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Autochthonous Upper Permian (Midian) Carbonates in the Western Sakarya Composite Terrane, Geyve Area, Turkey: Preliminary Data

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Abstract: Permian limestones occur widely within the clastic units of the "Karakaya Complex" and are interpreted as allochthonous bodies or olistoliths. In the Kadirler area to the south of Geyve, however, Upper Permian (Midian) quartz sandstones and carbonates with a rich foraminifer fauna disconformably overlie a crystalline basement complex. This basement complex comprises metaclastic rocks, recrystallised limestones, metacherts, and metadiabases, and is intruded by granodiorites. The overlying basal conglomerates and quartzitic sandstones are dominated by pebbles from the basement complex and are followed upward by medium- to thick-bedded dolomites, dolomitic limestones and limestones.

The foraminiferal assemblage with *Neoschwagerina haydeni* Dutkevitch and Khabakov, *Neoschwagerina* ex. gr. *ventricosa* Skinner, *Charliella rossae* Altıner and Özkan-Altıner, *Hemigordiopsis renzi* Reichel, *Yabeina* sp., *Pseudokahlerina* sp. and *Kahlerina* sp. in these carbonates is indicative of deposition in a shelf-lagoon during the Midian stage of the Late Permian.

This new finding constitutes further support for models that suggest a composite character for the Sakarya Terrane, and that the "Karakaya basin" in NW Anatolia opened above a Variscan-consolidated crustal basement and its Permian platform, whence the limestone olistoliths of the "Karakaya Complex" were mainly derived. Moreover, the Midian transgression and the foraminiferal assemblage in the studied successions are typical features of the northern Tauride-Anatolide Platform, indicating that the Sakarya Composite Terrane was attached to the latter prior to the opening of the İzmir-Ankara branch of Neotethys.

Key Words: Karakaya Complex, basement, autochthon, limestone, Upper Permian

Sakarya Kompozit Birliği Batısında (Geyve, Türkiye) Otokton Üst Permiyen (Midiyen) Karbonatları: Ön Bulgular

Özet: Permiyen yaşlı kireçtaşları "Karakaya Kompleksi"nin kırıntılı birimleri içinde yaygın olarak gözlenirler ve allokton kütleler veya olistolitler olarak yorumlanırlar. Ancak, Geyve'nin güneyinde, Kadirler yöresinde foraminiferce zengin kumtaşları ve kireçtaşları metamorfik bir temel üzerinde uyumsuz olarak yer almaktadır. Metamorfik temel; metakırıntılı kayalar, rekristalize kireçtaşları, metaçörtler ve metadiyabazlardan oluşur ve bir granodiyorit kütlesi tarafından kesilmiştir. Bu temel üzerinde yer alan taban konglomerası ve kuvarsitik kumtaşları metamorfik temelden türeme çakıllar içerir ve üste doğru orta-kalın tabakalı dolomitler, dolomitik kireçtaşları ve kireçtaşlarına geçişlidir.

Karbonat kayalarının kapsadığı foraminifer topluluğu (*Neoschwagerina haydeni* Dutkevitch and Khabakov, *Neoschwagerina* ex. gr. *ventricosa* Skinner, *Charliella rossae* Altıner and Özkan-Altıner, *Hemigordiopsis renzi* Reichel, *Yabeina* sp., *Pseudokahlerina* sp. ve *Kahlerina* sp.), bu birimin Midiyen sırasında sığ denizel bir ortamda (şelf lagünü) çökeldiğini gösterir.

Bu bulgu, "Sakarya Tektonik Birliğinin" kompozit nitelikte olduğu, Karakaya baseni'nin Permiyen platform karbonatları ile örtülü bir Varisken kıtasal kabuk parçası üzerinde açıldığı ve içinde yer alan kireçtaşı olistolitlerinin bu platformdan kaynaklandığı hususundaki görüşleri desteklemektedir. İncelenen alandaki belirgin Midiyen transgresyonu ve foraminifer topluluğu Torosların kuzey kesimi ile özdeş nitelikte olup, Sakarya ve Torid-Anatolid tektonik birliklerinin Neotetis'in İzmir-Ankara kolu açılana değin bitişik olduklarına işaret etmektedir.

Anahtar Sözcükler: Karakaya Kompleksi, otokton, temel, kireçtaşı, Üst Permiyen

Introduction

One of the most debated issues concerning the geology of NW Turkey is the geological evolution of the Karakaya Complex in NW Anatolia. The term “Karakaya” was initially introduced by Bingöl (1968) as the “Karakaya Series”, for a slightly metamorphic succession at Karakaya Hill to the south of Beyobası Village in the Edremit area, NW Anatolia. Since then, the name has been applied by different authors to a wide range of rock units in different parts of northwestern and northern Anatolia (Figure 1a). Tekeli (1981) proposed that this partly metamorphic and extremely tectonised assemblage represents the remnants of the Late Palaeozoic–Early Mesozoic Palaeotethys of Şengör (1979) (for a brief review see Okay *et al.* 1996; Okay & Göncüoğlu 2002).

The controversy regarding the overall geodynamic evolution also includes the crystalline “basement rocks” of the Karakaya Complex, their palaeogeographic location, age and contact relations with the Permo–Triassic non-to-slightly metamorphic sedimentary and volcanic rocks. Tekeli (1981)’s original suggestion was that the “metamorphics at the base” were “coeval with the Karakaya mélange and, hence, of Late Palaeozoic–Early Mesozoic age”. With some differences in the timing of the events, Şengör *et al.* (1984), Göncüoğlu *et al.* (1987), Okay *et al.* (1991) and, Yılmaz *et al.* (1995) have noted that the basement rocks are characterised by a Variscan-consolidated crystalline complex (Sakarya basement) and its Upper Palaeozoic carbonate cover. The latter represents the northern margin of the Gondwanan Tauride-Anatolide unit, upon which the Triassic Karakaya clastic rocks formed in a marginal basin, above the southward-subducting Palaeotethyan oceanic lithosphere (Figure 2a). Okay *et al.* (1996) and Leven & Okay (1996) proposed a completely different scenario, in which the Sakarya basement was attached to the Laurasian margin next to the İstanbul Unit. All the Triassic Karakaya units (Nilüfer: Early–Middle Triassic fore-arc, Çal: island arc or mature seamount with Permo–Triassic carbonate platform, Hodul and Orhanlar: Middle–Late Triassic accretionary complexes, Denizgören: Triassic ophiolites) were formed during the closure of the Palaeotethys. The Permian carbonates (including the Ezine Unit) were derived from a Tauride-Anatolide-type continental sliver, which was rifted from the latter by back-arc spreading (Figure 2b) resulting in the opening of the İzmir-Ankara branch of Neotethys.

