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TRACE FOSSILS FROM DEEP SEA SEDIMENTS OF THE LATE EOCENE CEYLAN FORMATION, GELİBOLU PENINSULA (SW THRACE, TURKEY)

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ABSTRACT

In this study, trace fossils of the Ceylan Formation (Late Eocene) in the area NW of Fındıklı village and on the coast of the Ece Bay the Gelibolu Peninsula are identified for the first time. They occur in gray siltstones and mudstones intercalated with thin-bedded, parallel and ripple laminated sandstones, which were deposited on a basin plain in proximilt of a slopes in the Thrace Basin. The Late Eocene Ceylan Formation includes pre-depositionl (*Belorhaphe zickzack*, *Desmograpton* isp., *Helicolithus ramosus, Helminthorhaphe flexuosa, Paleodictyon majus, Paleodictyon minimum, Paleodictyon strozzii, Saerichnites* isp., *Urohelminthoida appendiculata*) and post-depositional (*Phycosiphon incertum, Spongeliomorpha oraviense, Trichichnus* isp., *Planolites* isp., *Ophiomorpha* isp., *Ophiomorpha annulata, Scolicia* isp., *Scolicia prisca*, and *Thalassinoides* isp.) trace fossils. This trace fossil assemblage is typical of the *Nereites* ichnofacies (*Paleodictyon* ichnosubfacies), which characterize deep-sea, thin bedded turbididitic sediments oxygenated sea floor.

1. Introduction

The Ceylan Formation is a characteristic Late Eocene lithostratigraphic unit of the Thrace Basin in the study area is located in badlands NW of Fındıklı village and in the coastal cliffs of the Ece Bay (Figure 1A). These areas were studied mainly in terms of stratigraphy and regional geology (Ternek, 1949; Druit, 1961; Önem, 1974; Saltık, 1974; Saner, 1985; Sümengen et al., 1987; Önal, 1987; Şentürk and Karaköse, 1987; Siyako et al., 1989; Okay et al., 1990; Sümengen and Terlemez, 1991; Erol, 1992; Temel and Çiftçi, 2002; Kesgin and Varol, 2003), palaeontology (Sönmez-Gökçen, 1964, 1973; Gökçen, 1967, 1971, 1972; Tekkaya, 1973; Taner, 1977, 1981, 1983, 1994; Freels, 1980; Toker and Erkan, 1985; Ünal, 1996; Şafak, 1999; Tunoğlu and Ünal, 2001*a, b*). Very few papers refer to ichnology (Demircan, 2008; Demircan and Uchman, 2016).

In this paper, trace fossils of the Ceylan Formation are presented and interpreted in reference to palaeoenvironment.

2. General Geology and The Ceylan Formation

The Gelibolu Peninsula is built of pre-Cenozoic basement units which are unconformably overlaid by Eocene deposits (Figures 1A–C).

In the Gelibolu Peninsula, the pre Cenozoic basement consists of the pre-Maastrichtian ophiolitic complex settled in and Maastrichtian-Paleocene limestones. They are covered by the Lower Eocene deep-sea mudstones and sandstones of the Karaağaç Formation. Generally, this formation shows an increase in grain sizes and bedding thicknesses up the section. The the Karaağaç Formation is overlain conformably by the fluvial red beds of the Early-Middle Eocene Fıçıtepe Formation. It is covered unconformably by *nummulitic*-reefal limestones of the Middle Eocene Soğucak Formation, which is locally accompanied by sandstones and conglomerates. Above, the deep-sea Late Eocene Ceylan Formation is present. It is dominated by calcareous, massive mudstones intercalated by turbiditic sandstone-mudstone beds. Contribution of the turbiditic sandstones is higher in the part of the sections studied. The overlying Mezardere, Osmancık and Armutburnu

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formations, with a transition from shales to nearshore sandstone-dominated facies of a deltaic complex mark a regression, which started at the beginning of Oligocene. An extensive volcanism (Hisarlıdağ-Ayvacık volcanics) predominated during Early-Middle Miocene in the region. Sedimentary deposition that developed during Late Miocene continued until the beginning of Early Pliocene.

The Gazhanedere, Kirazlı and Alçıtepe formations have been formed in this time period. The Pliocene-Quaternary Ergene Formation, which does not outcrop on the land was detected in drills and seismic sections carried out by TPAO. All these units in the study area have then been unconformably covered by Quaternary alluvia (Siyako et al., 1989).

The Ceylan Formation was named by Ünal (1967), with its type sections in Fındıklı-1 and Ece Bay-1 in which basin plain deposits were interpreted.

In the study area, the Ceylan Formation sediment succession begins with volcanic tuffs and grades up into calcareous, massive mudstones. The tuffs are subdivided into two part: thin bedded and massive tuffs. The thin bedded tuff consists of fine-grained volcanic groundmass which contain mud pieces,

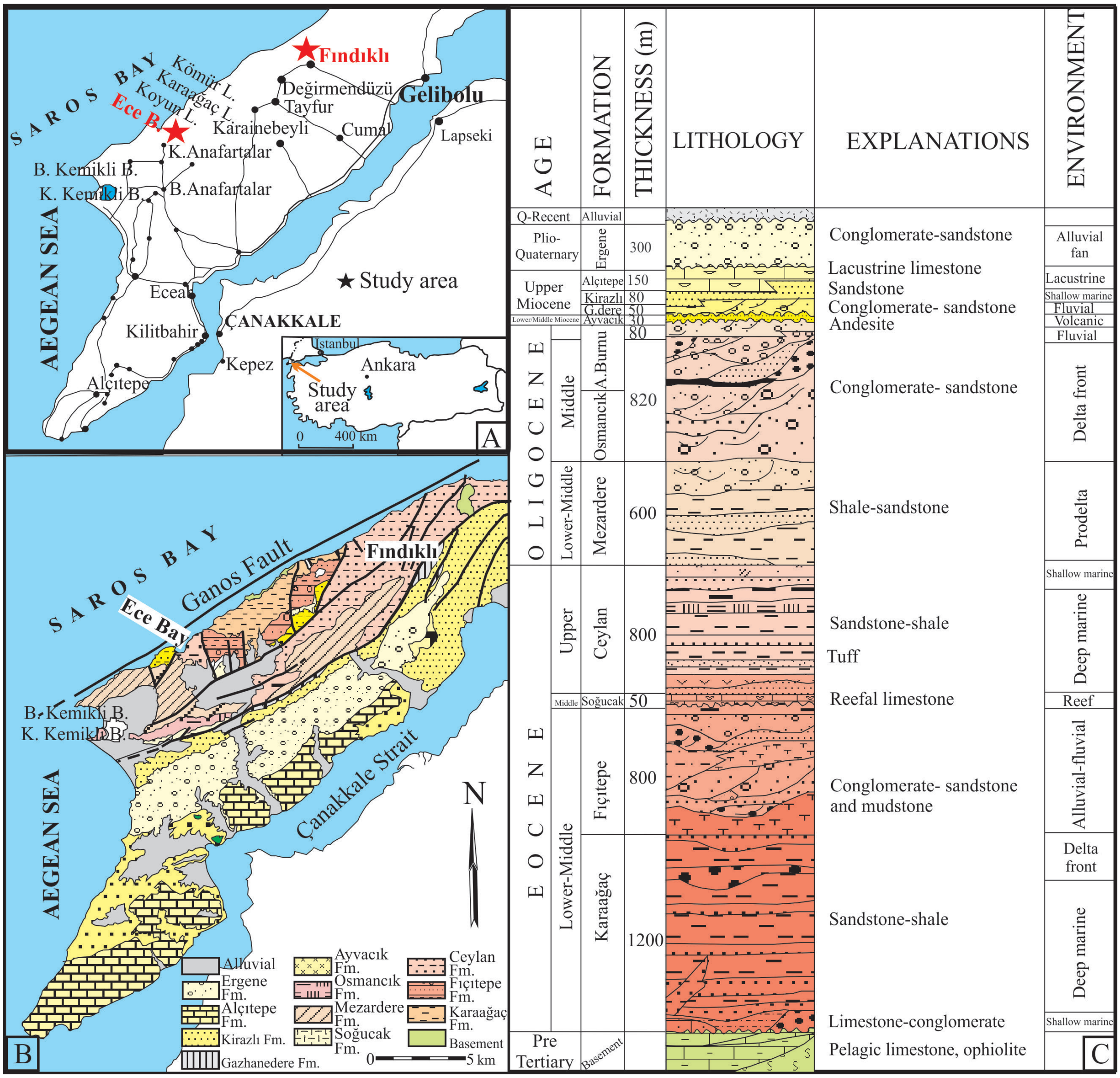

Figure 1- A) Location map of the study area. B) Geological map. C) Generalized stratigraphic column of the Gelibolu Peninsula (from Temel and Çiftçi, 2002).

pebble grains and volcanic rock fragments of various sizes. It passes gradually up into bedded and unbedded fine-grained tuffs. These tuffs also grade up into calcareous mudstones, which are rich in carbonates, structureless, and rarely interbedded by thin bedded, granular sandstone layers. The calcareous mudstones gradually pass up into gray massive mudstones, which contain vertical and horizontal trace fossils. In the lower and middle part, they contain intercalations of thin-bedded sandstones, which contribution increases up the section.

