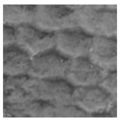
First records of trace fossils from the Lake District, southwestern Turkey

Jan Kresten Nielsen, Muhittin Görmüş, Kubilay Uysal & Sűveyla Kanbur



Important new ichnological data was obtained from the Isparta Çay Formation (Triassic to early Cretaceous), Koçtepe Formation (middle Paleocene to Early Eocene), Isparta Formation (Early to Middle Eocene) and İncesu Formation (Middle Eocene to Early Oligocene). These formations are significantly exposed in the Eğirdir, Gönen and Isparta regions within the northern part of the Isparta Angle. An overview of the stratigraphy and its trace-fossil bearing formations and microfossil content is presented together with recommendations. The density and diversity of trace fossils vary between and within these formations, which originated in deep-marine shelf slope and shelf environments of the Neotethys ocean. Changes in the frequency of abrupt turbiditic deposition, oxygenation of the bottom water and possibly food availability are reflective in the trace fossil distribution. The trace fossils of the Isparta Çay, Koçtepe and Isparta formations are typical of deep-marine settings with occasional high-energy turbiditic conditions. The Isparta Çay Formation (*Paleodictyon* ichnosubfacies) is seen as the bedrocks of the region, whereas the Isparta Formation (*Ophiomorpha rudis* ichnosubfacies) overlies conformably the Koçtepe Formation (*Nereites* and *Arenicolites* ichnofacies). The İncesu Formation is laterally interlaced with the Isparta Formation. A high diversity of trace fossils occurs in the İncesu Formation (*Zoophycos* ichnofacies), which was formed in an outer shelf environment. Findings from previous ichnological investigations in Turkey are compiled and compared with the present results from the Isparta Angle. • Keywords: stratigraphy, trace fossils, ethology, ichnofacies, shelf, bathyal, Turkey.

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The development of concepts concerning the tectonic evolution of the Neotethys in the Eastern Mediterranean region is notably connected with the Isparta Angle in southwestern Turkey (Fig. 1). The investigation area, which is located between Gönen (Isparta) and Ağlasun (Burdur) in the northern part of the Isparta Angle, is known for its Mesozoic-Tertiary sediments. Previous studies define the Isparta Angle as a complex geological structure including various autochthonous and allochthonous units (*e.g.*, Monod 1976; Gutnic *et al.* 1979; Koçyiğit 1981, 1983, 1984; Ţenel 1997; Yalçınkaya *et al.* 1986; Yalçınkaya 1989; Karaman 1990, 1994; Robertson 1993; Görmüş & Özkul 1995; Yağmurlu *et al.* 1997). The allochthonous units of the Isparta Angle comprise the Antalya Complex and reflect a Mesozoic-Tertiary polyphase deformational history (*e.g.*, Robertson *et al.* 2003). The northern part of the Isparta Angle is particularly well known for its Paleocene to Miocene marine successions located between Gönen (Isparta) and Ağlasun (Burdur). These successions, which are composed of shelf and shelf slope deposits, are geographically extensive and represented by a thickness of several hundred metres. Most researchers used and followed the geological maps and the identified geological units of Gutnic *et al.* (1979), Yalçınkaya *et al.* (1986) and Şenel (1997). The previous work resulted in a number of problems being identified regarding boundary relationships, geological ages and palaeoenvironmental interpretation of the formations (Görmüş *et al.* 2001a). There has been no common agreement so far on the stratigraphy and tectonics of the region.

The geology of the Isparta Angle has received increasing attention during recent years; however, the trace fossils of the Triassic to Oligocene successions have not previously been studied in detail (Fig. 1). Preliminary findings of trace fossils were breifly commented on by Görmüş *et al.* (2003, 2008) and are reported further herein. The diversity and density of trace fossils, and models of ancient behavioural activity, can provide crucial knowledge about successions which are poor in skeletal and shelly fossils

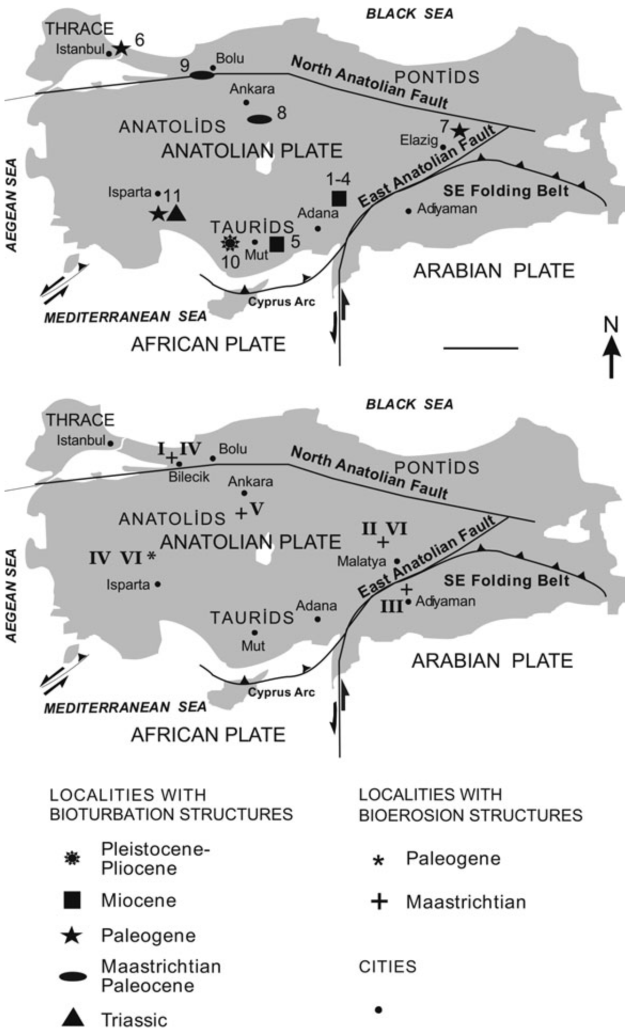

Figure 1. Geographical overview of macroscopic bioturbation structures presented herein and in previous studies: 1, 2 – Uchman & Demircan (1999a, b), 3 – Demircan & Toker (2003), 4 – Demircan & Toker (2004), 5 – Uchman *et al.* (2002), 6 – Demircan (2008), 7 – Özkul (1993), 8 – Yıldız *et al.* (2000), 9 – Sevim (2003), 10 – Yıldız *et al.* (2003), 11 – this study. Investigations of microscopic bioerosion structures are also shown: I – Görmüş & Sagular (1998), II – Görmüş & Meriç (2000), III – Meriç & Görmüş (2001), IV – Nielsen & Görmüş (2004), V – Görmüş *et al.* (2005), VI – Görmüş & Nielsen (2006).

(*e.g.*, Nielsen *et al.* 1996). The primary objective of this paper is therefore to present the ichnological characteristics of carbonate and siliciclastic successions from the Mesozoic and Tertiary of the Isparta Angle. Previously published findings from Turkey are also summarised and presented.

Geological setting

Although previous work indicated the problems mentioned above, the following summarizes the stratigraphical framework of the region (Figs 2, 3). Based on the previous literature and our fieldwork observations, the autochthonous units are as follows from bottom to top: (1) Jurassic to Cretaceous Davras Limestone (synonym Beydağları limestone, Yalçınkaya *et al.* 1986) including Söbüdağ Limestone Member, Upper Cretaceous, (2) Çiğdemtepe Formation, sheet limestones (synonym Senirce limestone, Karaman *et al.* 1988), ?Campanian-Maastrichtian, (3) Koçtepe Formation, clastics (synonym Kızılkırma Formation, Karaman *et al.* 1988), Upper Paleocene, (4) Isparta Formation, marls and clastics (synonym: Isparta flysch, Gutnic *et al.* 1979), Upper Paleocene to Eocene, (5) İncesu Formation, coarse clastics, Eocene to Oligocene, (6) Karabayır Formation, limestones (synonym İmrezi limestone, Yalçınkaya 1989, Yazır limestone, Karaman 1990), Lower Miocene, (7) Güneyce Formation, clastics (synonym Aglasun Formation, Yalçınkaya 1989), Lower to Middle Miocene, (8) Gökdere Formation, medium to coarse grained clastics, Middle Miocene, (9) Terrestrial, Pliocene-Quaternary Gölcük Volcanics, (10) Terrestrial Atabey Conglomerate, Pliocene-Quaternary in age, and (11) recent sediments. The allochthonous units are known as the Antalya nappes and Lycian nappes (Figs 2, 3). The formation names have been adopted from the previous work carried out at different places in the region (Poisson & Poignant 1974, Gutnic *et al*. 1979, Akbulut 1980, Koçyiğit 1980, Sarıiz 1985). The first names have been used according to the stratigraphical rules (Hedberg 1976).

The Antalya and Lycian nappes are related to Cretaceous-Miocene compression (Koçyiğit 1983, 1984; Şenel 1984, 1997; Robertson 1993; Glover & Robertson 1998; Robertson 2000; Temiz *et al*. 2001; Poisson *et al*. 2003a, b; Ţentürk & Yağmurlu 2003). However, the horst and graben systems controlling the Burdur, Eğirdir and Kovada Lake formations exist as a result of post-Miocene tension (Koçyiğit 1983, 1984, 2000; Yağmurlu *et al*. 1997; Poisson *et al.* 2003a, b; Robertson *et al.* 2003), and it is known as the neotectonic period. In addition, volcanic dykes formed by the different tensional forces are also seen in the angle.