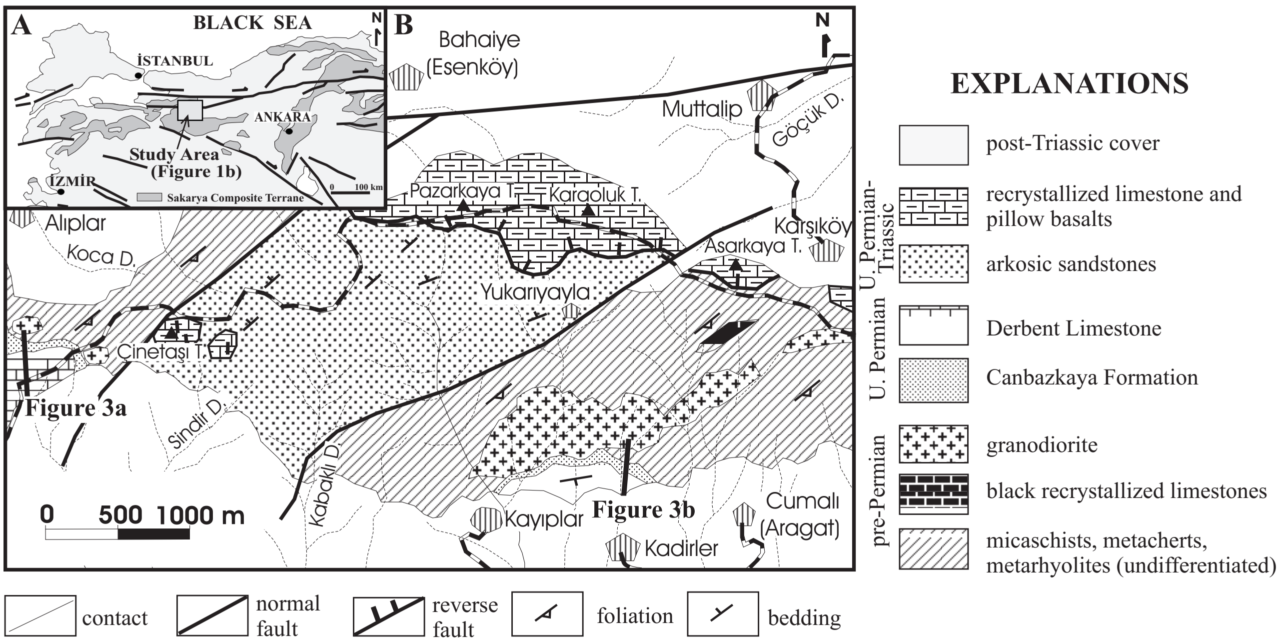

Figure 1. (a) Distribution of the Sakarya Composite Terrane in NW Anatolia and (b) the geological map of the study area with and the locations of the studied sections.

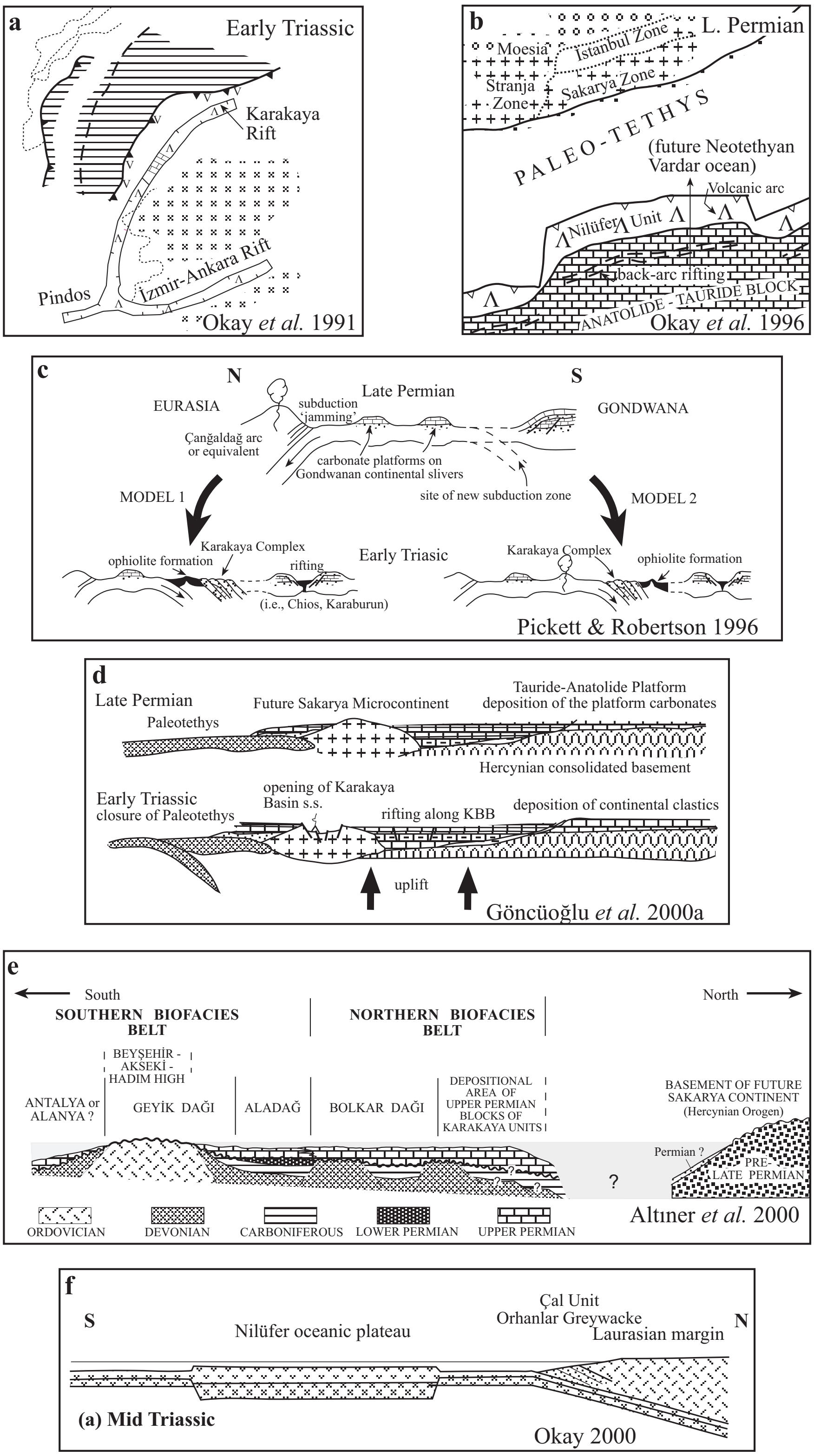

Figure 2. Cartoons of previously suggested geodynamic models for the evolution of the Karakaya units. For the details concerning the cartoons, see text.

Pickett & Robertson (1996)'s model involves the closure of the Palaeotethys by south and northward subduction (Figure 2c). They considered the Karakaya Complex as a Palaeotethyan accretionary complex with Triassic ophiolites (Denizgören Ophiolite), seamounts (Nilüfer Unit), trench sequences (Ortaoba Unit) abyssal-plain deposits (Kalabak Unit) and Permian carbonate platforms on Gondwanan continental slivers with intra-platform rifts (Çal Unit).

Göncüoğlu *et al.* (1997, 2000c) pointed out that the pre-Liassic "Karakaya Complex" within the Alpine Sakarya unit in northern Turkey actually includes remnants of Variscan basement, a Triassic rift-complex formed above its Permian cover, as well as thrust slices of the Palaeotethyan orogenic complex (Figure 2d). It was also involved in the Alpine orogenic cycle by formation of a Liassic–Lower Cretaceous carbonate platform and affected by Alpine deformation due to the closure of Neotethyan oceanic branches (Intra-Pontide and İzmir-Ankara oceans) at the end of Cretaceous; hence it should be considered a "composite terrane" (Sakarya Composite Terrane, Göncüoğlu *et al.* 1997).