In average, The Ceylan Formation is 560 m thick, but it the thickness varies from 300 to 600 m depending on the geometry of the basin (Sümengen and Terlemez, 1991). The late Eocene age is based on *Pityosporites* spp., *Triletes* sp., *Echinatisporites* sp., *Batiacasphaera* sp., *Homotryblium plectilum, Diphyes colligerum*, *Deflandrea phosphoritica, Hystrichokolpoma* sp., *Ceistosphaeridium* sp., *Cordosphaeridium* sp., chitinous foraminiferal inner walls and the Hypae palynomorph assemblage obtained from the mudstone samples (Batı et al., 2002). The sandstone and shale dominated parts are referred to a deep sea turbiditic system (Kesgin and Varol, 2003).

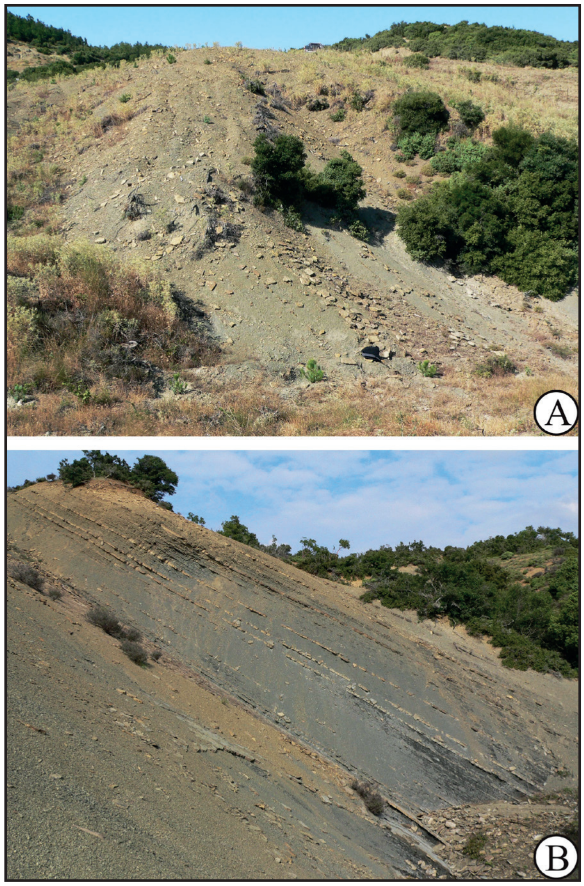

Figure 2- The Ceylan Formation in the Fındıklı-1 section. A) The outcrop with sandstones containing graphoglyptids of the Ceylan Formation (Fındıklı village). B) Thin-bedded sandstone intercalations in calcareous mudstones in the lower part of the gorge.

3. The Studied Sections

3.1. The Fındıklı-1 section

Fındıklı-1 section is located in the NW part of the Gelibolu Peninsula, along the road between Fındıklı village and Kömür limanı (harbor) and gorges SW of the road (GPS coordinates: N40°26.866′; E026°31.700′; ±9 m). (Figures 1A, B).

The succession is formed by thin-bedded, fine-grained, turbiditic sandstone-siltstone beds intercalated with turbiditic and hemipelagic calcareous mudstones (Figure 2). The sandstones are parallel and ripple laminated. Lower bedding surfaces of the sandstone beds are rich in semi-reliefs of patterned, meandering, star- and net-shaped invertebrate trace fossils ascribed mainly to graphoglyptids.

The trace fossils include (from the bottom to the top) pre-depositional *Paleodictyon majus*, *Helminthorhaphe flexuosa*, *Urohelminthoida appendiculata*, *Belorhaphe zickzack*, *Phycosiphon incertum*, *Ophiomorpha annulata*, *Desmograpton* isp., *Saerichnites* isp. and post-depositional *Spongeliomorpha oraviense* and *Thalassinoides* isp., which occur on the lower bedding surfaces of the thin- and medium-bedded sandstone beds. Moreover, the trace fossils *Trichichnus* isp., *Phycosiphon incertum* are present in the gray mudstones (Figure 3).

3.2. The Ece Bay-1 section

The Ece Bay-1 (Ece Limanı-1) section is located in the cliffs of the Ece limanı coast, in the NW part of the Gelibolu Peninsula (GPS coordinates: N40°21.810′; E025°19.710′; ±9 m) (Figures 1-A, B).

The succession is formed by gray mudstone intercalated with thin-bedded, fine-grained sandstone beds (Figure 4). In the mudstones, *Trichichnus* isp., was recognized. The sandstone beds contain *Thalassinoides* isp., *Planolites* isp., *Ophiomorpha annulata*, *Scolicia* isp., *Scolicia prisca* (rare), *Helminthorhaphe flexuosa, Phycosiphon incertum* and *Helicolithus ramosus* (formerly known as *Punctorhaphe paralella*) (Figure 5).