Material and methods

A number of localities with Mesozoic to Cenozoic successions were systematically examined during fieldwork for the presence of trace fossils. The studied successions are from bottom to top as follows: Triassic limestones of the Antalya nappes, Paleocene to Eocene mudstones of the Koçtepe Formation, marls of the Isparta Formation, and calcarenites of the İncesu Formation (Fig. 3). The localities included road sections as well as natural outcrops (Fig. 1). About fifty hand-picked samples were obtained from these localities. Selected samples are housed in the Department of Geological Engineering of Süleyman Demirel University (Isparta).

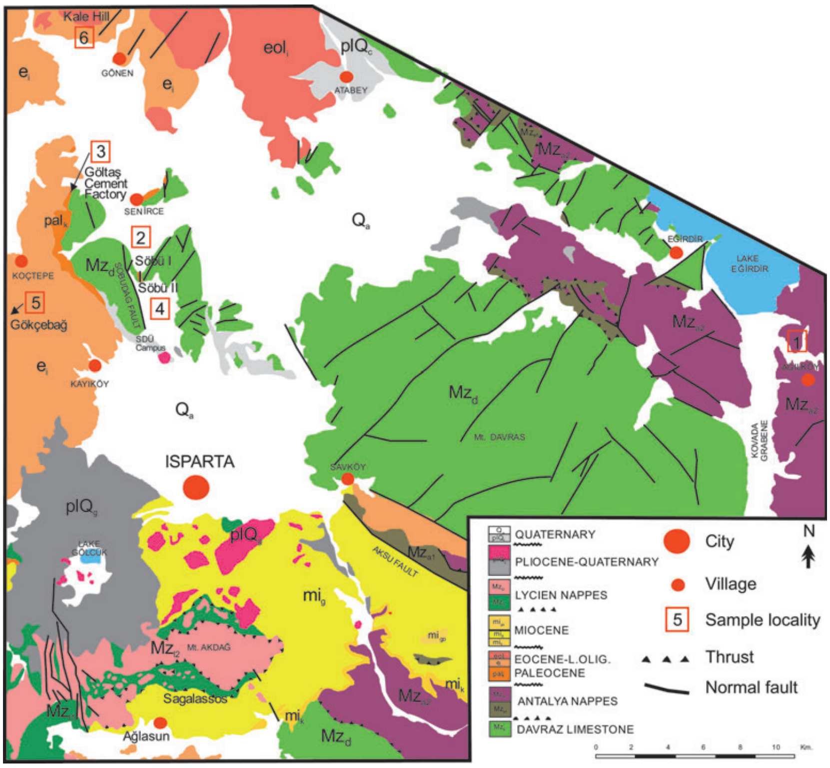

Figure 2. Geological map of the studied Ağlasun, Eğirdir, Gönen and Isparta regions and the geographic distribution of Triassic to early Cretaceous and Paleocene to Miocene sedimentary successions. Localities are indicated by rectangle symbols (modified from Gutnic *et al*. 1979, Şenel 1997).

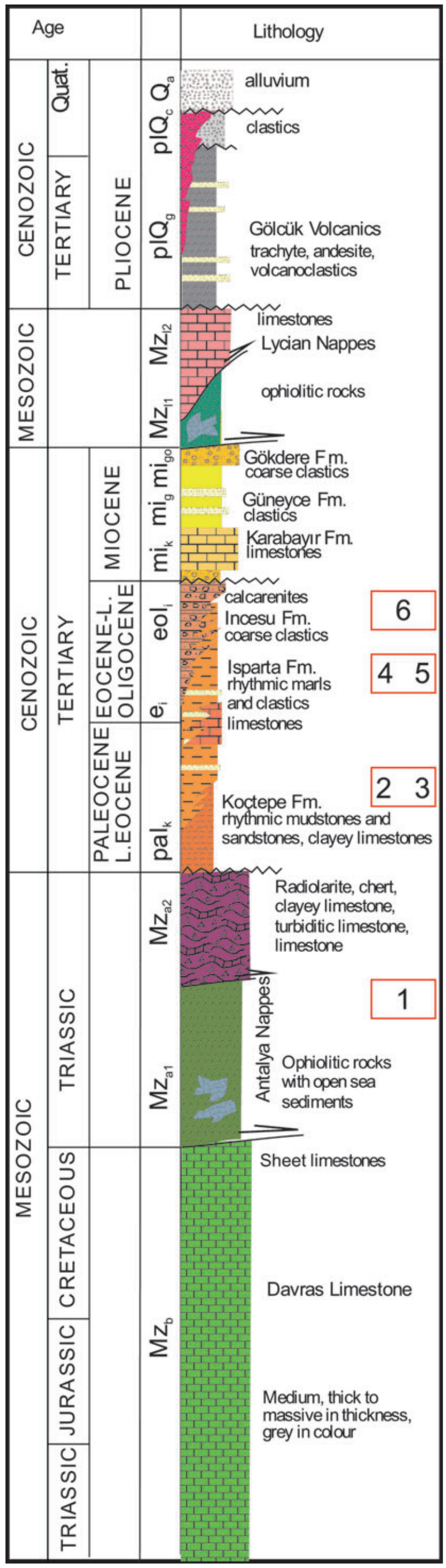

Figure 3. Generalised stratigraphical column showing sample levels (rectangle symbols) of trace fossils. 1 – Isparta Çay Formation, Ağilköy, 2 – Koçtepe Formation, Söbü I, 3 – Koçtepe Formation, Göltaş cement factory, 4 – Isparta Formation, Söbü II, 5 – Isparta Formation, Gökçebağ, 6 – Incesu Formation, Kale Tepe Gönen.

Investigation of the trace fossils included macroscopic and microscopic observation. The term *margin* is used for the boundary surface between a trace fossil and the surrounding substrate (Goldring & Pollard 1996, Nielsen & Nielsen 2001). Following the guidelines given by Bertling *et al.* (2006), the identification of ichnotaxa is based exclusively on morphological features. Density of the trace fossils is described by using a semi-quantitative scheme, *i.e*., low, moderate and high. Preservation of the trace fossils is described using the terminology developed by Seilacher (1964a, b).

Stratigraphy and ichnology

Although various geological units have been identified in the region, here we only present trace fossil bearing formations. They come from Triassic to Oligocene sediments (Figs 2, 3). These trace fossils have until now not been documented.

Triassic to Early Cretaceous

The Antalya nappes are composed of various geological units (Gutnic *et al*. 1979, Robertson 1993, Vrielynck *et al.*

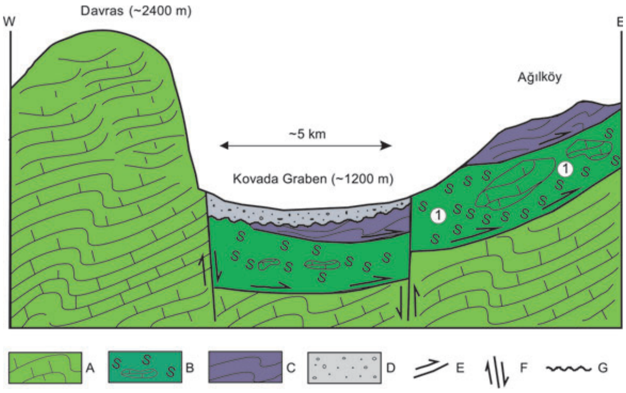

Figure 4. Schematic cross-section between Davraz and Ağilköy. A – Davraz Limestone, B – Ophiolitic Mélange in the Antalya Nappes, C – large blocks of Davraz Limestone in the Antalya Nappes, D – alluvium, E – thrust nappe, F – normal fault, G – discordance, 1 – locality 1.

2003), including the Isparta Çay Formation and the Isparta Ophiolitic Mélange, which contain various Triassic to Early Cretaceous sediments (Fig. 4).

Isparta Çay Formation. – Deep-marine sediments of Triassic to Early Cretaceous age are associated with the Isparta Çay Formation, outcropping widely between the Savköy and Dereboğazı tunnels, and the surroundings of Ağılköy (Eğirdir)-Kovada (Figs 2, 4). This unit was named the "Isparta Çay Unit" or "Isparta Çay Formation" in the literature (Dumont *et al.* 1972, Allasinaz *et al.* 1974, Poisson 1977, Gutnic *et al.* 1979, Yalçınkaya 1989). It comprises three members, *i.e.*, radiolarite cherts, turbiditic limestone and sheet limestones (Yalçınkaya 1989). The Antalya nappes derive from the south (southern Neotethys and adjacent areas) and were emplaced during Late Cretaceous to Paleocene times (Gutnic *et al.* 1979, Görmüş *et al.* 2001b, Vrielynck *et al.* 2003). The Miocene Karabayır Formation covers unconformably the Isparta Çay Formation around the İmrezi village. The underlying units were not seen in the studied area. According to our field observations of different cross sections, the unit is more than 700 m thick. Various foraminifera, bivalves, ammonites and radiolaria were recorded. Foraminifera: *Ammodiscus* sp., *Galeanella* sp., *Miliolipora* sp., *Nodosaria* sp., *Protopenoroplis striata*, *Reophax* sp., *Textularia* sp., *Trochammina* sp., pseudocyclamines and trocholines. Radiolaria: *Emiluvia* sp., *Cinguloturris carpatica*, *Leugeo hexacubicus*, *Parahsuum* sp., *Paronaella* sp., *P.* cf. *kotura*, *Parvicingula dhimenaensis*, *P.?spinata*, *P.* sp., *Podobursa* sp., *Transhuum maxwelli* and *Triactoma jonesi*. Bivalvia: *Halobia austriaca*, *H. halorica*, *H. charliana*, *H. lineate*, *H. striatica*. Cephalopoda: *Aulacoceras* cf. *sulcatum,*

Table 1. Overview showing the stratigraphical distribution of trace fossils in the Triassic to early Cretaceous and Paleocene to Oligocene formations of the Eğirdir, Gönen and Isparta regions. Note: +, few specimens; ++, common; +++, abundant.