Altıner *et al.* (2000), in their Late Permian reconstruction, adopted a part of Okay *et al.* (1996)'s model and separated the Tauride-Anatolide carbonate platform from the Sakarya basement by a suspect basin (Figure 2e). However, they confirmed the rift character of the Karakaya basin (e.g., Altıner & Koçyiğit 1993) and the derivation of Permian limestone blocks from the northern part of the Tauride-Anatolide platform (Northern Facies Belt, Altıner *et al.* 2000). Okay (2000) proposed a new model suggesting that Palaeotethys was consumed by northward subduction beneath the Laurasian margin, giving way to the formation of Middle–Late Triassic accretionary complexes (Çal and Orhanlar units). In this model, the Nilüfer Unit represents a huge oceanic plateau (Figure 2f), and the Hodul Unit formed as a clastic wedge above the subduction-accretionary complexes and was sourced from the Eurasian Variscan basement. This model provides no definitive answer regarding the source area of the Permian carbonate blocks, but does not exclude their derivation from the north (e.g., northern margin of eastern Palaeotethys in Afghanistan, etc.).

As clearly seen in this brief review of different hypotheses, one of the critical questions regarding the geological evolution is whether there is "evidence for a Gondwana continental basement, which must have underlain the Permo–Carboniferous limestones in the Sakarya Zone" as clearly formulated by Okay (2000).

In this study, we will first briefly summarise the previous data on the basement rocks of the Karakaya unit and their relations with Permian limestones. Field and palaeontological data from the Geyve area will then be presented and the evolution of the "Karakaya Complex" discussed.

Review of Previous Interpretations

According to the original description of Bingöl (1968), the Karakaya unit includes in its type locality quartzites, feldspathic sandstone, metaspilite and metamorphosed spilitic basalts that disconformably overlie the crystalline rocks of the "Kazdag Massif" on the Biga Peninsula. The name "Karakaya Formation" was applied by Bingöl *et al.* (1973) to include the "detrital unit with Permian olistoliths" and the "spilites with Permian olistoliths".

On the Yenişehir-Geyve ridge, Saner (1977) described a metamorphic basement with mica schists, which shows gradational contacts to the overlying metasandstones (Canbazkaya Formation). They are followed by thick-bedded sandstones and grade into recrystallised limestones (Derbent Limestone). The transitional zone is characterised by an alternation of fossiliferous marls and limestones. The fossil list given for this transition zone, as well as for the overlying limestones, suggests an interval covering Murgabian–Midian (re-evaluation of the present authors) stages of the Late Permian.

Based on their field observations in Bergama-Kozak area, Akyürek & Soysal (1983) suggested the name "Halilağa Group" for a part of the "Karakaya Formation", which is tectonically underlain by the Upper Permian clastic rocks and carbonates of the Çamoba Formation. It has no stratigraphic contacts with the Karakaya Formation and its equivalents. However, blocks of the Çamoba-type limestones are abundant in the slightly metamorphic clastic rocks of the Lower Triassic Kınık Formation of the Halilağa Group.

The basement of the Karakaya unit in the same area was assigned by Kaya *et al.* (1986) to the "low grade greenschist facies metamorphic unit" or "Madradağ Formation", upon which the uppermost Middle to Upper Triassic Dışkaya Formation rests unconformably. The Dışkaya Formation then had been attributed to the "Hodul Unit" and the Madradağ Formation to the "Nilüfer Unit" by Okay *et al.* (1991).

In a series of studies, Okay and his co-workers (Okay *et al.* 1991, 1996; Okay & Siyako 1993; Okay & Mostler 1994; Leven & Okay 1996) proposed a new structural classification for the main tectono-stratigraphic units in NW Anatolia (Gelibolu, Ezine, Ayvacık-Karabiga and Sakarya zones). Of these, only the Ezine and Sakarya zones are characterised by the presence of Karakaya-type Upper Palaeozoic–Lower Mesozoic rocks and their pre-Karakaya basement.

In the Karadağ Unit of the Ezine Zone, the pre-Karakaya basement is characterised by slightly metamorphic Permo–Carboniferous clastic rocks that grade into massive recrystallised limestones of Late Permian age. They are followed by syn-orogenic clastic rocks of latest Permian to Early Triassic age and finally tectonically overlain by the Palaeotethyan Denizgören Ophiolite (Okay *et al.* 1991; later shown to be emplaced in Aptian, Okay *et al.* 1996). The Çamlıca mica schist unit, another pre-Karakaya tectonic unit within this zone, is represented by medium-grade metaclastic rocks with few eclogitic metabasite and marble interlayers.

In the pre–Jurassic basement of the Sakarya Zone, Okay and his co-workers proposed the presence of three main tectono-stratigraphic units that were juxtaposed during the Late Triassic: (a) the pre-Karakaya units including the Kalabak Formation and the Çamlık Metagranodiorite; (b) the Kazdağ Group; and (c) the Karakaya Complex. The Kalabak Formation consists of phyllites, quartzofeldspathic schists and a-few-meters-thick scarce marble and green metabasite horizons (Okay *et al.* 1991). The phyllites were intruded by the Çamlık Metagranodiorite, which yielded a mean single zircon Pb/Pb age of 399 ± 13 Ma. The type locality of the Çamlık Metagranodiorite in the vicinity of Çamlık Village (N of Havran) is one of the few localities where there is a consensus concerning a disconformable stratigraphic contact with the pre-Karakaya units and the overlying "Karakaya Complex" (Hodul Unit, Okay *et al.* 1991; Çal Unit, Pickett & Robertson 1996). Further areas with disconformable contacts between the pre-Karakaya basement and Karakaya-type Upper Triassic sediments (units A, B and E) are given in Altıner *et al.* (2000).

To summarise, apart from the studies of Saner (1977, 1978), Göncüoğlu *et al.* (1987) and Y. Yılmaz and his co-workers (e.g., Yılmaz 1990; Yılmaz *et al.* 1995; Genç & Yılmaz 1995), there is almost a consensus concerning the allochthonous character of the Permian limestones within the Karakaya unit. In the study of Saner (1977), the Upper Permian clastic rocks and the limestones are mentioned to be transitional with the underlying crystalline rocks. Göncüoğlu *et al.* (1987) reported for the first time Lower Permian limestones, disconformably overlying the crystalline basement, which in turn are overlain by Karakaya-type clastic rocks. In several studies, Y. Yılmaz and his co-workers briefly noticed that the pre–Carboniferous crystalline basement of the Sakarya unit is disconformably overlain by Carboniferous–Permian clastic rocks and limestones, which were eroded and incorporated into the Triassic assemblages (Kendirli and Abadiye formations of Genç & Yılmaz 1995) by rifting of the Sakarya basement during the Early Triassic. Unfortunately, they neither provide detailed stratigraphic sections nor palaeontological evidence to support this very critical view.