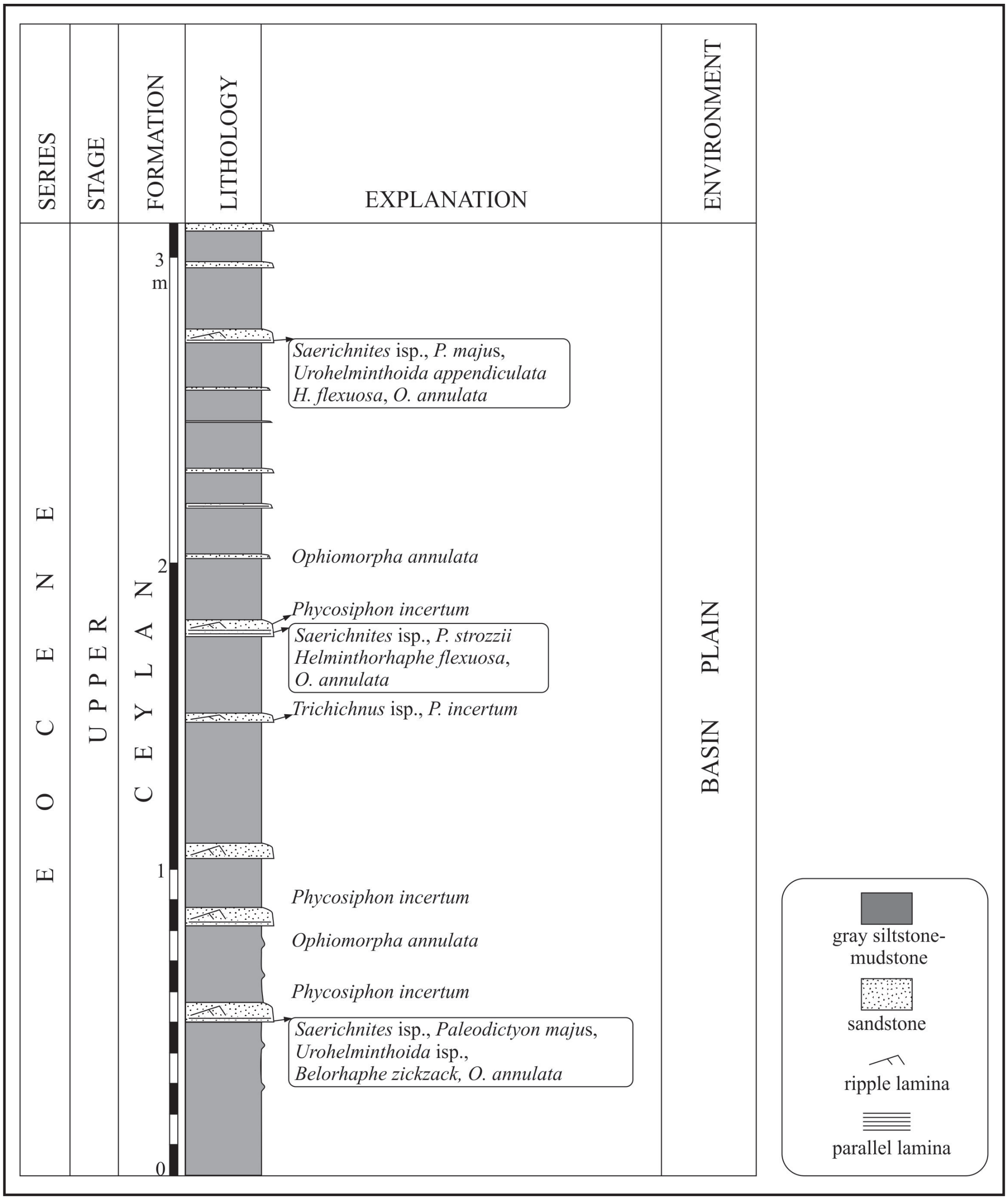

Figure 3- The Fındıklı-1 measured section with trace fossil distribution.

4. Trace Fossils

The section were studied “bed-by-bed”, with registration of lithology and trace fossils, which were documented by photography, mostly in place.

Nineteen ichnotaxa are have been recognized in the study area. Their more extensive is in the monographs and papers by Häntzschel (1975), Książkiewicz (1977), Seilacher (1977), Fillion and Pickerill (1990), Crimes and Crossley (1991) and Uchman (1998).

4.1. Simple and Branching Structures

This group consists of mostly tubular, variable oriented structures, formed mainly by “worms” and “crustaceans” (e.g., Książkiewicz, 1977; Demircan and Toker, 2003).

***Planolites* Nicholson, 1879**

***Planolites* isp.**

Description: Horizontal, hypichnial, tubular structures, without wall, 2–4 mm in diameter.

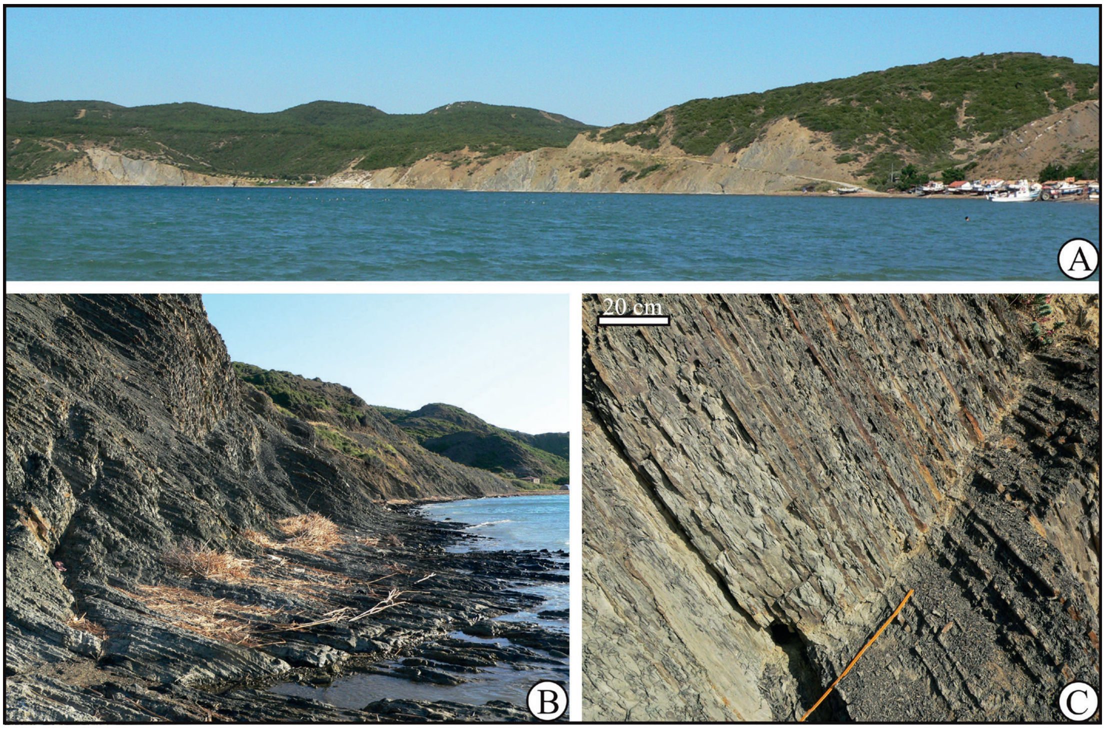

Figure 4- The Ceylan Formation in the Ece Bay-1 section A) General view of the Ceylan Formation outcrops along the Ece limanı coast. B, C) Intercalations of sandstone and siltstone beds in fine in mudstones.

Remarks: *Planolites* occurs in a great variety of facies and is formed mainly by deposit-feeding "worms" (Pemberton and Frey, 1982). It ranges from the Precambrian to the Recent (Häntzschel, 1975).

Ophiomorpha **Lundgren, 1891**

Ophiomorpha **isp.**

(Plate III, Figure B)

Description: Horizontal, hypichnial, tubular structures, with a wall, preserved in full relief, 8–9 mm in diameter, traced for a distance up to 60 mm.

Remarks: The described *Ophiomorpha* isp., resembles *Ophiomorpha rudis* Książkiewicz, 1977 (Uchman, 1991, 2009). *Ophiomorpha*, produced mainly by decapod crustaceans, can intergrade with *Thalassinoides, Spongeliomorpha* and *Gyrolithes* (e.g., Kennedy, 1967; Fürsich, 1973; Bromley and Frey, 1974; Kern and Warme, 1974.

Ophiomorpha annulata **(Książkiewicz, 1977)**

(Plate I, Figure A)

Description: Mainly horizontal, tubular structure with a wall, 3.3 mm wide, observed on the distance up to 40 mm.

Remarks: This ichnospecies was described under *Granularia* Pomel or *Sabularia simplex* Książkiewicz, 1977) but it was included in *Ophiomorpha* (Uchman, 1995; Tunis and Uchman, 1996 *a,b*).

Saerichnites **Billings, 1866**

Saerichnites **isp.**

(Plate I, Figure B)

Description: A group of hypichnial hemispherical mounds, approximately 8.3 mm in diamneter.

Remarks: *Saerichnites* Billings, 1866 (see also Häntzschel, 1975) has then been interpreted by Uchman (1995) as casts of shafts connecting a burrow system with the sea floor.

Spongeliomorpha oraviense **(Książkiewicz, 1977)**

(Plate I, Figure C)

Description: A short, tubular structure covered by oblique short ridges, about 10 mm in diameter.

Remarks: This trace fossil was described under *Halymenidium* by Książkiewicz (1977) and was included in *Spongeliomorpha* by (Uchman, 1998).