	Triassic-early Cretaceous	Middle Paleocene to early Eocene		Early to middle Eocene	Middle Eocene to early Oligocene
Formations	Isparta Çay	Koçtepe		Isparta	İncesu
Locality	1	2	3	4 & 5	6
Arenicolites sparsus Salter, 1856		+			
Helminthopsis isp.	+			+	
Helminthorhaphe flexuosa Uchman, 1995	+				
Lorenzinia isp.	+				
Megagrapton submontanum (Azpeitia & Moros, 1933)	+				
Nereites isp.			+		
Ophiomorpha rudis (Książkiewicz, 1977)				+	
Palaeophycus tubularis Hall, 1847					++
Paleodictyon (Glenodictyum) arvense Barbier, 1956	+		+		
Planolites beverleyensis (Billings, 1862)	+		+		++
Planolites montanus Richter, 1937					+
Polykladichnus isp.		++			
Scolicia ?vertebralis Książkiewicz, 1977			++		
Scolicia isp.					++
Thalassinoides cf. *suevicus*					++
Thalassinoides suevicus (Rieth, 1932)	++				
Zoophycos isp.					+

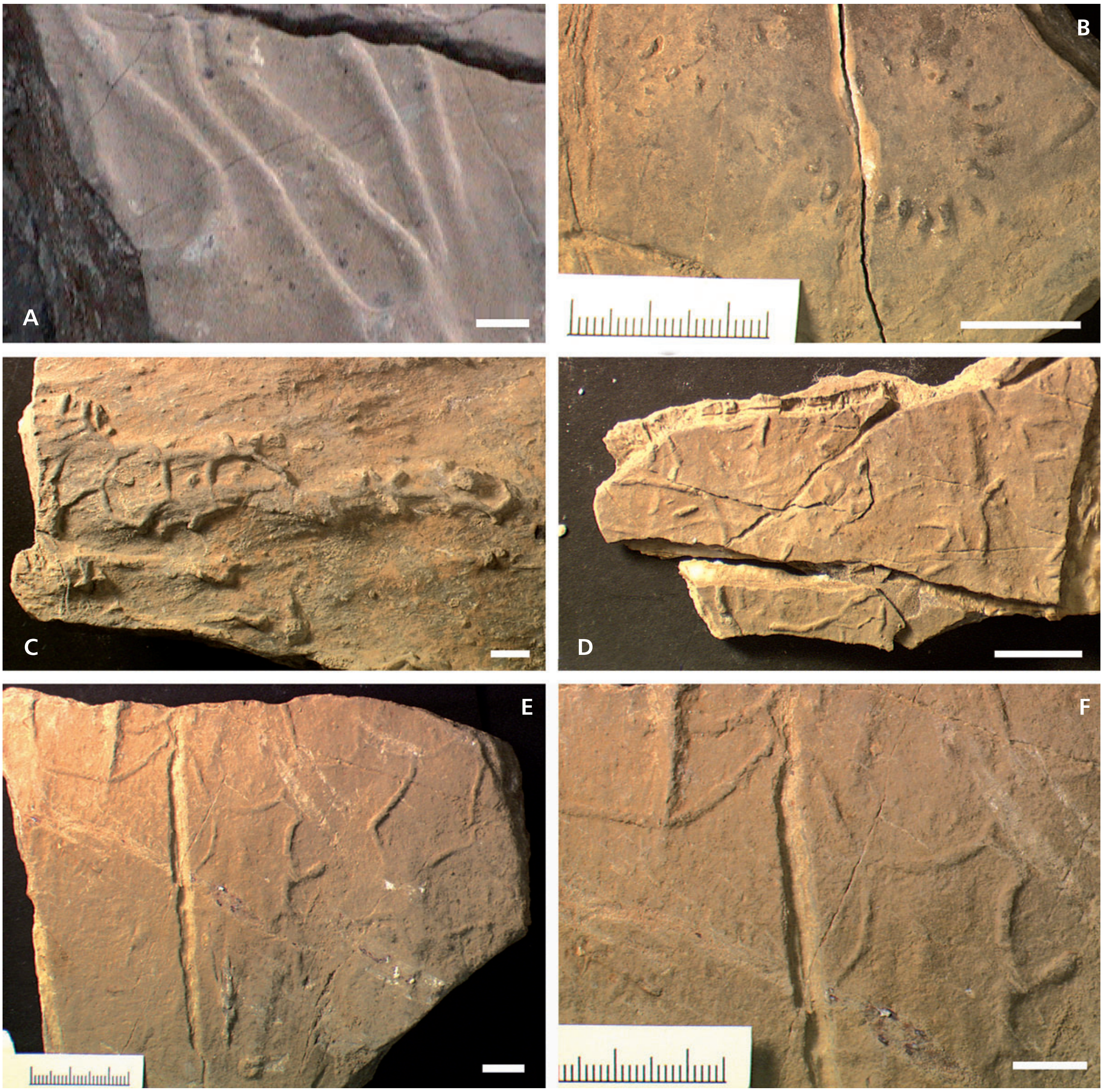

Figure 5. Trace fossils from the Isparta Çay Formation, locality 1. • A – *Helminthorhaphe flexuosa*, preserved in hyporelief. • B – *Lorenzinia* isp., hyporelief. • C – *Paleodictyon arvense*, hyporelief. • D – *Helminthopsis* isp., hyporelief. • E, F – *Megagrapton submontanum*, hyporelief. Scale bars: 1 cm.

Aulacoceras sp., *Clacidites* sp., *Juvatites* sp. and *Megaphyllites* sp. (Yalçınkaya 1989, Tekin 1999, Vrielynck *et al.* 2003). According to the species of *Halobia recoreded*, a Late Triassic age can be assigned to the bottom part of the formation, whereas the middle and upper parts of the formation contain Jurassic to Early Cretaceous ammonites and radiolaria (Vrielynck *et al.* 2003). Lithological and faunal characteristics indicate a deeper palaeoenvironment for the Isparta Çay Formation with turbiditic currents.

Isparta Ophiolitic Mélange. – This geological unit contains ophiolitic rocks mixed with Triassic to Early Cretaceous sediments. It was named the Isparta Ophiolitic Complex by Yalçınkaya (1989). Here we prefer the suffix mélange instead of complex due to mixing of both sediments and ophiolites. They are exposed in the areas around Darıoren, Savköy, Ağılköy and Kovada. Trace fossils occur within the sedimentary blocks of the mélange, which derived from the Isparta Çay Formation and other Triassic to Cretaceous carbonates.

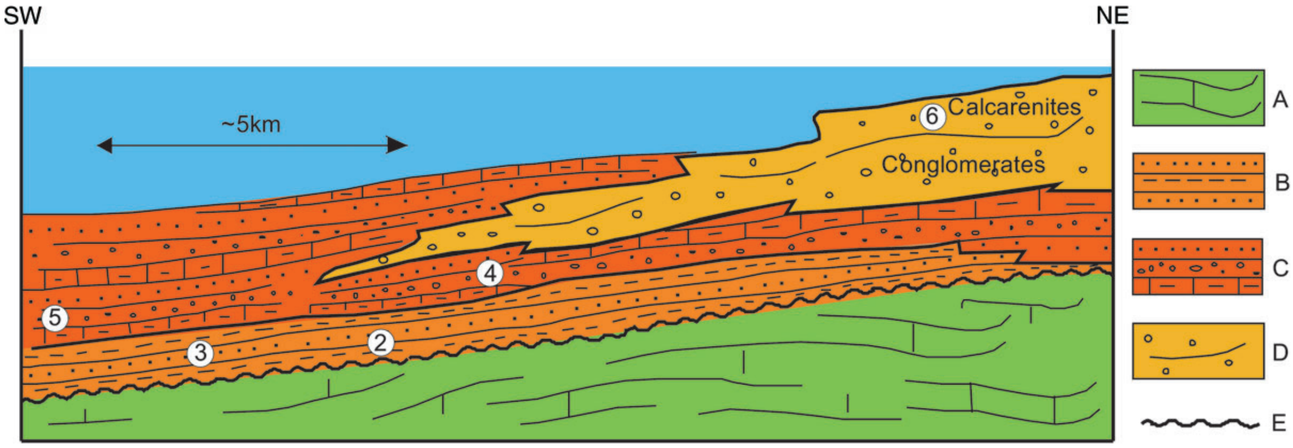

Figure 6. Palaeoenvironmental reconstruction of Paleocene to Early Oligocene successions. • A – Davraz Limestone, B – Koçtepe Formation, C – Isparta Formation, D – İncesu Formation, E – disconformity, 2–6 – localities.