Geological Framework

The study area is located on the eastern part of the E–W-trending Yenişehir-Geyve ridge to the south of Geyve (Figure 1) in NW Anatolia. Towards the north, the ridge is bounded by the Geyve Basin, the Karamurat and Karaçay faults of the southern strand of the North Anatolian Fault Zone (Koçyiğit 1988), and the Taraklı-Orhaneli Tertiary Basin (Saner 1978) to the south. On both margins of the ridge, an Upper Cretaceous–Lower Tertiary succession (Gölpazarı Group) unconformably overlies a complex consisting of metamorphic rocks and granitoids, Permian limestones, Karakaya-type sedimentary and volcano-sedimentary successions and their Liassic cover (Saner 1977). The Jurassic limestones were not encountered in the study area, and the Campanian–Maastrichtian pelagic limestones of the Vezirhan Formation of the Gölpazarı Group are in direct contact with the pre–Liassic rock units (Figure 1b).

The rock units in this area belong to the Sakarya Composite Terrane (Figure 1a) of Göncüoğlu *et al.* (1997). The pre-Liassic rocks encountered in the study area are informally grouped as the pre–Permian crystalline basement, the Canbazkaya and Derbent Limestone formations of Permian age, and the tectonic packages of the Karakaya units, including the informal "arkosic sandstone unit" and the "pillow basalt-limestone association" (Figure 3a, b).

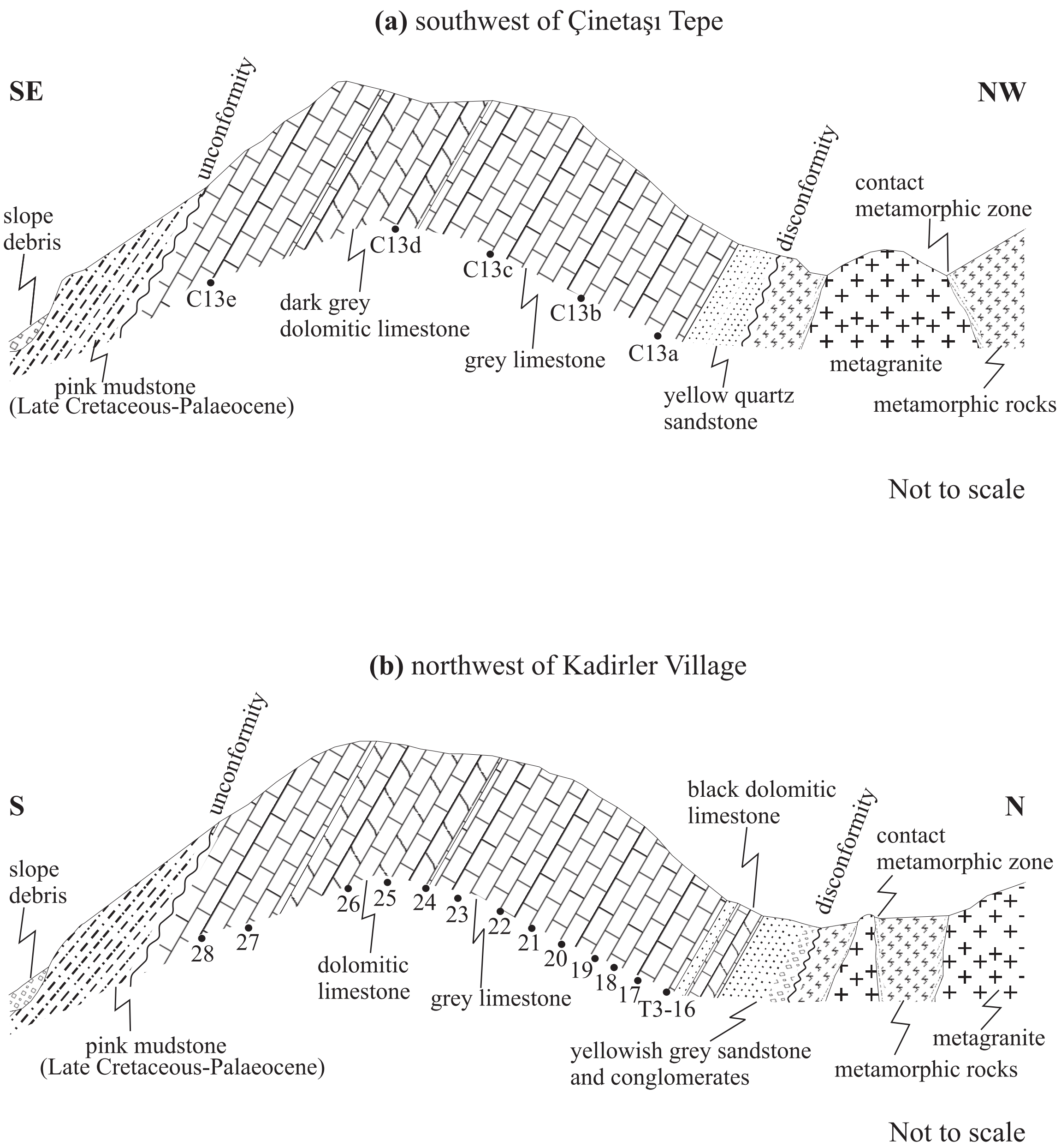

Figure 3. Measured cross-sections of Upper Permian successions, in the SW of Çinetaşı tepe (a) and NW of Kadirler village (b).

Pre-Permian Crystalline Basement

The pre-Permian crystalline basement crops out to the SE and NW of the study area (Figure 1b) and consists of metamorphic rocks, recrystallised limestones and intrusive felsic igneous rocks. The unit is highly tectonised, so that no continuous successions can be observed. Tectonic slices with relatively preserved internal parts include metasedimentary successions with slates, phyllites, metasandstones, black quartz schists, muscovite-biotite schists and black limestones, alternating with felsic metatuffs and metarhyolites. The slates and phyllites are grey to brown and are characterised by very fine-grained muscovite + albite + graphite as the main metamorphic paragenesis. Metasandstones are characterised by clasts of quartz and less abundant feldspar. The matrix is replaced by fine-grained sericite and biotite. Black quartz schists occur as disrupted bands up to 2 m thick, and comprise very fine-grained and strained quartz-grains and opaque minerals. They include elongated ghosts of radiolarians, indicating a radiolarian chert origin. Muscovite-biotite schists are characterised by lepidoblastic biotite and muscovite, and also completely altered porphyroblasts of chloritoid and garnet. Limestones within the basement are mainly observed along the forest track to the south of Asarkaya Tepe (Figure 1b). They are black, fine- to medium-bedded, and occur as 3–5-m-thick bands, which alternate with the surrounding metapelites and metacherts. Microscopically, these limestones are made up of fine-grained calcite and are rich in radiolarians. Petrographically, the limestone corresponds to the SFB 1 to 3 of the Wilson's (1975) Standard Facies Belts (SBF) classification, indicative of a deep shelf margin or basin margin according to Wilson's (1975) wide belts.

Metamorphosed felsic rocks within this succession are either interbedded with the metasediments or display cross-cutting relations. Both types are foliated and characterised by preserved phenocrysts of corroded quartz and feldspar, such that a rhyolitic protolith is presumed. The metamorphic succession is cut by metre-scale, weakly foliated diabase dikes. The diabase dikes comprise mainly relict clinopyroxene, plagioclase and opaque minerals. The metamorphic mineral assemblage is chlorite+albite, and there is no indication of blueschist-facies metamorphism in the study area as mentioned by MTA (1978).