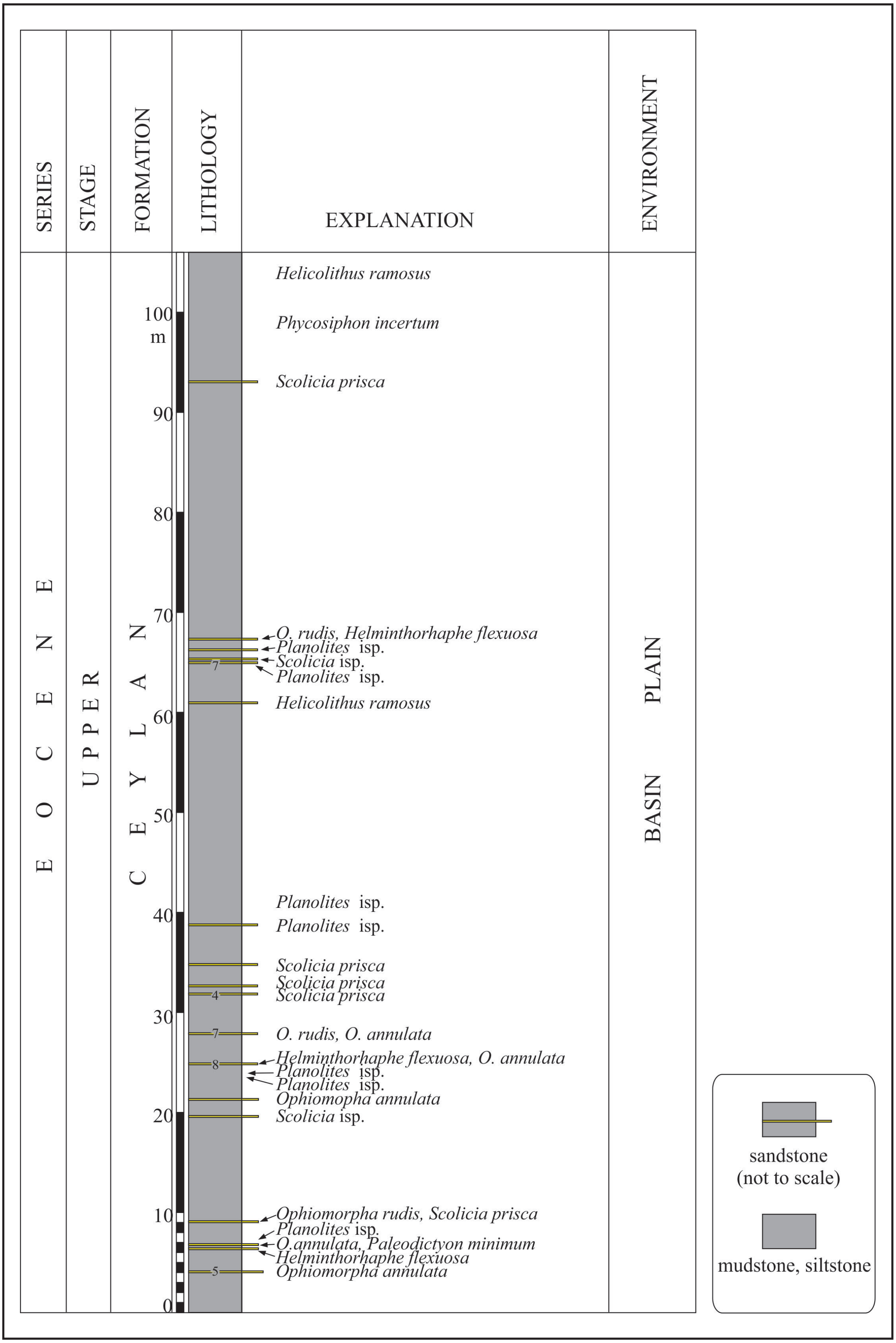

Figure 5- The Ece Limanı-1 measured section with distribution of trace fossils.

The ridges are interpreted as casts of scratch marks of crustaceans.

***Thalassinoides* Ehrenberg, 1944**

***Thalassinoides* isp.**

(Plate I, Figures D, E)

Description: Mostly horizontal, tubular, branched burrows, about 10 mm in diameter. They show Y- and T-shaped branches. They form three-dimensional burrow systems, which include shafts connecting the horizontal parts with the sediment surface.

Remarks: *Thalassinoides* is produced mainly by crustaceans, typically in shallow-marine environments, but also in the deep sea (Frey et al., 1984; Ekdale, 1992). According to Föllmi and Grimm (1990), the *Thalassinoides* crustacean tracemaker can survive transportation by turbiditic currents and make burrows even in anoxic conditions for a limited time. *Thalassinoides,* widely distributed in the Mesozoic and Cenozoic, occurs also in shallow-water sediments in the Paleozoic (e.g., Palmer, 1978; Archer and Maples, 1984; Sheehan and Schiefelbein, 1984; Stanistreet, 1989; Kulkov, 1991).

Large tubular burrow

(Plate I, Figure F)

Description: Horizontal, cylindrical structure, 27–30 mm in diameter, without branches.

Remarks: Usually, such large burrows are mainly formed by crustaceans in shallow-marine environments (Frey et al., 1984), but they can occur also in turbiditic systems (Uchman, 1991).

***Trichichnus* Frey, 1970**

***Trichichnus* isp.**

(Plate II, Figure A)

Description: Branched or unbranched, thread-like, cylindrical, straight or slightly winding structure, filled with pyrite or iron oxides, variable oriented, less than 1 mm in diameter.

Remarks: *Trichichnus*, formed by opportunistic organisms, was discussed by Fillion and Pickerill (1990) then by Uchman (1995, 1999). It is interpreted as a structure formed by sulphur bacteria in the transition between anoxic-dysoxic sediments (Kędzierski et al., 2015).

4.2. Winding and Meandering Structures

The studied trace fossils ascribed to this group include horizontal structures produced by irregular echinoids (*Scolicia*) and some graphoglyptids produced by small, unknown invertebrates.

***Scolicia* de Quatrefages, 1849**

***Scolicia* isp.**

(Plate II, Figure B)

Description: Hypichnial, trilobate, curved or meandering ridge, 25–30 mm wide.

Remarks: *Scolicia* is formed by irregular echinoids (Uchman, 1995) and ranges from Late Jurassic to Recent (Tchoumatchenco and Uchman, 2001).

***Scolicia prisca* de Quatrefages, 1849**

(Plate II, Figure C)

Description: Epichnial, trilobate, curved or meandering furrows, 15–25 mm wide and up to 3.5 mm deep. The middle lobe is convex up and 6 mm wide, covered with perpendicular ribs. The lateral lobes are covered by oblique ribs.

Remarks: This ichnospecies is formed by irregular echinoids at the transition between sandstone and mudstone within turbiditic beds (Uchman, 1995). It ranges from Late Jurassic to Recent (Tchoumatchenco and Uchman, 2001).

***Helminthorhaphe* Seilacher, 1977**

***Helminthorhaphe flexuosa* Uchman, 1995**

(Plate II, Figures D-E)

Description: Hypichnial meandering strings in fine-grained sandstones. The strings are 1.5-2 mm in diameter and the meanders are 55–60 mm deep and 2–3 mm wide, without bulges in the turns.

Remarks: This is graphoglyptid burrow produced by unknown worms, described also *Helminthorhaphe crassa* (see Seilacher, 1977).

***Helicolithus ramosus* (Vialov, 1971)**
(Plate II, Figure F; Plate III, Figure A)

Description: Hypichnial, tight meanders composed of aligned knobs, 0.8–1.0 mm in diameter, 1.5–2.0 mm.

Remarks: The aligned knobs are casts of shafts connecting spiral string arranged in meanders (Tunis & Uchman, 1996b). *Helicolithus ramosus* ranges from the Senonian (Książkiewicz, 1977) to the Miocene (D'Alessandro, 1980.

4.3. Branched Winding and Meandering Structures

***Belorhaphe* Fuchs, 1895**
***Belorhaphe zickzack* (Heer, 1877)**
(Plate III, Figure B)

Description: Hypichnial semi-relief zigzag meanders in fine grained turbiditic sandstones. The turning points of the zigzag are enlarged and are 5 mm wide. The zigzag turnsat the angle of approximately 50°. The string is 1.0–1.5 mm wide.

Remarks: *Belorhaphe zickzack* ranges from the Beriassian (Książkiewicz, 1977) to the Oligocene (Nowak, 1970) and occurs mainly in deep marine clastic sediments.

***Desmograpton* Fuchs, 1895**
***Desmograpton* isp.**
(Plate III, Figure C)

Description: Hypichnial rows parallel to sub-parallel ribs in fine grained turbiditic sandstones, preserved in semi-relief. The ribs are curved, their relief is semicircular od asymmetrically oval. The ribs are 5.5-6.0 mm, 1–1.5 mm wide.

Remarks: *Desmograpton* is a typical three dimensional graphoglyptid (Seilacher, 1977) showing a series of preservational variants (Uchman, 1995). It ranges from the Silurian (McCann, 1989, 1993) to the Miocene (D Alessandro, 1980; Uchman, 1995).