Ichnological observations. – The Isparta Çay Formation, which is poorly exposed at Ağılköy (locality 1), has a low density and moderate diversity of trace fossils (Table 1; Fig. 5). Cross-cutting relationships between them were not found.

Thalassinoides suevicus is preserved in full relief and displays mainly horizontally orientated galleries, which are approximately 2 cm wide and their margin is smooth. *Thalassinoides suevicus* formed as branched burrow systems parallel to the bedding, with enlargement at junctions between some branches. These junctions are Y- or T-shaped and show a branching angle up to 70°. The probable trace maker was an arthropod.

Planolites beverleyensis occurs as simple horizontal or oblique cylindrical burrows, less than 1 mm wide, without walls or internal structures, circular to oval in transverse cross-sections. They are preserved in full relief.

Lorenzinia isp. consists of up to twenty radially arranged, separated hypichnial ridges, which are up to 5 mm long (Fig. 5B). The diameter of the entire trace fossil is about 26 mm. The number of preserved ridges is partly controlled by sedimentary erosion.

Paleodictyon (Glenodictyum) arvense occurs as a convex hyporelief on the underside of erosive turbiditic sandstones (Fig. 5C). The networks resemble a honeycomb pattern, with a lateral extent of at least 12.8 cm. The strand diameter is approximately 2 mm. Maximum mesh size is 21 mm. These measurements are within the morphometric range of *P. (Glenodictyum) arvense* as defined by Uchman (1995).

Megagrapton submontanum occurs rarely in the Isparta Çay Formation (Fig. 5E, F). The network consists of irregularly shaped meshes. The mesh size appears to be up to 43 mm. The winding strands are 2 mm wide. The branching angle may be acute. *Megagrapton submontanum* was revised by Uchman (1998) and is distinguished from *M. irregulare* by its winding strings and the branching angle.

Helminthorhaphe flexuosa is a hypichnial unbranched, smooth, regularly meandering semicircular ridge (Fig. 5A). The ridge is 3 to 4 mm wide and forms one-order meanders, which are irregular and poorly defined in outline. *Helminthorhaphe flexuosa* differs from *H. japonica*, which has densely defined meanders with high amplitude and bulging turns (Uchman 1998).

Helminthopsis isp. displays an unbranched, hypichnial ridge showing an irregularly winding course (Fig. 5D). The ridge is unlined and semicircular in cross-section. The width is 2 mm and the ridge can be traced to a distance of at least 12 cm.

Paleocene to Early Oligocene

The Paleocene to Eocene formations are from bottom to top as follows: Koçtepe Formation, Isparta Formation and İncesu Formation (Fig. 6). The Isparta Formation includes rhythmic clastics (succession I), carbonates (succession II) and calcarenites (succession III). The İncesu Formation contains medium to coarse-grained clastics (succession I) and calcarenites (succession II).

Koçtepe Formation. – It was named after Koçtepe village near to the Süleyman Demirel University Campus by Sarıiz (1985). The Kızılkırma Formation from the Söbüdağ area and Kabaktepe Formation from the Savköy area are thought to be synonyms for the Koçtepe Formation (Koçyiğit 1984, Karaman *et al*. 1988, Yalçınkaya 1989). The Koçtepe Formation consists of a succession of interbedded reddish mudstones and yellowish sandstones of siliciclastic composition. The thin to medium bedded sandstones, which are generally fine-grained and moderately sorted, may be structureless or contain small-scale cross-bedding. The succession is around 50 m thick. The Koçtepe Formation is underlain by sheet limestones of the

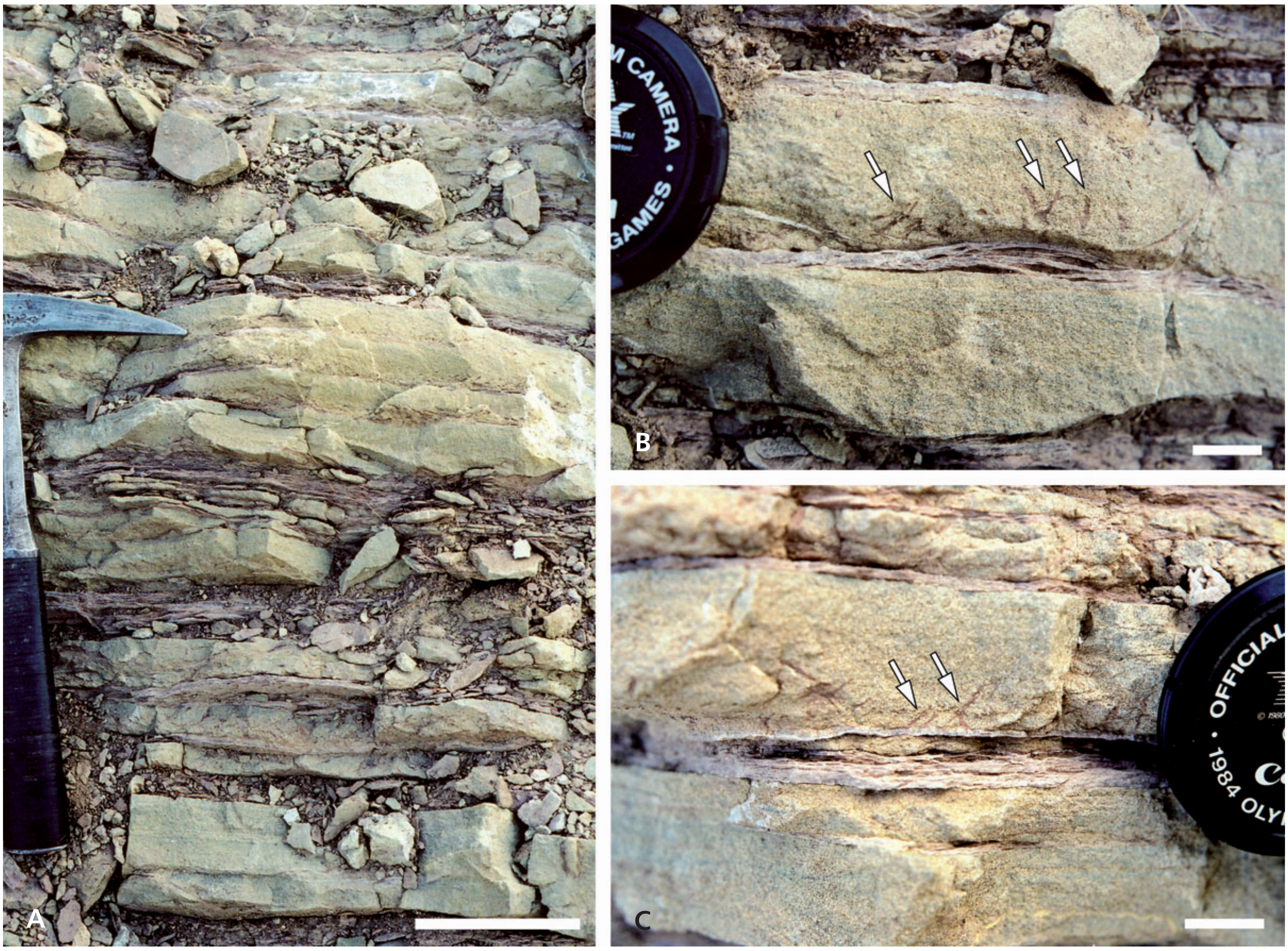

Figure 7. A – overturned heterolithic beds of the Koçtepe Formation, locality 2 (Söbü I). • B, C – examples of overturned *Polykladichnus* isp. (arrows). Scale bars: A = 10 cm; B, C = 1 cm.

Campanian to Maastrichtian Çiğtemtepe limestone, and overlain by the Isparta Formation clastics. The transition between the Koçtepe and Isparta formations is gradual in facies. The mudstones contain a rich content of planktonic foraminifera but fewer benthic foraminifera: *Acarinina primitive*, *A.* sp., *Globigerina linaperta, G. triangularis, G. triloculinoides, G. trivalis, G. veloscoensis*, *Morozovella angulata, M. aragonensis, M. conicotruncata, M. formasa formasa, M. quetra, M.* sp., *Planorotalites chapmani, P.* cf. *pusilla pusilla* and *P.* sp. Benthic foraminifera: *Ammodiscus* sp., *Anomolina* sp., *Bulimina* sp., *Cibicides* sp., *Clavulinoides* sp., *Dorothia* sp., *Ellipsonodosaria* sp., *Gaudryina* sp., *Guttulina* sp., *Gyroidina* sp. *Haplophragmoides* sp., *Neoflabellina* sp., *Oolina* sp., *Robulus* sp., *Textularia* sp. and *Verneuilina* sp. (Görmüş & Karaman 1992). Within the sandstones, reworked Cretaceous planktonic and benthic foraminifera are common including taxa such as *Alveolina* sp., *Discocyclina* sp., *Nummulites* sp. and *Sphaerogypsina globules*. An alga, *Dictichoplax biserialis*, was also recorded in the sandstones. The foraminifers point to a middle Paleocene-Early Eocene age for the Koçtepe Formation. Faunal contents indicate a middle to outer shelf palaeoenvironment.

Ichnological observations. – In the Koçtepe Formation, two different trace fossil assemblages were recognized (Table 1; Figs 7, 8). At the road section (locality 2, Söbu I), the assemblage is characterized by low diversity and density of trace fossils.