SE and NW of the study area (Figures 1b & 3), granitoids with well-preserved primary contacts with the metamorphic succession are exposed. The granitoid to the N of Kadirler is the larger body and extends from Kayıplar village to Asarkaya Tepe. The granitoid body around Çinetaşı Tepe occurs as discontinuous stocks and is highly mylonitic.

Macroscopically, the granitoid is holocrystalline-porphyritic, moderately altered and medium grained. On the basis of its modal composition, it is a granodiorite with plagioclase, K-feldspar, brown biotite, pale-green hornblende and clinopyroxene as the main mafic phases. An unusual feature is the presence of pinitized cordierite, typically enclosed in biotite phenocrysts. At the contact of the granodiorite with the slates and phyllites, a variably thick contact metamorphic zone with spotted schists is present.

Metasedimentary basement rocks have already been described by various authors in NW Anatolia (e.g., Kalabak formation in Edremit and Havran, Okay *et al.* 1991; Yazılı metamorphite in the İnegöl area, Genç 1993). However, the studied metaclastic succession with bands of black chert and limestone are quite similar to the metasedimentary rocks of the Karadağ Unit in the Ezine area (authors' own observations and Okay *et al.* 1991). Regarding its stratigraphic relation with the overlying Permian rocks (Göncüoğlu *et al.* 1987), a pre-Early Permian age has been tentatively assigned to the basement rocks. A very similar rock-association (Halıcı Group) is present in the Konya area (Özcan *et al.* 1988; Göncüoğlu *et al.* 2000b). The Halıcı Group in the Konya area is Visean in age and has been interpreted as a Variscan back-arc development along the margin of the Tauride-Anatolide platform.

Permian Rocks

The Upper Permian rocks which have been studied in detail are represented by the Canbazkaya Formation and Derbent Limestone (Figure 4). The formation names were initially proposed by Saner (1977) and Eroskay (1965), respectively.

The Canbazkaya Formation disconformably rests on the crystalline rocks of the pre–Lower Permian basement. The contact relations are well exposed along the small valley to the north of Kadirler and to the southwest of Çinetaşı Tepe (Figures 1 & 3). At the former locality, the Canbazkaya Formation starts with a discontinuous yellowish-grey conglomerate. The pebbles range in size from 0.5 to 4 cm, and include moderately rounded rock fragments of mylonitic granodiorite, metarhyolite, pelitic hornfels (contact metamorphic slate), muscovite schist, metachert, as well as clasts of strained quartz, muscovite, plagioclase, tourmaline and zircon. The clayey matrix is replaced by very fine-grained sericite. This unit grades into thick-bedded to massive yellowish-grey quartzitic sandstones and quartzite. The upper part of the quartzitic sandstones is grey and carbonate-cemented. A two-m-thick band of black, medium-to-thick-bedded, sandy dolomite with undetermined algae represents the transitional zone toward the overlying Derbent Limestone (Figure 4). The sandstones of the Canbazkaya Formation do not contain any fossils.

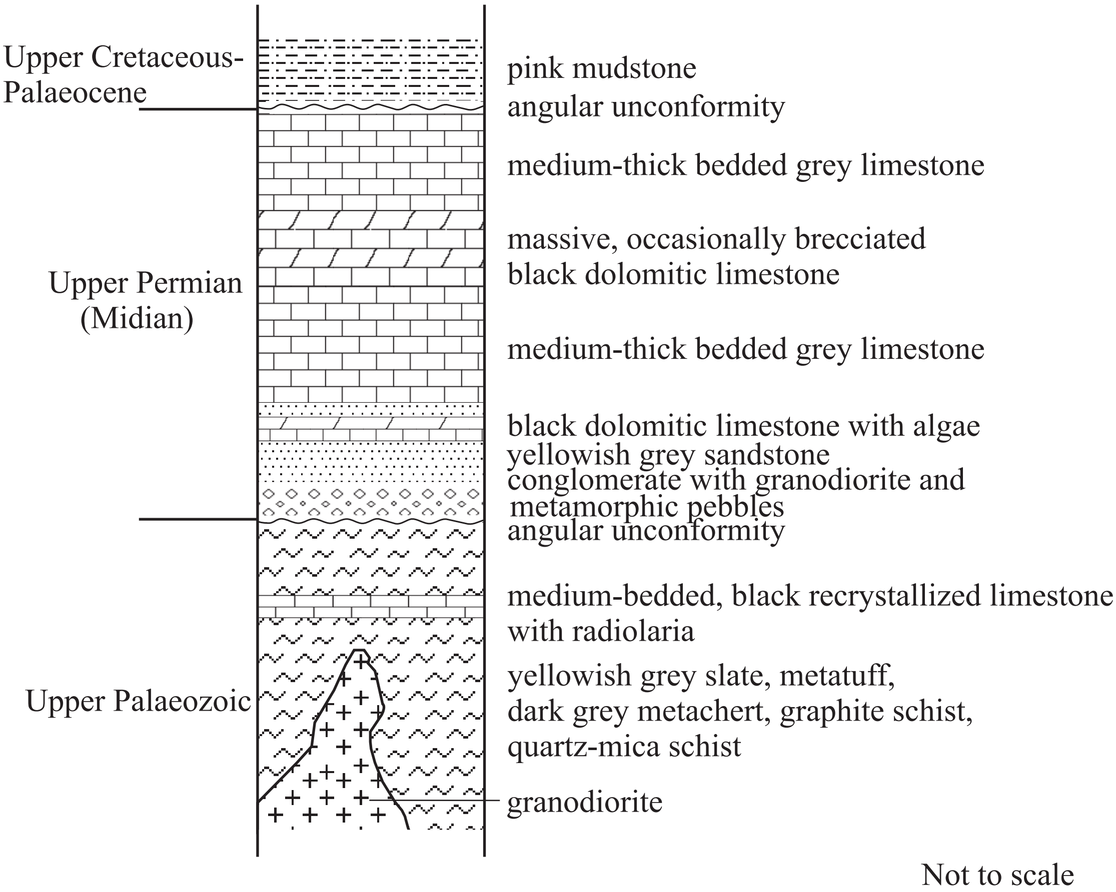

Figure 4. Generalised columnar section of the Upper Permian successions on thein Yenişehir-Geyve ridge.

The Derbent Limestone in both of the studied locations (Figures 5 & b) starts with an alternation of black sandy dolomites and carbonate-cemented quartz sandstones and grades into a 40-m-thick carbonate succession. The lower half of the succession is made up of medium- to thick-bedded grey limestones. These limestones are characterised by bioclastic grainstone and wackestone with *Hemigordius*, *Hemigordiopsis*, fusulinids and ostracods. The following eight meters include black and massive dolomites and dolomitic limestones that grade into grey, thick-bedded limestones. The dolomitic middle part is represented by bioclastic grainstone and wackestone with fusulinid and small foraminifera. The thick-bedded limestones in the upper part are bioclastic grainstone with *Hemigordius*, *Hemigordiopsis* and fusulinids. The fossil content of the Derbent Limestone is given in Figures 5a and b.

The foraminiferal assemblage covers the Murgabian and Midian stages of the Upper Permian as a whole. However, *Neoschwagerina haydeni* Dutkevitch and Khabakov, *Neoschwagerina* ex. gr. *ventricosa* Skinner, *Charliella rossae* Altıner and Özkan-Altıner, *Hemigordiopsis renzi* Reichel, *Yabeina* sp., *Pseudokahlerina* sp. and *Kahlerina* sp. are indicative of the Midian.