***Urohelminthoida* Sacco, 1888**
***Urohelminthoida appendiculata* (Heer, 1877)**

Description: Hypichnia meanders with protrusions in the turning points of the meanders, preserved in semi-relief in fine grained turbiditic sandstones. The string is undulating, 2 mm wide, and the meanders are 35-40 mm deep and 4 mm wide.

Remarks: This is a typical graphoglyptid (Seilacher, 1977; Uchman, 1995).

4.4. Networks Structures

***Paleodictyon majus* Meneghini in Peruzzi, 1880**
(Plate III, Figure E)

Description: Hypichnial hexagonal nets in fine-grained turbiditic sandstones. Meshes of the net are 6.0-7 mm wide and the string is 0.5 mm wide.

Remarks: This is common ichnospecies of *Paleodictyon* in Cenozoic turbidites (Książkiewicz, 1977). *Paleodictyon*, a typical graphoglyptid, is interpreted mainly as a farming structure (Seilacher, 1977), produced mostly in the deep-sea sediments, occasionally occurring in shelf sediments in the Paleozoic (Archer and Maples, 1984; Paczesnia, 1985) and in the Mesozoic (Häntzchel, 1964; Gierlowski-Kordesch and Ernst, 1987; Hantzpergue and Branger, 1992). *Paleodictyon* stratigraphically ranges from the Cambrian (Crimes and Anderson, 1985; Pacześna, 1985) to Recent (Ekdale, 1980; Miller, 1991).

***Paleodictyon minimum* (Sacco, 1888)**

Description: Hypichnial net composed of a string which is 0.25–0.3 mm wide and arranged in meshes which are1–2 mm wide.

Remarks: This ichnospecies is known mostly from Cenozoic turbidites (e.g.,Kindelan, 1919; Vialov & Golev, 1965).

***Paleodictyon strozzii* Meneghini in Savi & Meneghini, 1850**
(Plate III, Figures D, E)

Description: Hypichnial hexagonal nets in fine grained turbiditic sandstones. Their strings are 0.5–1.0 mm wide and the meshes are 3.6–4.5 mm wide .

Remarks: Individual meshes are of different size and can be elongated.

4.5. Spreite Structures

Phycosiphon incertum **Fischer-Ooster, 1858**
(Plate III, Figure F)

Description: Small, horizontal lobes encircled by meandering marginal tunnel. The lobes are 1–3 mm wide and up to 10 mm long. The marginal tunnel is about 1 mm wide.

Remarks: *Phycosiphon incertum* is generally formed by sediment-feeders in the early stage of colonization of turbiditic fine-grained sediments (Wetzel and Uchman, 2001; Uchman et al,. 2004). For discussion of this trace fossil see Wetzel and Bromley (1994).

5. Discussion

Taking the morphological characteristics of the trace fossils into consideration, the determination of the trace fossil assemblages in the sections studied, composed of pre-depositional *Belorhaphe zickzack, Desmograpton* isp., *Helicolithus ramosus, Helminthorhaphe flexuosa*, *Paleodictyon majus, Paleodictyon minimum, Paleodictyon strozzii, Saerichnites* isp., *Urohelminthoida appendiculata* and post-depositional *Phycosiphon incertum, Planolites* isp., *Ophiomorpha* isp., *Ophiomorpha annulata, Scolicia* isp., *Scolicia prisca*, *Spongeliomorpha oraviense*, *Trichichnus* isp., and *Thalassinoides* isp. is typical of the *Nereites* ichnofacies; the high contribution of graphoglyptids points to the *Paleodictyon* ichnosubfacies, which is characteristic of thin-bedded sandy turbidites in different parts of depositional systems (Uchman & Wetzel, 2012). The turbidites studied formed in the basin plain or the lower slope, probably in fringes of small fans or isolated lobes. The trace fossils, especially these formed without permanent connection to the sea floor (*Planolites, Phycosiphon, Scolicia*), indicate good oxygenation in pore waters.

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References

Archer, A.W., Maples, C.G. 1984. Trace fossil distribution across a marine to nonmarine gradient in the Pennsylvanian of South Western Indiana. *Journal of Paleontology* 58, 448–466.

Batı, Z., Alişan, C., Ediger, V.Ş., Teymur, S., Akça, N., Sancay, H., Ertuğ, K., Kirici, S., Erenler, M., Aköz, Ö. 2002. Kuzey Trakya Havzası'nın Palinomorf, Foraminifer ve Nannoplankton Biyostratigrafisi. Trakya Litostratigrafi Birimleri Kitabı, *General Directorate of Mineral Research and Exploration.* 14.

Billings, E. 1866. Catalogues of the Silurian Fossils, 93, *Geological Survey of Canada, Dawson Brothers, Montreal.*

Bromley, R.G., Frey, R.W. 1974. Redescription of the trace fossil *Gyrolites* and taxonomic evaluation of *Thalassinoides, Ophiomorpha* and *Spongeliomorpha*: *Bulletin of the Geological Society of Denmark* 23, 311–335.

Crimes, T. P., Anderson, M. M. 1985. Trace fossils from Late Precambrian-Early Cambrian strata of southeastern Newfoundland (Canada): temporal and environmental implications. *Journal of Paleontology* 59, 310–343.

Crimes, T.P., Crossley, J.D. 1991. A diverse ichnofauna from Silurian flysch of the Aberystwyth Grits formation, Wales. *Geological Journal* 26, 27–64.

D'Alessandro, A. 1980. Prime osservacioni sulla ichnofauna miocenica della "formazione di Gorgolione" (Castelmezzano, Potenza). *Rivista Italiana di Paleontologia e Stratigrafia* 86, 357–398.

Demircan, H. 2008. Trace fossil associations and palaeoenvironmental interpretation of the late Eocene units (SW-Thrace). *Bulletin of the Mineral Research and Exploration* 136, 29–47.

Demircan, H., Toker, V. 2003. Trace fossils in the western fan of the Cingöz Formation in the northern Adana Basin (southern Turkey). *Bulletin of the Mineral Research and Exploration* 127, 15–32.

Demircan, H., Uchman, A. 2013*a*. Ichnological features of prodelta sediments from the Mezardere Formation (Late Eocene – Early Oligocene), Gökçeada Island, NW Turkey. Paper presented during conference: H. Demírcan (Ed.), XII. International ichnofabric workshop, 30th June– 5th July 2013, Çanakkale – Türkiye, Abstracts (pp. 24–25).

Demircan, H., Uchman, A. 2013*b*. 4th July 2013, Gökçeada Island. In H. Demírcan and A. Uchman (Eds.), Ichnological sites of the Gelibolu Peninsula and the Gökçeada Island, Thrace, NW Turkey. XII. International Ichnofabric Workshop, 30th June–5th July 2013, ÇanakkaleTürkiye. Field Guidebook (pp. 69–82).

Demircan, H., Uchman, A. 2016. Ichnology of prodelta deposits of the Mezardere Formation (late Eocene – early Oligocene) in the Gökçeada island, western Turkey. Geodinamica Acta 28, 86–100.

Druit, C. E. 1961. Report on the petroleum prospect of Thrace, Turkey: Turkish Gulf Oil Co. TPAO, Archive no: 1427 (unpublished).

Ekdale, A. A. 1980. Trace fossils in Deep Sea Drilling Project Leg 58 cores. *Initial Reports of Deep Sea Drilling Project.* 58, 601-605.

Ekdale A.A. 1992. Muckraking and mudslinging: the joys of deposit−feeding. In: C.G. Maples and R.R. West (eds) Trace fossils. Short Courses in Paleontology 5: 145–171. *The Paleontological Society,* Knoxville, Tennessee.

Erol, O. 1992. Çanakkale Yöresinin Jeomorfolojik ve Neotektonik Evrimi. *Bulletin of Turkish Association of Petroleum Geologists,* 4/1, 147–165.

Fillión, D., Pickerill, R. K. 1990. Ichnology of the Upper Cambrian? to Lower Ordovician Bell Island and Wabana groups of eastern Newfoundland, Canada. *Palaeontographica Canadiana* 7, 1–119.