Arenicolites sparsus is a vertical U-shaped burrow without spreite, filled with reddish fine-grained sediment. The trace fossil is up to 15 mm tall. The limbs are unlined and smooth, 10 mm apart and 2 mm in diameter. The limbs diverge upwards. Based on these characteristics, the specimens are assigned to *Arenicolites sparsus* (see Salter 1857, Rindsberg & Kopaska-Merkel 2005).

Polykladichnus isp. is a vertical shaft having upward-directed Y shaped branching (see Fürsich 1981, Schlirf & Uchman 2005). This trace fossil is 30 mm long and 10 mm wide. The shaft and branches are smooth, unlined and 1 mm in diameter. They are filled with the overlying muddy sediment. Notably the trace fossils differ from

Figure 8. Trace fossils from the Koçtepe Formation, Göltaş cement factory, locality 3. • A – *Paleodictyon (Glenodictyum) arvense*. • B, C – *Scolicia ?vertebralis*. Lens cap: 6 cm in diameter.

Polykladichnus irregularis by the lack of wall lining. The ichnogenus *Polykladichnus* is defined by its burrow pattern of mainly vertical tubes with Y-bifurcations (Fürsich 1981). The branching pattern is a significant ichnotaxobase in simple, vertical structures, whereas the presence or absence of wall lining may be used for ichnospecific differentiation (Schlirf & Uchman 2005).

The succession in a nearby road section consists of similar deposits as at locality 2. Notably the deposits have been tectonically overturned as indicated by the upside down trace fossils of *Polykladichnus* isp. (Fig. 7). This is in accordance with structural indicators such as orientation of the folded succession in the area.

The Koçtepe Formation which is exposed at the Göltaş cement factory (locality 3) contains a different trace fossil assemblage. The under surfaces of the sandstone beds may contain *Scolicia ?vertebralis*, *Planolites beverleyensis*, *Paleodictyon (Glenodictyum) arvense* and *Nereites* isp. (Fig. 8).

Scolicia ?vertebralis has a winding course and displays remnants of meniscate backfill (Fig. 8B, C). A narrow central groove and one strand along its base are present. The width of the entire trace fossil is about 7 cm. There is incomplete diagnostic evidence for specific determination. In addition, *Scolicia vertebralis* is possibly a preservational variant of *S. prisca* and, therefore, its status is unclarified (Uchman 1998).

Paleodictyon (Glenodictyum) arvense is a convex hyporelief regular network, which resembles a honeycomb pattern (Fig. 8A). Individual strands are up to 7.5 mm long. The strand width is about 2 mm. Maximum mesh size is 16.5 mm. The morphometric range defines the specific identification (Uchman 1995).

Planolites beverleyensis is an unlined hypichnial cylinder, 7–12 mm wide, traced over a distance of 12 cm.

Isparta Formation. – At first it was called Isparta flysch by Gutnic *et al.* (1979) and is widely exposed between the cities of Isparta and Burdur. Around Isparta city, the Kayıköy Formation from the Söbüdağ area and Savköy Formation from the Savköy area are thought to be synonyms for the Isparta Formation (Karaman *et al.* 1988, Yalçınkaya 1989). Yalçınkaya (1989) described the Kurttepe Formation from the Eocene of the Ağlasun area. It is also a synonym for the Isparta Formation. Sarıiz (1985) uses the name Isparta Formation. We prefer this name due to different accumulation of the sediments, such as carbonate-dominated sediments and siliciclastic dominated sediments, during the Late Paleocene to Eocene. In addition, the formation was formed in shallow-marine to open-marine palaeoenvironments. Thus, the Isparta Formation may be separated into different successions such as rhythmic clastics and marls (succession I), carbonates (succession II) and calcarenites (succession III). Rhythmic clastics and marls are seen around Kayıköy and Mensucat, and at the Göltaş cement factory. Carbonates crop out around the Savköy area, and the third succession crops out on the Kayısivrisi Hill near to Kayıköy village. The third succession was distinguished by Yeşilot (2000) as the Kayısivrisi Member. The thickness of the Isparta Formation is more than 700 m. It

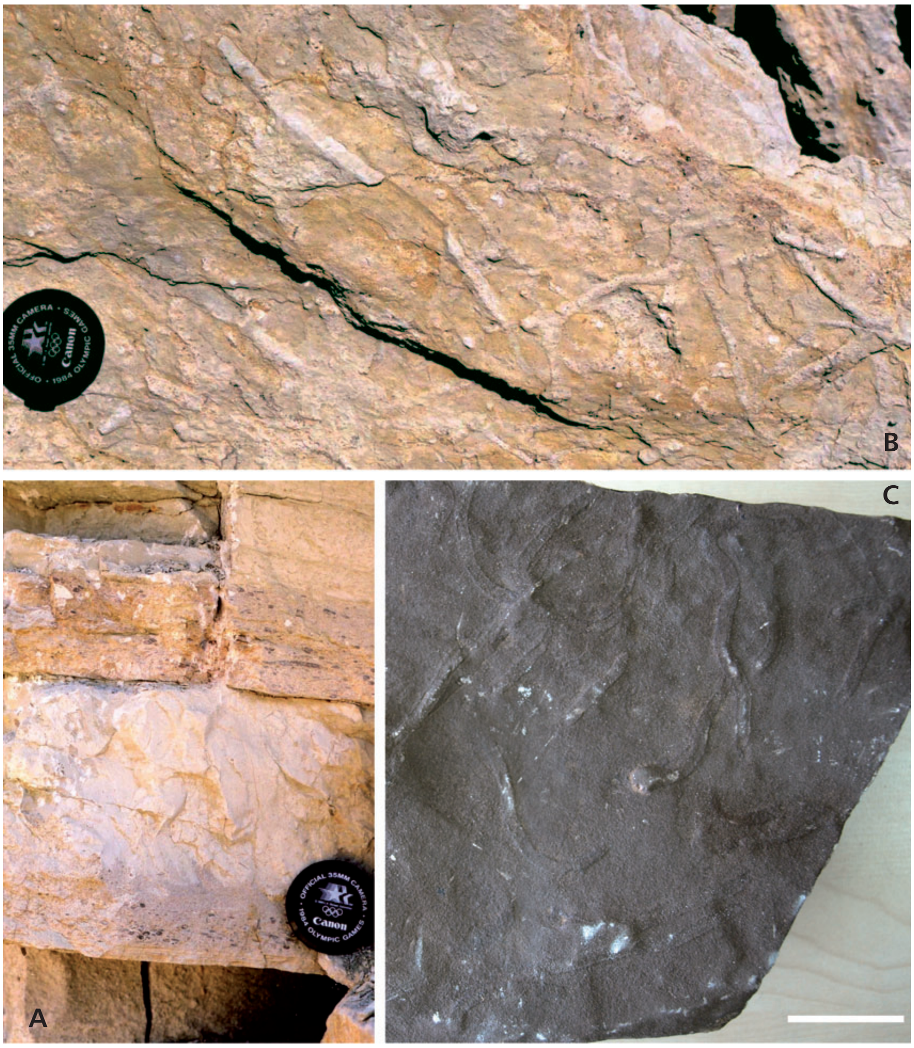

Figure 9. The Isparta Formation at locality 4. • A – normal graded beds with erosive bases. • B – *Ophiomorpha rudis*, full relief. • C – *Helminthopsis* isp., hyporelief. Lens cap: 5.5 cm in diameter. Scale bar: 5 cm.

has vertical and lateral facies underlain by the Koçtepe Formation and overlain by the İncesu Formation. Akkiraz *et al.* (2007) suggested an unconformity between the Isparta Formation and İncesu Formation; however, we consider it as facies transition. The facies changes are clearly observable around the Gönen and İğdecik areas. The faunal content can be summarised as follows: Planktonic foraminifera: *Acarinina broedermanni, A. bullbrooki*, *Globigerina linaperta, G. senni, G. turgida, G. yeguaensis, Globigerinoides higginsis, Morozovella aragonensis, M. caucasica, M. crassata, M. gracilis, M.* cf. *lehneri, M.* cf. *quetra, M. spinulosa, M. subbotina, Turborotalia centralis* and *Truncorotaloides rohri*. Benthic foraminifera: *Alveolina* sp., *Amphistegina* sp., *Dictyoconus* sp., *Discocyclina* sp., *Elphidium* sp., *Europertia magna, Fabiania cassis, Gypsina* sp., *Nummulites aturicus, N. beaumonti, N. millecaput, N. perfaratus, N.* sp., *Operculina* sp., *Peneroplis* sp., *Rotalia* sp., *Silvestriella tetraedra, Sphaerogypsina globula* and *Textularia* sp. (Karaman 1994, Görmüş & Özkul 1995). Reworked Cretaceous planktonic and benthic foraminifera and *Dictichoplax biserialis*, an alga. Synsedimentary nannofossils: *Braarudosphaera bigelowii, Chiasmolithus californicus, C. consuetus, C. grandis, Cooccolithus pelagicus, Discoaster barbadiensis, D. binodosus, D. deflandrei, D. diastypus, D. gemmifer, D. kuepperi, D. lodoensis, D. salisburgensis, D. scrippsae, Ericsonia cava, E. formosa, E. ovalis, Lophodolithus nascens, Reticulofenestra dictyoda, Sphenolithus conspicuous, S. editus, S. moriformis, S. radians, Toweius crassus, T. gammation, T. occultatus, T. pertusus, Tribrachiatus orthostylus* and *Zygrhablithus bijugatus.* Reworked nannofossils from the Cretaceous to Early Paleocene: *Arkhangelskiella cymbiformis*, *Aspidolithus parcus constrictus*, *Biantolithus sparsus, Cribrosphaerella ehrenbergii*, *Cruciplacolithus primus, Cyclagelosphaera reinhardtii, Eifellithus eximius, E. turriseiffelii, Fasciculithus involutus, F. tympaniformis*, *Lithraphidites quadratus, Microrhabdulus attenuatus, Micula decussata M. murus*, *Nannoconus* sp., *Placozygus fubiliformis, Prinsius dimorphosus, P. bisulcus, Rhabdolekiskus parallelus, Stradneria crenulata*, *Thoracosphaera operculata* and *Watznaueria barnesae* (Sagular & Görmüş 2006). The fossils indicate an Early to Middle Eocene age for the Isparta Formation. Lithological characteristics and fossil content indicate an open-marine palaeoenvironment.