A similar assemblage was described by Altıner *et al.* (2000) from the Northern Taurides and ascribed to a distinct “Northern Facies Belt”. The characteristic foraminiferal taxa of the Midian stage of the Northern Biofacies Belts are as follows: *Yabeina*, *Sumatrina longissima*, *Sumatrina annae*, *Sumatrina fusiformis*, *Afghanella sumatrinaeformis*, *Neoschwagerina ventricosa*, *Kahlerina* and *Dunbarula* (Altıner *et al.* 2000).

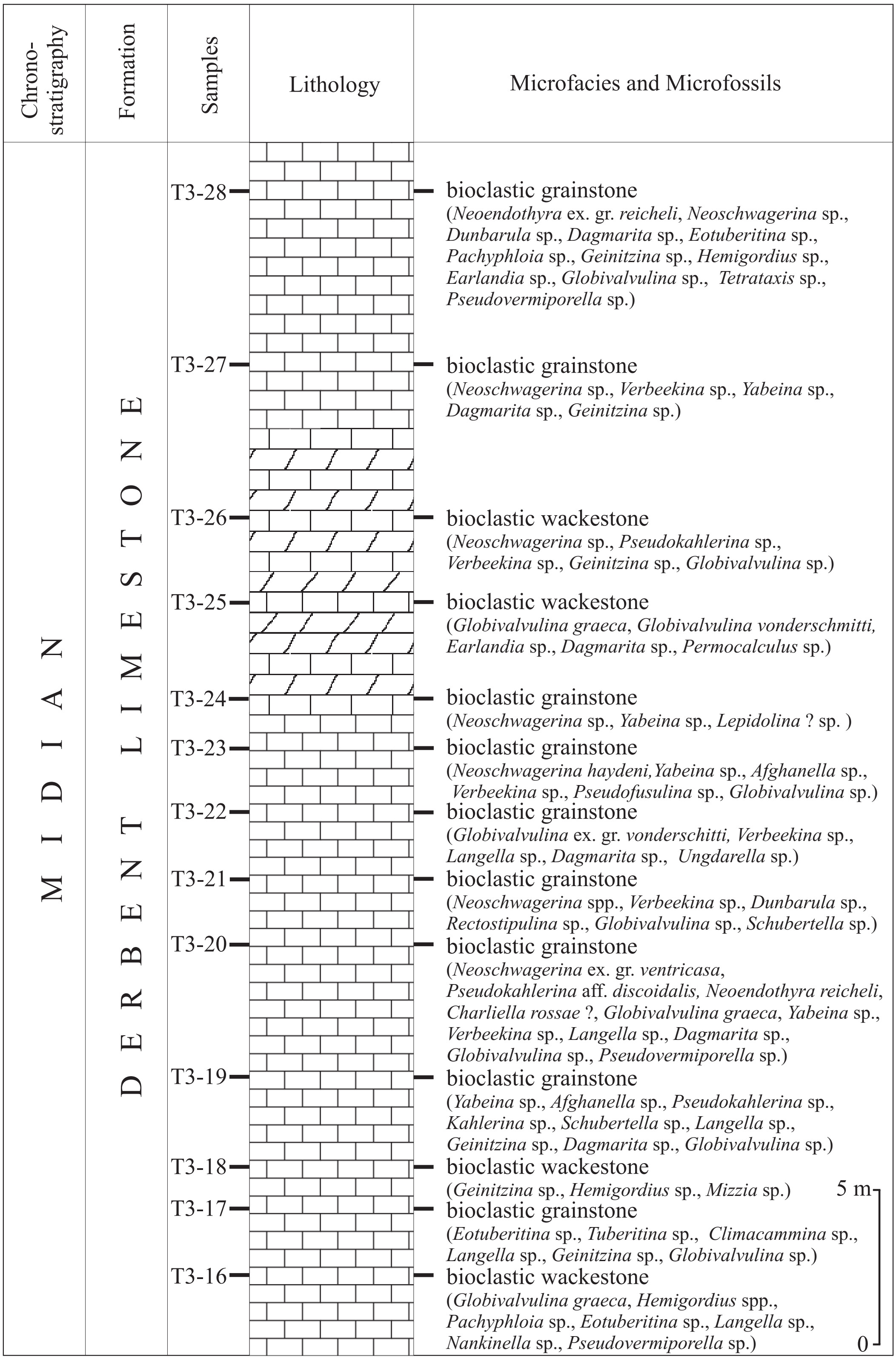

Figure 5. Petrography and fossil contents of the studied Upper Permian successions, in NW of Kadirler village and SW of Çinetaşı tepe.

The overall petrographic evaluation of the Derbent Limestone in both studied sections indicates that deposition of the carbonates corresponds to the SFB 7-8 of Wilson's (1975) SFB classification and indicative of a shelf lagoon (with open circulation), and shelf and tidal flats (with restricted circulation) of Wilson's (1975) wide belts.

The successive transition from conglomeratic facies to sandstones, sandy dolomites and limestones is indicative of transgressive deposition in a shallow-marine environment. The similarity between ages of the massive limestones mentioned in this study and the fossil content (*Dagmarita chanakchiensis* Reitlinger, *Neoendothyra reicheli* Reitlinger, *Neoschwagerina* sp., *Yabeina* sp., *Verbeekina* sp., *Afghanella* sp.) of the transitional zone between the Canbazkaya and Derbent formations reported by Saner (1977) are indicative of *in situ* deposition of the Derbent Limestones and the underlying clastic rocks of the Canbazkaya Formation. Accordingly, the possibility of interpreting the studied limestones as allochthonous blocks is excluded.

Karakaya Units

Arkosic Sandstone Unit

In the northwestern part of the study area along a NE–SW-trending zone (Figure 1b), an internally disrupted unit with predominant arkoses and arkosic sandstones crops out. The arkosic sandstones include bands and lenses of feldspathic siltstone, volcanic-volcaniclastic successions, conglomerates and very scarce bands of radiolarian cherts (Göncüoğlu *et al.* 2004). The unit is bounded toward the south by a normal fault; hence the primary relation of the unit with the pre-Permian basement or the autochthonous Permian cover is not clear. To the south of Pazarkaya and Karaoluk hills (Figure 1b), the unit is overthrust by the "pillow basalt-limestone unit". As a whole, the unit is extremely disrupted such that the internal stratigraphy and the primary relations of the more-or-less comprehensive lithological packages cannot be identified. These lithological packages include several tens-of-metres-thick debris-flow conglomerates as well as thin-bedded, grey to pink, cherty, micritic limestones associated with basaltic lava flows. This unit corresponds to the Avdancık formation of Genç *et al.* (1986) or to the Kendirli formation of Koçyiğit *et al.* (1991, in Altıner & Koçyiğit 1993). Considering the rock types and their structural relationships, this unit may correspond to the Hodul Unit of Okay *et al.* (1991).