Föllmi, K. B., Grimm, K. A. 1990. Doomed pioneers: Gravity-flow deposition and bioturbation in marine oxygen-deficient environments. *Geology* 18, 1069–1072.

Freels, D. 1980. Limnische Ostracoden aus Jungtertiar und Quaterder Turkei. *Geologisches* Jahrbuch*,* Reihe *B, Heft* 39, 172.

Frey, R. W., Curran, A.H., Pemberton, S.G. 1984. Trace making activities of crabs and their environmental significance: the ichnogenus *Psilonichnus*. *Journal of the Paleontology* 58, 511–528.

Fürsich, F. T. 1973. A revision of the trace fossils *Spongeliomorpha, Ophiomorpha* and *Thalassinoides*: *Neues Jahrbuch für Geologie und Paläontologie* Monatshefte, 1972, 719–735.

Gierlowski-Kordesch, E., Ernst, F., 1987. A flysch trace fossil assemblage from the Upper Cretaceous shelf of Tanzania: Mathies, G. and Schandelmeir, H., eds., Current Research in *African Earth Sciences, 14th Colloquium on African Geology,* Berlin, 18–22 August, 1987, p. 217–221.

Gökçen, S., L. 1967. Keşan Bölgesinde Eosen-Oligosen Sedimantasyonu, Güneybatı Türkiye Trakyası, *Bulletin Mineral and Research Exploration*, 69, 1–10.

Gökçen, S., L. 1971. Keşan Bölgesi Türbiditlerinde Sedimantasyon. *Hacettepe Fen ve Mühendislik Bilgileri Dergisi* 1, 1, 26–40.

Gökçen, S., L. 1972. Keşan Bölgesi Kumtaşlarının Yapısal, Dokusal Özellikleri ve Bölgenin Sedimanter Fasiyesleri. *Hacettepe Fen ve Mühendislik Bilgileri Dergisi*, 2, 1, 50–65.

Hantzpergue, P., Branger, P. 1992. L'ichnogenre *Paleodictyon* dans les depots neritiques de l'Oxfordien superieur NordAquitaine (France*). Geobios* 25, 195–205.

Häntzschel, W., 1964. Spurenfossilien und Problematica im Campan von Beckum (Westf.). Fortschritte in der *Geologie von Rheinland und Westfalen* 7, 295–308.

Häntzschel, W. 1975. Trace fossils and problematica. In: C. Teichert (ed.), Treatise on Invertebrate Paleontology. Part W, Miscellanea, Supplement I, W1–269. *Geological Society of America and University of Kansas Press*, Colorado, Boulder.

Kennedy, W.J. 1967. Burrows and surface traces from the Lower Chalk of southern England: *Bulletin of the British Museum (Natural History) Geology* 15, 127–167.

Kern, J.P., Warme, J. E. 1974. Trace fossils and bathymetry of the Upper Cretaceous Point Loma formation, San Diego, California. *Geological Society of America Bulletin* 85, 893–900.

Kędzierski, M., Uchman, A., Sawłowicz, Z. and Briguglio, A. 2015. Fossilized bioelectric wire – the trace fossil *Trichichnus*. *Biogeosciences* 12, 2301–2309. doi:10.5194/bg-12-2301-2015.

Kesgin, Y., Varol, B. 2003. Gökçeada ve Bozcaada' nın Tersiyer jeolojisi (Çanakkale), Türkiye. *Bulletin of Mineral Research Exploration,* 126, 49–67.

Kindelan, D.V. 1919. Nota sobre el Cretácico y el Eoceno de Güipozcoa, España: Inst. *Boletín del Instituto Geológico de España,* 20,165–198.

Książkiewicz, M. 1977. Trace fossils in the flysch of the Polish Carpathians. *Paleontologica Polonica* 36, 208.

Kulkov, N.P. 1991. The trace fossil *Thalassinoides* from the Upper Ordovician of Tuva: *Lethaia*, 24, 187–189.

McCann, T., 1989. The ichnogenus *Desmograpton* from the Silurian of Wales- first record from the Paleozoic. *Journal of Paleontology* 58, 950–953.

McCann, T., 1993. A *Nereites* ichnofacies from the Ordovician - Silurian Welsh Basin. *Ichnos* 3, 39–56.

Miller, M.F. 1991. Morphology and distribution of Paleozoic *Spirophyton* and *Zoophycos*: implications for the *Zoophycos* ichnofacies. *Palaios* 6, 410–425.

Nowak, W., 1970. Problematical organic traces of *Belorhaphe* and *Sinusites* in the Carpathian Lower Cretaceous and Paleogene flysch deposits. (In Polish, English summary). *Kwartalnik Geologiczny*, 14, 149–162.

Okay, İ. A., Siyako, M., Burkan, K. A. 1990. Biga Yarımadası' nın Jeolojisi ve Tektonik Evrimi. *Bulletin of Turkish Association of Petroleum Geologists,* 2/1, 83–121.

Önal, M., 1987. Gelibolu Yarımadası orta bölümünün çökelme istiflen ve tektoniği, KB Anadolu, Türkiye. *Yerbilimleri* 5, 21–38.

Önem, Y. 1974. Gelibolu ve Çanakkale dolaylarının jeolojisi. TPAO Report no: 877 (unpublished).

Pacześnia, J.I. 1985. Ichnorodzaj *Paleodictyon* ini z dolnego kambru Zbilutki (Góry Świętokrzyskie). *Kwartalnik Geologiczny* 29, 589–596

Palmer, T.J. 1978. Burrows at certain omission surfaces on the Middle Ordovician of the Upper Mississippi Valley. *Journal of Paleontology* 52, 109–117.

Pemberton, S. G., Frey, R. W. 1982. Trace fossil nomenclature and the *Planolites–Palaeophycus* dilemma. *Journal of Paleontology* 56, 843–881.

Saltık, O. 1974. Şarköy-Mürefte sahalarının jeolojisi ve Petrol olanakları: TPAO Raport no: 879, 30pp.

Saner, S. 1985. Saros Körfezi Dolayının Çökelme İstifleri ve Tektonik Yerleşimi, Kuzeydoğu Ege Denizi, *Geological Bulletin of Turkey* 28/l, 1–10.

Seilacher, A. 1977. Pattern analysis of *Paleodictyon* and related trace fossils: Crimes, T. P. &Harper, J. C. eds., Trace fossils 2. Geological Journal, *Special Issue* 9, 289–334.

Sheehan, P.M., Schiefelbein, J.D.R., 1984. The trace fossil *Thalassinoides* from the Upper Ordovician of the eastern Great Basin: deep Burrowing in the Early Paleozoic. *Journal of Paleontology* 58, 440–447.

Siyako, M., Burkan, K.A., Okay A.I. 1989. Biga ve Gelibolu Yarımadaları Tersiyer Jeolojisi ve Hidrokarbon olanakları: *Turkish Association of Petroleum Geologist Bulletin* 1, 183–199.

Sönmez-Gökçen, N. 1964. Notice sur le novvel age determine par les Ostracodes de la şerre a Congeria du Neogene des environs de Çatalca (Thrace). *Bulletin of Mineral Research Exploration,* 63, 47–58.

Sönmez-Gökçen, N. 1973. Etüde Paleontolowgique (Ostracodes) et Stratigraphique de nive aux du Paleogene du subest dela Thrace, Publ. D'Etud. *Bulletin of Mineral Research Exploration,* 147, 12.

Stanistreet, I.O. 1989. Trace fossil association related to facies of an Upper Ordovician low wave energy shoreface and shelf, Oslo – Asker district, Norway. *Lethaia* 22, 345–357.

Sümengen, M., Terlemez, İ., Şentürk., Karaköse, C., Erkan, E., Ünay, E., Gürbüz, M., Atalay, Z. 1987. Gelibolu Yarımadası ve GB Trakya Tersiyer havzasının stratigrafisi, sedimantolojisi ve tektoniği. General Directorate of Mineral Research and Exploration*, Report* No: 8218, (unpublished).

Sümengen, M., Terlemez, İ. 1991. Güneybatı Trakya Yöresi Eosen çökelleri Stratigrafisi. *Bulletin of Mineral Research Exploration,* 113, 17–30.

