time ocean (Karaburun-Bolkardağ Ocean) was present that is characterized by a very thick siliciclastic Ordovician sequence followed by a Llandovery-Wenlock oceanic sequence of shales, radiolarites and basic volcanics, overlain by an Upper Silurian to Pragian siliciclastic turbidite-olistostrome sequence. This accretionary complex was attached to the Tauride peri-Gondwana shelf and became part of the southern shelf of the Variscan NW-Anatolian Ocean.

(4) The Tauride shelf south of the Caledonian Karaburun-Bolkardağ Ocean has a typical peri-Gondwana sequence. The Cambro-Ordovician sequence is identical with that of Sardinia, and has Ordovician peri-Gondwana cold-water fossil associations.

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