The Pillow Basalt-Limestone Association

The pillow basalt-limestone association crops out as a separate thrust slice to the north of the study area covering the Pazarkaya, Karaoluk and Asarkaya hills, and as klippen around Çinetaşı Tepe (Figure 1b). The unit rests on the arkosic sandstone unit with a tectonic contact. The clastic rocks at the contact are extremely brecciated and are stained by Fe-oxides. The characteristic feature of this unit is the interfingering of recrystallised, white, algal-pisolitic shallow-marine limestones and pillow lavas, indicative of contemporaneous formation.

The pillow basalt-limestone association resembles the Abadiye formation of Genç *et al.* (1986), the Bahçecik formation of Koçyiğit *et al.* (1991, in Altıner & Koçyiğit 1993) and the Ortaçaltepe limestone of Göncüoğlu *et al.* (1996). Similar rock associations were considered by Okay *et al.* (1991) to be a part of the Çal Unit. A Middle Triassic age was assigned to the limestones on the basis of their foraminifera and conodont contents (e.g., Genç *et al.* 1986).

Discussion

With few exceptions (e.g., Saner 1977), Upper Permian limestones in the Karakaya Complex are considered allochthonous bodies, either derived from a completely eroded Permian carbonate cover of the pre–Permian Sakarya basement (e.g., Yılmaz *et al.* 1995), or from the Tauride-Anatolide Platform (e.g., Okay *et al.* 1991), or alternatively from the northern margin of Palaeotethys (e.g., Leven & Okay 1996). Each of these suggestions requires a different geodynamic scenario for the formation of the Karakaya Complex. Moreover, the discrepancy resulted in completely different models regarding the location of Palaeotethys. The first group of models suggests that Palaeotethys was located between the Sakarya microcontinent and the Laurasian margin, and that the Karakaya units represent remnants of a short-lived basin opened within the Permian platform of the pre-Permian Sakarya basement above the southward-subducting Palaeotethys (e.g., Bingöl *et al.* 1973; Şengör *et al.* 1984; Okay *et al.* 1991). Based on the original suggestion of Stampfli (1978), the second group of models advocates a southerly located Palaeotethys, located

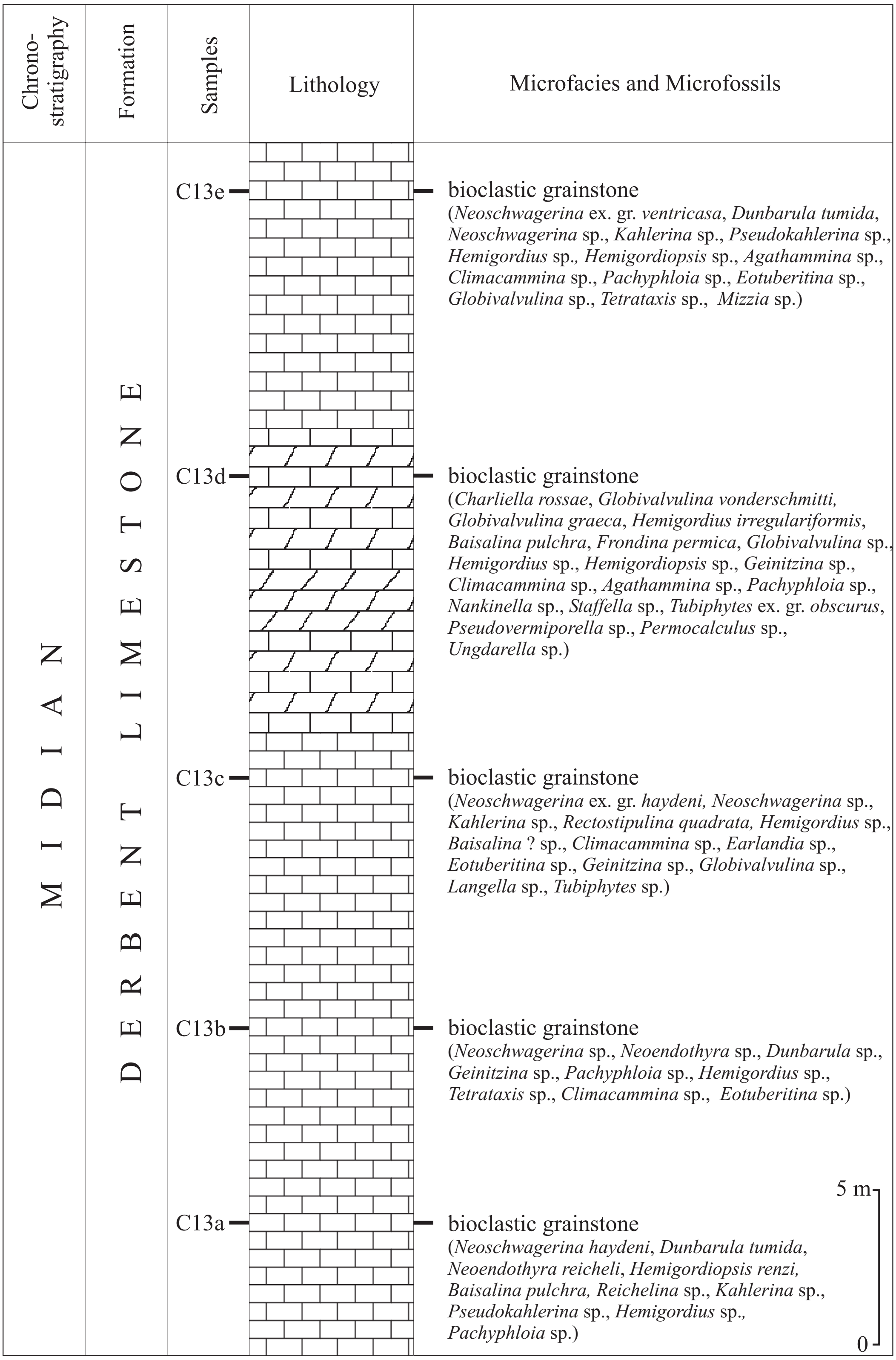

Figure 6. Petrography and fossil contents of the studied Upper Permian successions, in SW of Çinetaşı tepe.

between the Sakarya microcontinent in the north and the Perigondwanian Tauride-Anatolide Platform in the south. The Karakaya units in this model (Karakaya Complex of Tekeli 1981) represent: (a) the remnants of this Palaeotethys and were formed by its northward intraoceanic subduction (Okay *et al.* 1996; Leven & Okay 1996; Okay 2000; Stampfli 2000) or, (b) remnants of a marginal basin within the Sakarya basement (Kozur 1999), formed above the northward subducting Palaeotethys.