Şafak, Ü. 1999. Recent ostracoda assemblage of the Gökçeada - Bozcaada - Çanakkale Region, Yerbilimleri (Geosound), 4 th European Ostracodologists Meeting, 35, 149-172, Adana.

Şentürk, K., Karaköse, C. 1987. Çanakkale Boğazı ve Dolayının Jeolojisi. *General Directorate of Mineral Research and Exploration* Report No: 9333. (unpublished).

Taner, G. 1977. Gelibolu Yarımadası Neojen Formasyonları ile Baküniyen Molluska Faunasının İncelemesi, Ankara University, Doçentlik tezi, 66. (unpublished).

Taner, G. 1981. Gelibolu Yarımadası 'nın Denizel Kuvaterner Molluskaları, Die meerequatare mollusken der Halbinsel-Gelibolu. *Jeomorfoloji Dergisi* 10, 71–116.

Taner, G. 1983. Hamzaköy Formasyonu' nun Çavda (Baküniyen) Bivalvleri, Gelibolu Yarımadası. *Geological Bulletin of Turkey* 26, 59– 64.

Taner, G. 1994. Mollusk kavkılarında 8016/ 5018 izotopu araştırma metodu ile Çanakkale Boğazı'nın Romaniyen-Baküniyen çağma ait paleosıcaklık bulguları. *47. Türkiye Jeoloji Kurumu Bildiri Özleri Kitabı*, 12, 13

Tchoumatchenco, P., Uchman, A. 2001. The oldest deep-sea *Ophiomorpha* and *Scolicia* and associated trace fossils from the Upper Jurassic - Lower Cretaceous deep-water turbidite deposits of SW Bulgaria. *Palaeogeography, Palaeoclimatology, Palaeoecology* 169(1- 2), 85–99.

Tekkaya, İ. 1973. Çanakkale güneydoğusundaki Bayraktepe omurgalı faunası hakkında ön bildiri (proceeding). *Bulletin of Mineral Research Exploration*, 81,191-194.

Temel, R. Ö., Çiftçi, N. B. 2002. Gelibolu Yarımadası, Gökçeada ve Bozcaada Tersiyer çökellerinin stratigrafisi ve ortamsal özellikleri. *Bulletin of Turkish Association of Petroleum Geologists* 14, 17–40.

Ternek, Z. 1949. Keşan – Korudağ Bölgesinin Jeolojisi. İstanbul Üniversitesi Fen Fakültesi, Doktora Tezi, 79. (unpublished).

Toker, V., Erkan, E. 1985. Gelibolu yarımadası Eosen formasyonları nannoplankton biyostratigrafisi. *Bulletin of Mineral Research Exploration*, 101–102, 68–72.

Tunis, G., Uchman, A., 1996*a*. Trace fossils and facies changes in the Upper Cretaceous-Middle Eocene flysch deposits of the Julian Prealps, (Italy and Slovenia): consequences of regional and world-wide changes. *Ichnos* 4, 169–190.

Tunis, G., Uchman, A. 1996*b*. Ichnology of the Eocene flysch deposits in the Istria peninsula, Croatia and Slovenia. *Ichnos* 5, 1–22.

Tunoğlu, C., Ünal, A. 2001*a*. Biyostratigraphy and chronostratigraphy of Pannonian-Pontian sequence of Gelibolu Paninsula, NW Turkey. *Geological Bulletin of Turkey* 44, 1, 15–25.

Tunoğlu, C., Ünal, A., 2001*b*. Pannonian-Pontian ostracoda fauna of Gelibolu Neogene Basin (NW Turkey). *Hacettepe Üniversitesi Yerbilimleri Dergisi* 23, 167–187.

Uchman, A.1991. ''Shallow Water'' trace fossils in Palaeogene flysch of the southern part of the Magura Nappe, Polish Outer Carpathians. *Annales Societatis Geologorum Poloniae* 61, 61–75.

Uchman, A. 1995. Taxonomy and palaeoecology of flysch trace fossils: The Marnoso-arenacea Formation and associated facies (Miocene, Northern Apennines, Italy). *Beringeria* 15, 1–115.

Uchman, A. 1998. Taxonomy and ethology of flysch trace fossils: A revision of the Marian Książkiewicz collection and studies of complementary material. *Annales Societatis Geologorum Poloniae* 68, 105–218.

Uchman, A. 1999. Ichnology of the Rhenodanubian flysch (Lower Cretaceous-Eocene) in Austria and Germany. *Beringeria 25*, 65–171.

Uchman, A. 2009. The *Ophiomorpha rudis* ichnosubfacies of the Nereites ichnofacies: characteristics and constraints. *Palaeogeography, Palaeoclimatology, Palaeoecology* 276, 107–119.

Uchman, A., Drygant, D., Paszkowski, M., Porębski, S. J., Turnau, E. 2004. Early Devonian trace fossils in marine to non-marine redbeds in Podolia, Ukraine: palaeoenvironmental implications. *Palaeogeography, Palaeoclimatology, Palaeoecology* 214, 67–83.

Uchman, A., Wetzel, A. 2012. Deep-sea fans. In: Bromley, R.G. & Knaust, D. (Eds.), Trace Fossils as Indicators of Sedimentary Environments. *Developments in Sedimentology* 64, 643–671. Elsevier, Amsterdam.

Ünal, A. 1996. Gelibolu Yarımadası Neojen Ostrakod Biyostratigrafisi, MSc Thesis. *Hacettepe University, Institute of Science* 160 pp. (unpublished).

Ünal, O. T. 1967. l. Bölge (Marmara) Trakya Jeoloji ve petrol imkânları. *Turkish Petroleum Corporation Archive* No; 391.

Vialov, O. S., Golev, B. T. 1965. O drobnom podrazdieleni gruppy Paleodictyonidae. Byulletin Moskovskovo Obshczhestva Ispityvania Prirody. *Odtiel Gieologii* 40, 93–114.

Wetzel, A., Bromley, R.G. 1994. *Phycosiphon incertum* revisited: *Anconichnus* horizontalis is junior subjective synonym. *Journal of Paleontology* 68, 1396–1402.

Wetzel, A., Uchman, A., 2001. Sequential colonization of muddy turbidites: examples from Eocene Beloveža Formation, Carpathians, Poland. *Palaeogeography, Palaeoclimatology, Palaeoecology* 168, 171–186.

PLATE

PLATE - I

A - *Ophiomorpha annulata*

Hypichnial full reliefs in a fine grained turbiditic sandstone bed (Fındıklı-1 section).

B - *Saerichnites* isp.

Hypichnial semi-reliefs in a fine-grained turbiditic sandstone bed (Fındıklı-1 section).

C - *Spongeliomorpha oraviense*

Hypichnial full relief in a fin-grained turbiditic sandstone bed (Fındıklı-1 section).

D, E - *Thalassinoides* isp.

Hypichnial full reliefs in a fine-grained turbiditic sandstone bed (Ece Bay-1 section).

F - Large tubular burrow

Hypichnial full relief in fine-grained turbiditic sandstone bed (Ece Bay-1 section).