Ichnological observations. – At localities 4 (Söbü II) and 5 (Gökçebağ), the Isparta Formation is comprised of rhythmic successions of marls, sandstones and conglomeratic sandstones. The ichnodensity is low (Table 1, Fig. 9). There are a few specimens of *Helminthopsis* isp. and *Ophiomorpha rudis*.

Helminthopsis isp. is a semicircular hypichnial ridge on the underside of the sandstone beds (Fig. 9C). The ridge is unbranched and about 3 mm wide. *Helminthopsis* isp. is recognized by its irregularly winding course.

Ophiomorpha rudis is a three-dimensional cylindrical burrow system, which contains horizontal to oblique, straight to slightly curved branched elements, all preserved in full relief (Fig. 9B). The branching angle ranges from 60 to 90°. The burrow diameter is about 14 mm. The distance between branches may reach 34 cm. Wall lining is weakly developed and occurs along the branch roof and at the branching points. The branching points may be slightly swollen.

İncesu Formation. – It was called the İncesu conglomerates after the village of İncesu near to Keçiborlu town in the city of Isparta by Gutnic *et al.* (1979). Koçyiğit (1984) named it the İncesu Formation, based on outcrops from the Senirkent area. We prefer the second alternative due to occurrences of various clastic deposits in the formation. The İncesu Formation crops out widely around Gönen, İğdecik and Gümüşgün. The formation is composed of sandstones, conglomerates and calcarenites. The calcarenites mainly occur in the uppermost part of the sedimentary succession, *e.g.* at Gönen Kale Hill. They were assigned by Akkiraz *et al.* (2007) to the Delikarkası Formation. The İncesu Formation may be subdivided into different units. However, we accept them as different successions of the same formation and divide them only into succession I (medium- to coarse-grained clastics) and succession II (calcarenites) due to insufficient documentation. The thickness of the İncesu Formation is around 600 m. The formation has vertical and lateral facies transitions with the underlain Isparta Formation. The faunal content of both succession I and II of this formation are as follows: *Alveolina* sp., *Assilina* sp., *Asterigerina* sp., *Discocyclina* sp., *Europertia* sp., *Fabiania* sp., *Gypsina* sp., *Halkyardia* sp., *Opertorbitolites* sp., *Nummulites aturicus, N. perfaratus* and *Silvestriella tetraedra*. Akkiraz *et al.* (2007) recorded the following faunal content from the calcarenites of the formation: *Nummulites intermedius*, *N. vascus*, *Lepidocyclina* sp. (foraminifera), *Boehlensipollis hohli*, *Dicolpopollis kockelii*, *Intratriporopollenites instructus, Leiotriletes maxoides* ssp., *Pediastrum* spp., *Plicapollis pseudoexcelsus*, *Polypodiaceoisporites* sp., *Slowakipollis hippophaëoides*, *Subtriporopollenites simplex*, *Triatriopollenites excelsus*, *Verrucatosporites* sp. and dinoflagellate cysts (palynomorphs). The previous records indicated a Middle Eocene to Early Oligocene age. Lithological characteristics and faunal content indicate a shallower marine palaeoenvironment. Akkiraz *et al*. (2007) also discussed marine and land influences, and palaeoclimatological aspects based on the aforementioned fossils and tree plant fossils ascribed to *Castanea, Pinus, Cathaya, Abies* and *Podocarpus*.

Ichnological observations. – The Middle Eocene to Early Oligocene İncesu Formation overlies and is laterally equivalent to the Isparta Formation. The İncesu Formation is exposed at Gönen Kale Hill (locality 6) and consists of whitish to yellowish calcarenites of packstone and grainstone with bioclasts. The calcarenites, which are up to 50 cm thick, may be structureless, parallel bedded or weakly cross bedded. The sediment may be normal graded. There are only a few ophiolitic clasts. A-form *Nummulites* may be common and occur parallel to bedding where the sediment is unbioturbated. Stratification surfaces represent times of non-deposition or erosion and are moderately bioturbated.

The ichnodiversity is moderate to high at Gönen Kale Hill (Table 1, Fig. 10). *Thalassinoides* cf. *suevicus*, *Planolites beverleyensis* and *Scolicia* isp. are common. *Zoophycos* isp. is rare. Overall the density of trace fossils is moderate.

Thalassinoides cf. *suevicus* displays straight to gently curved Y-shaped branches (Fig. 10C, D). The individual branches are up to 40 cm long and about 0.5–2 cm in diameter. The branching angle ranges from 30 to 80°. The burrow fill is structureless and consists of calcareous sand. In some specimens, the fill contains numerous benthic foraminiferal tests.

Planolites beverleyensis is a cylindrical burrow about 2–5 mm in diameter (Fig. 10B, E). The fill is structureless and appears to be slightly more fine-grained than the surrounding sediment in lithology.

Scolicia isp. as the preservational variant *Laminites* is common and occurs parallel to the bedding. The trace fossil consists of biserial meniscate backfill in which only the upper part is visible (Fig. 10A–C). This preservational variant lacks further diagnostic features (Uchman 1995). The diameter of the backfill is 0.8 cm. The length may be at least 50 cm. The backfill is of sediment lithologically similar to the adjacent substrate.

Palaeophycus tubularis occurs as straight to gently curved, rarely branched, predominantly horizontal to oblique tubular burrows with thin wall lining of fine-grained sediment (Fig. 10A, B, F). They are circular to slightly elliptical in cross-section and uncommonly show secondary successive branching. The branching angle is