Our confirmation of *in situ* Upper Permian clastic rocks and carbonates disconformably overlying the pre-Permian basement in the Geyve area supports the first group of models and the presence of an Upper Permian carbonate platform above the Sakarya basement. The Upper Permian disconformity described in this study is probably related to the regional Midian transgression, a typical feature of the Tethyan realm (e.g., Leven & Okay 1996). It is frequently observed along the northern margin of the Tauride-Anatolide Platform (Northern Facies Belt of Altıner *et al.* 2000) and within the Alpine nappes (in Lycian Nappes, Graciansky 1972) which were derived from this margin. Moreover, the Midian foraminiferal assemblage in the autochthonous limestones of the study area is not only very similar to that reported from the northern Taurides (e.g., Altıner *et al.* 2000), but also to that described from the contemporaneous blocks and pebbles within various rock units of the Karakaya unit. This fact implies the following assumptions: (1) During the Late Permian, the northern Tauride-Anatolide and Sakarya units were covered by the same extensive carbonate platform and the two units were still attached. This postulation (Göncüoğlu 1989; Göncüoğlu *et al.* 2000a, c) was opposed by various authors (e.g., Altıner *et al.* 2000). The opposition was mainly based on the presupposition that Variscan events were only noted in the Sakarya unit but not in the Tauride-Anatolide platform. However, the presence of these events, including the regional Carboniferous unconformities, ocean island-type volcanic rocks and back-arc basin formations in the Kütahya-Bolkardağ Belt and the Lycian Nappes, were demonstrated by Göncüoğlu *et al.* (1997, 2000a, b, c, 2001) and Kozur *et al.* (1999). These Variscan events are in some way recognised in Altıner *et al.* (2000)'s model (Figure 2e), suggesting fault-controlled basins during the deposition of Carboniferous sediments in the northern Tauride-Anatolide platform. (2) The Upper Permian blocks within the Karakaya unit may well have been derived from this autochthonous carbonate succession. If this was the case, the Karakaya basin should have opened above the Variscan Sakarya basement, with metamorphites, granitoids and Permian carbonate cover. This interpretation may be supported by the presence of granitic pebbles and arkosic sandstones within the Çal and Hodul units of the Karakaya Complex.

The source of the Lower Permian and lowermost Upper Permian limestones may also have been the locally preserved autochthonous successions which disconformably overlie the Variscan Sakarya basement. Such an outcrop, with Lower Permian algal limestones containing *Pseudoschwagerina* sp., *Parafusulina* sp., *Staffella* sp. and *Pseudofusulina* sp., was previously reported from the western part of the present study area (Göncüoğlu *et al.* 1987). On the other hand, the source of the pre–Permian shallow-marine limestone blocks within the Karakaya units, should be sought elsewhere. Leven & Okay (1996) have shown that different blocks contain foraminiferal assemblages, indicating the presence of all the Carboniferous stages, except Tournasian, Kasimovian and Bolorian. Visean and Serpukhovian limestone blocks have mainly been encountered in the Orhanlar Greywacke, whereas blocks of Bashkirian (Okay & Mostler 1994) to Murgabian ages have been described from the Hodul and Çal units of Okay *et al.* (1991). It is important to note that the rock assemblage (Orhanlar Greywacke with Permian blocks) reported in the Bursa-Mustafakemalpaşa region (Leven & Okay 1996) does not resemble the unit in its type area, and belongs to the Hodul Unit. Similarly, we found dark grey limestone pebbles with Lower Carboniferous (Visean) foraminifers in Hodul-type feldspathic sandstones to the north of Kızılöz village (9 km W of the study area). At its type locality, the Orhanlar Greywacke only includes Lower Carboniferous (mainly Visean) carbonate blocks but no Permian olistoliths (authors' unpublished data). The depositional environment of these carbonate blocks ranges from reef to slope and basin. The clastic rocks include black radiolarian chert interlayers. The unit as a whole is quite similar to the Lower Carboniferous flysch of the Konya (Göncüoğlu *et al.* 2000b), Karaburun (Kozur 1998) and Fethiye (Tavas Nappe of the Lycian Nappes, Kozur *et al.* 1999; Göncüoğlu *et al.* 2000c) areas, all of which belong to the northern margin of the Tauride-Anatolide platform. Hence, the Orhanlar Greywacke unit in the Balya area may represent a part of the Tauride-Anatolide platform, or alternatively, a mega-block that was incorporated into the Karakaya basin during its post–Midian opening. The Carboniferous (or even older) blocks in the Hodul and Çal units may be from the same source, if no in situ pre-Permian rocks can be proven from the Sakarya basement.

Another important constraint on the autochthonous Midian shallow-marine carbonates reported in the present study pertains to the opening age of the Karakaya basin and its correlation with the Palaeotethys Ocean. With the exception of late Djulfian and Dorashamian pelagic limestones (Kozur & Kaya 1994) and Dorashamian radiolarian cherts (Kozur 1999; Göncüoğlu *et al.* 2004), all the Permian blocks found in different Karakaya units are shallow-marine limestones. Hence, there is no evidence for a pre–Late Permian rifting that resulted in the opening of the Karakaya basin. This fact stands out against a correlation of the Karakaya basin with the Palaeotethyan oceanic basins of Şengör (1979) or Stampfli (1978), both of which were assumed to have opened during the Carboniferous or even earlier.

Last but not least, the geochemical characteristics of the associated volcanic rocks of the Karakaya units do not suggest an oceanic or subduction/accretion-related tectonic setting. With the exception of typical ocean-island-type (plume-related, Yalınız & Göncüoğlu 2002) Nilüfer volcanics of unknown age, no igneous rocks with mid-ocean ridge or subduction affinity have yet been encountered in the "Karakaya Complex". In contrast, limited geochemical data (Genç 1993) on the volcanic rocks of the Çal Unit are suggestive of alkaline within-plate (rift-type) volcanism; this data stands against any interpretation for Palaeotethyan oceanic involvement.

Conclusions

1. The Variscan basement of the Sakarya Composite Terrane on the Yenişehir-Geyve ridge includes a low-grade metaclastic association with radiolarian cherts and limestones intruded by felsic and basic igneous rocks. It resembles the Visean back-arc complex with bimodal volcanism observed in the Kütahya-Bolkardağ Belt of the Tauride-Anatolide platform. This would indicate that Sakarya basement was a northern continuation of the Gondwanan Tauride-Anatolide unit prior to the opening of the Neotethyan İzmir-Ankara oceanic branch (Figure 2d).
2. The basement complex is disconformably overlain by quartzitic sandstones and carbonates of Midian age. The fossil assemblage of this succession is quite similar both to the coeval limestone olistoliths in different Karakaya units and to the autochthonous limestones in the northern Tauride-Anatolide platform (Northern Facies Belt of Altıner *et al.* 2000). The deposition of these limestones onto the Sakarya and the Taurides is ascribed to a regional Midian transgression. The blocks/detritus of Permian limestones and crystalline rocks within different Karakaya units may have been derived directly from the Sakarya basement and its Permian cover. This would support a rift-related generation of the Karakaya units except the ocean-island-type Nilüfer Unit of unknown age.
3. Shallow-marine limestone blocks of Carboniferous and Lower Permian in different Karakaya units have their autochtonous equivalents in the northern Tauride-Anatolide platform or in the nappes derived from its northern margin. In light of this, the best candidate as the source area for these blocks is the Tauride-Anatolide platform. As there is no indication for a post–Permian to pre–Jurassic collision of the Sakarya and Tauride-Anatolide terranes (as evidenced by continuous Triassic–Cretaceous deposition on the Kütahya-Bolkardağ Belt, Göncüoğlu *et al.* 2000a), their incorporation into the Karakaya units must have been accomplished by another mechanism, followed by compressional tectonics (nappe emplacement, etc). Therefore, we support the rift model and the accommodation of these blocks as gravity slides/mass flows from the rift shoulders of the Karakaya rift basin.

To conclude, all the models proposed (including the rift model supported in the present paper) have a number of uncertainties which can be solved by a detailed multidisciplinary study, including comprehensive sedimentological, petrological, structural and biostratigraphical investigations.

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