PLATE I

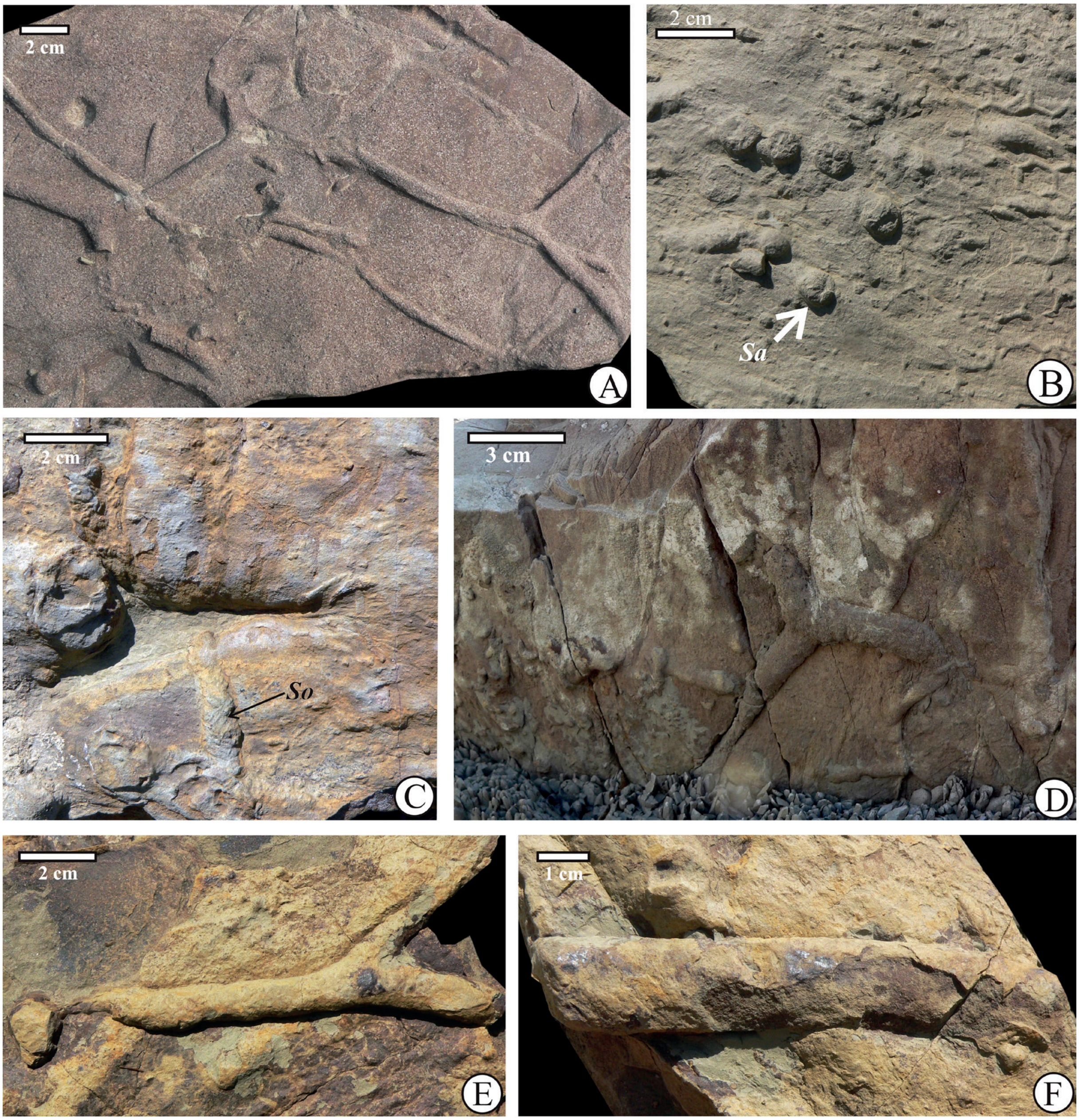

PLATE – II

A - *Trichichnus* isp.

Endichnial full relief in calcareous mudstone (Ece Bay-1 section).

B - *Scolicia* isp.

Hypichnial full relief in a fine-grained turbiditic sandstone bed (Ece Bay-1 section).

C - *Scolicia prisca*

Originally, full relief; its lower part is seen at the top of a turbiditic sandstone bed (Ece Bay-1 section).

D, E - *Helminthorhaphe flexuosa*

Hypichnial semi-relief in a fine-grained turbiditic sandstone bed (Ece Bay-1 section).

F - *Helicolithus ramosus*

Hypichnial semi-relief in a fine-grained turbiditic sandstone bed (Ece Bay-1 section).

PLATE II

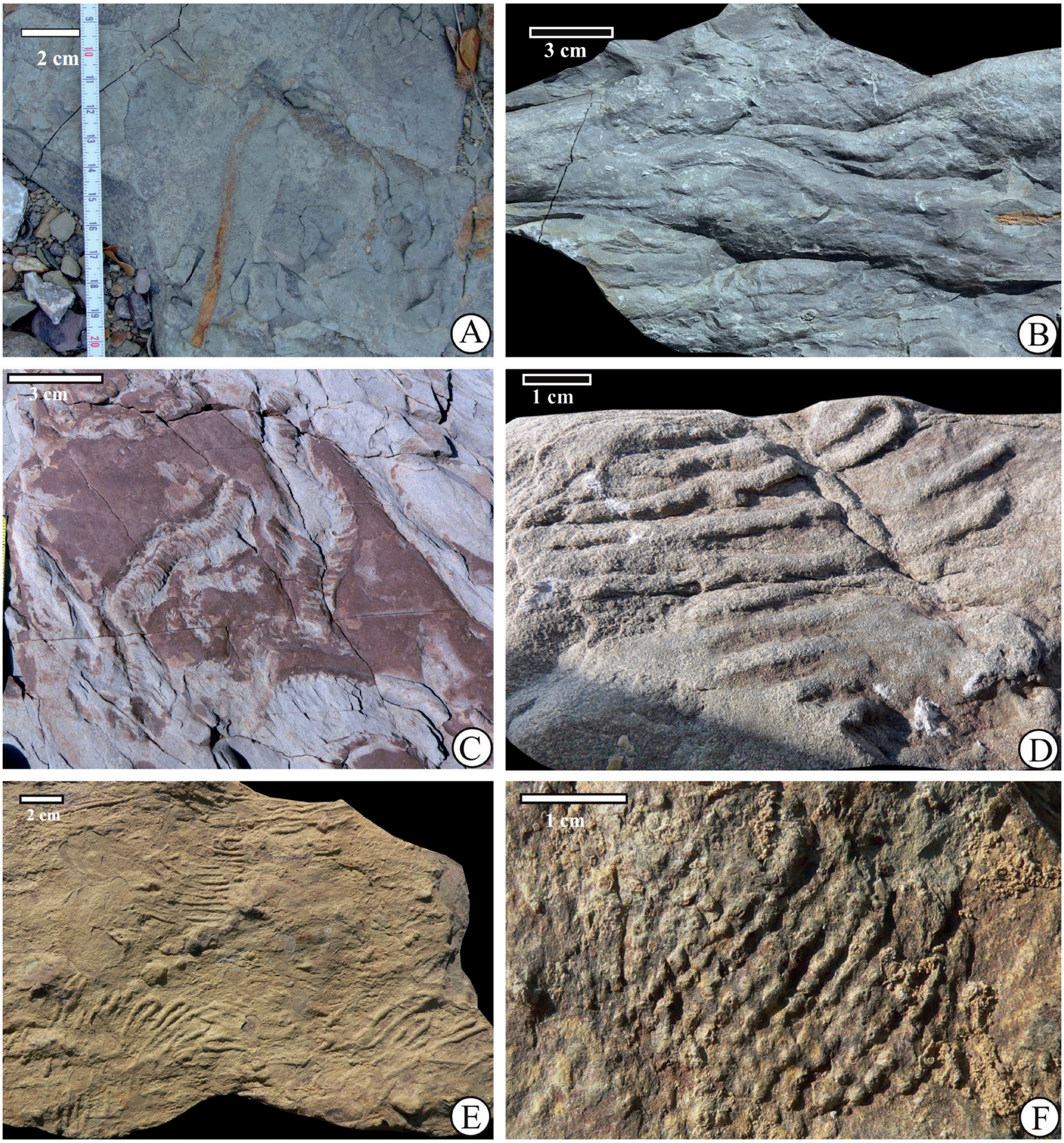

PLATE - III

A - *Helicolithus ramosus*

Hypichnial semi-relief in a fine-grained turbiditic sandstone bed (Ece Bay-1 section).

B - *Belorhaphe zickzack* and *Ophiomorpha* isp.

Hypichnial semi-relief (*Belorhaphe*) and hypichnial full relief (*Ophiomorpha*) in a fine-grained turbiditic sandstone bed (Fındıklı-1 section).

C - *Desmograpton* isp.

Hypichnial semi-relief in a fine-grained turbiditic sandstone bed (Fındıklı-1 section).

D - *Paleodictyon strozzii*

Hypichnial semi-relief in a fine-grained turbiditic sandstone bed (Fındıklı-1 section).

D - *Paleodictyon strozzii* and *Paleodictyon majus*

Hypichnial semi-reliefs in a fine-grained turbiditic sandstone bed (Fındıklı-1 section).

F - *Phycosiphon incertum*

Endichnial full relief in a fine grained turbiditic sandstone bed (Fındıklı-1 section).

PLATE III