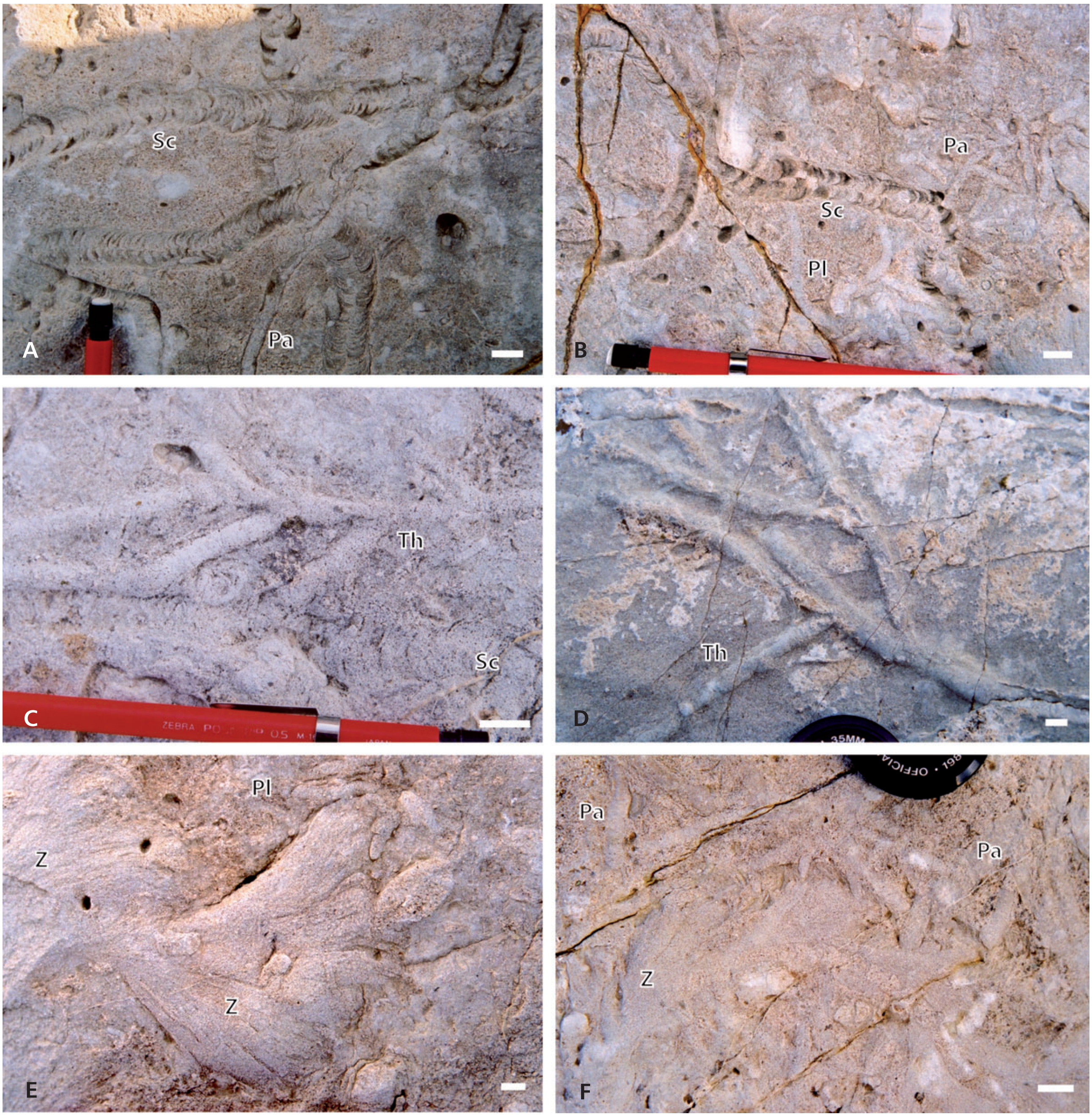

Figure 10. Trace fossils from the İncesu Formation at locality 6. • A – *Scolicia* isp. (Sc) and *Palaeophycus tubularis* (Pa). • B – *Scolicia* isp., *Palaeophycus tubularis* and *Planolites beverleyensis* (Pl). • C – *Thalassinoides* cf. *suevicus* (Th) cross-cut by *Scolicia* isp. • D – *Thalassinoides* cf. *suevicus*. • E – *Zoophycos* isp. cross-cutting *Planolites beverleyensis*. • F – *Zoophycos* isp. and *Palaeophycus tubularis*. The trace fossils are preserved in full relief. Scale bars: 1 cm.

acute. The diameter is up to 8 mm. The filling is structureless and of the same lithology as the surrounding sandy sediment. The trace fossil is preserved as full reliefs.

Zoophycos isp. are fan-shaped spreite structures. The fan angle is about 30 to 85° and up to 7 cm wide (Fig. 10E, F). The length of individual fans is approximately 5–6 cm. The largest fan is 19 cm long and 10 cm wide. This fan structure is intersected by a single burrow with meniscate backfill resembling *Taenidium* isp. The latter is 5 mm in diameter and contains a coarser fill compared with the fan structure. The filling of the fan structures resembles the surrounding sandy sediment; subtle variation in grain size enhances the internal structures. The fans are located parallel to the bedding.

Table 2. Previous ichnological investigations in Turkey and their findings of trace fossil assemblages for comparison with the present study. A – Yıldız *et al*. (2000; Kalecik, ANKARA), B – Sevim (2003; Göynük-Taraklı, ADAPAZARI), C – Özkul (1993; ELAZIĞ), D – Doğdu (2007; Haymana, ANKARA), E – Demircan (2008; Saros Körfezi KD'su Yenimuhacir-Keşan-Korudağ), F – Uchmann & Demircan (1999a; Karaisalı-Eymirler, Çatalhan-Eylence River, ADANA), G – Uchmann & Demircan (1999b; Kalaycılar-Çorlu-Hacımusalı, ADANA), H – Uchman *et al*. (2002; Dağpazarı-Kavaközü, MUT), I – Demircan & Toker (2003; Karaisalı-Çatalan-Eğner, ADANA), J – Demircan & Toker (2004; Karaisalı-Çatalan-Eğner, ADANA), K – Yıldız *et al*. (2003; Hacıahmetli-Sarıkavak-Kargıcak, MUT), P-P – Plio-Pleistocene

	Cretaceous-Paleocene		Paleocene-Eocene			Miocene					P-P
	A	B	C	D	E	F	G	H	I	J	K
Arthrophycus tenuis (Książkiewicz, 1977)										?	
Arthrophycus cf. *tenuis* (Książkiewicz, 1977)						•					
Asterichnus isp.			•								
Belorhaphe tebteqae Azpeitia, 1933			•								
Capodistria vettersi Vialov, 1968									•		
Caulostrepsis taeniola Clarke, 1908								•			
Chondrites affinis (Brongniart, 1828)			•								
Chondrites intricatus (Brongniart, 1823)						•					
Chondrites isp.		•		•	•		•		•		•
Conchotrema? isp.								•			
Cosmorhaphe sinuosa (Azpeitia & Moros, 1933)					•	•			•	•	
?*Cosmorhaphe* isp.						•					
Curvolithus simplex Buatois *et al.*, 1998		•									
Desmograpton dertonensis (Sacco, 1888)										•	
Desmograpton ichthyforme (Macostay, 1967)						•				•	
Desmograpton isp.										•	
Echinospira Girotti, 1970						•	•		•		
Entobia cf. *goniodes* Bromley & Asgaard, 1993a								•			
Entobia laquea Bromley & D'Alessandro, 1984								•			
Entobia cf. *ovula* Bromley & D'Alessandro, 1984								•			
Entobia cf. *solaris* Mikuláš, 1992								•			
Gastrochaenolites isp.								•			
Gastrochaenolites lapidicus Kelly & Bromley, 1984								•			
Gastrochaenolites torpedo Kelly & Bromley, 1984								•			
Ghondrites isp.											•
Glockeria isp.			•								
Gordia isp.			•								
Gyrolithes isp.											•
Halmenidium orivanse		•									
Halopoa annulata (Książkiewicz, 1977)		•		•	•					?	
Helicolithus tortuosus (Książkiewicz, 1970)										•	
Helminthoida crassa (Schafhäutl, 1851)			•								
Helminthoidichnites isp.					•						
Helminthopsis Heer, 1877	•				•				•	•	
Helminthorhaphe flexuosa Uchman, 1995						•				•	
Lockeia isp.					•						
Lophoctenium isp.										•	
Lorenzinia pustulosa (Książkiewicz, 1977)									•		
Meandropolydora isp.								•			
?*Megagrapton* isp.										•	

Table 2 – continued

	Cretaceous-Paleocene		Paleocene-Eocene			Miocene					P-P
	A	B	C	D	E	F	G	H	I	J	K
Neonereites uniserialis Seilacher, 1960			•								
Nereites irregularis (Schafhäutl, 1851)					•	•				•	
Ophiomorpha annulata (Książkiewicz, 1977)		•		•	•				•		
Ophiomorpha rudis (Książkiewicz, 1977)		•		•	•	•			•		
Ophiomorpha isp.	•	•		•	•				•		•
Paleodictyon croaticum Uchman, 1995				•						•	
Paleodictyon delicatulum Uchman, 1995										•	
Paleodictyon majus Meneghini *in* Peruzzi, 1880						•				•	
Paleodictyon minumum Sacco, 1888				•							
Paleodictyon Savi & Meneghini, 1850			•							•	
Paleodictyon strozzii Savi & Meneghini, 1850				•	•					•	
Paleodictyon cf. *strozzii* Meneghini, 1850						•					
Palaeophycus tubularis Hall, 1847		•									
Phymatoderma Brongniart, 1849										•	
Planolites beverleyensis (Billings, 1862)									•		
?*Planolites* isp.		•			•	•	•				•
Planolithus isp.				•							•
Protopaleodictyon submantanum Azpeitia & Moros, 1933										•	
Rhizocorallium isp.									•		
Rutichnius isp.				•	•						
Sabularia simplex Książkiewicz, 1977			•								
Scolicia isp.		•					•				
Scolicia plana Książkiewicz, 1970			•		•	•			•		
Scolicia prisca de Quatrafages, 1849				•	•				•		
Scolicia strozzii (Savi & Meneghini, 1850)				•	•	•			•		
Scolicia vertebralis Książkiewicz, 1970		•		•	•				•		
Skolithos isp.		•									•
Spirorhaphe involuta (de Stefani, 1895)			•								
Subphyllochorda striata Książkiewicz, 1970			•								
Taphrhelminthopsis isp.			•								
Thalassinoides isp.	•	•			•	•	•		•		•
Urohelminthoida dertonensis Sacco, 1888						•			•	•	
Urohelminthoida isp.									•		
Zoophycos brianteus Massalongo, 1855			•								
Zoophycos isp.					•				•		

Cross-cutting relations between trace fossils in the İncesu Formation are common. In general, the specimens of *Palaeophycus tubularis* and *Planolites beverleyensis* may be cut by *Scolicia* isp. The latter shows intraspecific cross-cutting. *Scolicia* isp. is also seen to cross-cut *Thalassinoides* cf. *suevicus*.

Discussion: Ethology and ichnofacies

Models of behavioural activity in deeper marine successions, and the diversity of trace fossils, are based on only a few detailed studies. The trace fossil assemblages only indirectly show the absolute bathymetry; however, the assemblages may also indicate other environmental parameters such as food supply, sedimentation rate, oxygenation and salinity (*e.g.*, Bromley & Ekdale 1984). In the following discussion we provide an overview of the recognized ichnofacies and an interpretation of the palaeoenvironments. The ichnofacies scheme was originally initiated by Seilacher (1964b, 1967) and elaborated further by others (*e.g.*, Bromley *et al.* 1984, Bromley & Asgaard 1991, Buatois & Mángano 2004).

Isparta Çay Formation. – The Triassic to Early Cretaceous sediments in the Ağilköy area (locality 1) contain graphoglyptid trace fossils typically found on the erosive undersides of flysch turbidites (Table 1, Fig. 5). The absence of cross-cutting trace fossils suggests that the trace makers avoided re-burrowing previous parts of the traces. The trace fossils are elaborated structures (*e.g.*, *Paleodictyon arvense*) with open tunnel systems, which may have become repeatedly revisited. These structures are assumed to have served as "gardens" for microbial symbionts exploring the surrounding sediment for nutrients (*e.g.*, Seilacher 1992). The tunnel walls may have been lined with mucus. The meandering trace fossils, *Helminthopsis* isp. and *Helminthorhaphe flexuosa*, are also considered to have formed as open tunnels. The open tunnels may have functioned as drainage systems (Seilacher 2007). Meandering trace fossils have previously been interpreted as burrows of deposit feeders. The trace fossil assemblage found in the Ağilköy area is assigned to the *Nereites* ichnofacies. Periodically the hydrodynamic energy level was high and traces in a certain tiering depth became partly eroded by turbiditic flow and filled with sand. In this way, the *Nereites* ichnofacies were formed by a combination of biological and taphonomical contributions (Bromley & Asgaard 1991).

Koçtepe Formation. – The Middle Paleocene to Early Eocene successions consist of sandstones and marly intervals. The latter represent the time intervals of deposition when the rates of sedimentation and sediment accumulation reached the lowest values, and starvation reached a maximum. The low diversity and density of trace fossils may indicate stressful living conditions for the trace makers. *Scolicia* is reflective of a mode of burrowing in which the sediment is moved from the front, passed along the exterior of the trace maker's body, and deposited as meniscoid backfill structure behind. Post-Jurassic specimens are known to have been produced by irregular echinoids (Spatangoidea) (*e.g.*, Bromley & Asgaard 1975, Seilacher 1992, Nielsen *et al.* 2008). The winding behaviour is an efficient approach to explore the food-bearing sediment (Seilacher 1992). *Scolicia ?vertebralis* found at the Göltaş cement factory (locality 3) shows examples of the behavioural pattern phobotaxis (Fig. 8). The trace makers utilised an avoidance strategy to prevent re-burrowing previous trace sections (Richter 1928, Simpson 1957, Osgood 1970). Crossings are usually absent. Similar behaviour is recognized in specimens of *Chondrites* from the northern Isparta Angle (this study). The trace makers may have used chemoreceptors for phobotaxis (Osgood 1970). In addition, *Scolicia ?vertebralis* exhibits closely spaced meanders reflecting efficient exploitation (thigmotaxis) and periodical reverse turns (strophotaxis) (Richter 1928, Osgood 1975).

Nereites isp. was found at locality 2. *Nereites* reflects the burrowing action of an unknown worm-like sediment feeder (enteropneust?) that proceeded through the sediment at the head and end before stowing it in lobes around the body (Seilacher 1992). The cavity behind the body became backfilled to form a core of sediment enveloped by an even or lobate mantle (Uchman 1995, 1998). Overall, the trace fossil assemblage at the Göltaş cement factory (locality 3) indicates the presence of the *Nereites* ichnofacies.

Another trace fossil assemblage is present close to locality 2 (Table 1, Fig. 7). The assemblage contains *Polykladichnus* isp. and *Arenicolites sparsus* which occur sporadically at a low density. The distribution may indicate sedimentation dynamics mostly governed by alternating low and high levels of hydrodynamic energy. The presence of small-scale primary sedimentary structures indicates similar depositional conditions with colonization windows available for opportunistic trace makers in periodically mobile substrate. The deposits are therefore allocated to the *Arenicolites* ichnofacies. This ichnofacies represents short-term post-event colonization in deposits of deep-marine environments, in addition to non-marine, shallow-marine and offshore settings (*e.g.*, Bromley & Asgaard 1991). The *Arenicolites* ichnofacies has been considered as unrepresentative of the variation and diversity of trace fossil assemblages in tempestite beds (*sensu* Frey & Goldring 1992, Goldring 1995). In addition *Arenicolites* reflects behaviour other than opportunism. According to Buatois & Mángano (2004), assemblages of *Arenicolites* ichnofacies can be difficult to distinguish from those of *Skolithos* ichnofacies. However, the usefulness of the *Arenicolites* ichnofacies has been demonstrated (*e.g.*, Bann & Fielding 2001, Buckman 1992, Singh 2009). Ethologically *Arenicolites* is representative of the category domichnion (*e.g.*, Bromley 1996, Moghadam & Paul 2000, Šimo & Olšavský 2007). Specimens of *Polykladichnus* within marine deposits are interpreted as domichnia of polychaetes or cerianthid anemones (Schlirf & Uchman 2005).

Isparta Formation. – The Early to Middle Eocene Isparta Formation has a low density of trace fossils (localities 4 and 5), which indicates a depositional environment stressful to trace makers, and probably with low preservation potential for traces (Fig. 9). The presence of *Helminthopsis* isp. and *Ophiomorpha rudis* implies a deeper marine palaeoenvironment where current flows caused the scouring and casting of the traces. Sedimentation rates and frequency of abrupt deposition were primary parameters. This led to coarse-grained graded beds of turbiditic origin. *Helminthopsis* isp. was formed by a mobile trace maker burrowing through the sediment. The trace fossil reflects repichnial behaviour. *Ophiomorpha rudis* can be interpreted as fodinichnion, formed as an open burrow system. Uchman (2009) suggested that the trace makers farmed microbes on phytodetritus at the redox boundary. The trace fossil assemblage of the Isparta Formation has a low ichnodiversity and ichnotaxonomically resembles the *Ophiomorpha rudis* ichnosubfacies as defined by Uchman (2009). This ichnosubfacies is part of the *Nereites* ichnofacies. The Isparta Formation was deposited as a proximal deep-marine fan with coarse-grained sediments. In comparison, the *Ophiomorpha rudis* ichnosubfacies has been recorded from channel and proximal depositional lobe facies of deep-sea fans. In addition, the ichnosubfacies may occur in thick interbedded facies of deep-sea clastic ramps (Uchman 2009).

İncesu Formation. – The Middle Eocene to Early Oligocene İncesu Formation contains a variety of trace fossil indicating well-oxygenated interstitial water and readily available food. At Gönen Kale Hill (locality 6), the trace fossil assemblage is characterised by fodinichnia such as *Palaeophycus tubularis*, *Thalassinoides* cf. *suevicus* and *Zoophycos* isp. (Table 1, Fig. 10). Pascichnial trace fossils are also common and include *Scolicia* isp. and *Planolites* ispp. Horizontal trace fossils prevail. The sediments are intensively bioturbated. The trace fossil assemblage is typical of the *Zoophycos* ichnofacies that was formed in relatively low-energy offshore depositional settings with a low to moderate sedimentation rate. The deposition is likely to have taken place in an outer shelf environment.

Overall, the trace fossil assemblages of the investigated formations indicate depositional conditions including substrate consistency and stability, events of gentle erosion and filling, and oxygenation levels. The density, diversity and preservation of the trace fossils successfully show the sedimentation history. These yield important new results about the Lake District in the northern Isparta Angle.

Ichnology of other regions in Turkey

Based on the previous literature, ichnological data from Turkey can be summarised in the following synthesis (Table 2). Trace fossils formed by bioturbational conditions were recorded from Maastrichtian-Paleocene sediments in the Bolu region (Sevim 2003); the Paleogene sediments in the Elazığ region (Özkul 1993), in the Thrace (Demircan 2008); the Miocene sediments in the Adana Basin (Uchman & Demircan 1999a, b; Demircan & Toker 2003, 2004), in the Mut (Mersin) Basin (Uchman *et al*. 2002); Pliocene-Pleistocene sediments in the Mut (Mersin) Basin (Yıldız *et al*. 2003) (Fig. 1). Microscopic bioerosion records come from the Maastrichtian sediments from the Bilecik, Bolu, Ankara, Isparta, Malatya and Adıyaman regions (Görmüţ & Sagular 1998, Görmüţ & Meriç 2000, Meriç & Görmüş 2001, Nielsen & Görmüş 2004, Görmüş *et al*. 2005, Görmüş & Nielsen 2006) (Fig. 1). A comparison with these investigations relies on two main factors. First, the biostratigraphical age of the deposits must be assumed to be accurately recognized from their content of indicator taxa. Second, the observed trace fossils are correctly assigned to ichnotaxa. The latter presupposes that the trace fossils are sufficiently well preserved to reveal diagnostic morphological features.

Conclusions

The Triassic to early Cretaceous and Paleocene to Oligocene trace fossils from southwestern Turkey presented in this paper provide a data set which highlights the different depositional conditions of shelf environments in relation to deep-marine shelf slope environments. The integration of ichnology with classical sedimentology has improved the understanding of the Neotethys sedimentary successions at Eğirdir, Gönen and Isparta within the Isparta Angle. The successions are characterized by a predominance of primary physical sedimentary structures, and subordinance or even absence of skeletal and shelly assemblages. The biogenic sedimentary structures, *i.e.*, traces, were strongly controlled by the prevailing environment. The Isparta Çay Formation and its trace fossils are interpreted as *Paleodictyon* ichnosubfacies of the *Nereites* ichnofacies. The Koçtepe Formation contains two distinct trace fossil assemblages, which comprise the *Nereites* and *Arenicolites* ichnofacies. The trace fossil assemblage of the Isparta Formation can be assigned to the *Ophiomorpha rudis* ichnosubfacies of the *Nereites* ichnofacies. The development of ichnofacies indicates that the Isparta Çay, Koçtepe and Isparta formations formed in deep-marine environments with different sedimentary regimes. The İncesu Formation and its trace fossils are interpreted as *Zoophycos* ichnofacies from a shelf setting in the Neotethys ocean.

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