

# ICHOLOGY OF UPPER CRETACEOUS–LOWER PALAEOGENE DEEP-SEA DEPOSITS IN THE HAYMANA BASIN OF CENTRAL ANATOLIA

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**Abstract:** Upper Cretaceous to lower Palaeogene carbonate and siliciclastic deposits that crop out widely in the Haymana and Polatlı districts (Ankara Province) of the Haymana Basin (Central Anatolia) are rich in larger benthic foraminifera, various macrofossils and ichnofossils. The ichnofossils of the Haymana and Yeşilyurt formations were studied at five localities. The Upper Cretaceous siliciclastics of the Haymana Formation contain moderately diverse trace fossils, belonging to the deep-sea *Nereites* ichnofacies. The Paleocene siliciclastic and carbonate deposits of the Yeşilyurt Formation comprise similar trace fossils, which do not show significant changes in comparison to the Haymana Formation. This indicates that the K-Pg boundary extinction event did not affect the ichnofauna with any longer consequences.

The Upper Cretaceous coarser, siliciclastic deposits of the Haymana and Beyobası formations are rich in shallow-marine, larger benthic foraminifera, including species of *Orbitoides*, *Omphalocyclus*, *Siderolites*, *Hellenocyclina*, and *Loftusia*, whereas fine siliciclastic deposits contain abundant planktonic, open-marine foraminifera, such as *Globotruncana* and *Heterohelix*. Palaeogene siliciclastic to carbonate deposits of the Kartal, Yeşilyurt and Çaldağ formations are rich in the larger, benthic foraminifera *Nummulites*, *Discocyclina*, *Assilina* and *Alveolina*. The larger foraminifers have been redeposited from nearby, shallow-marine parts of the basin.

**Key words:** Trace fossils, benthic foraminifera, Campanian, Paleocene, Turkey.

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## INTRODUCTION

The study area is in the Haymana Basin, southwest of Ankara (Central Anatolia; Fig. 1). Due to the economic and scientific value of the Haymana Basin, previous studies date back to the early and middle 20<sup>th</sup> century (e.g., Chaput, 1935). Many studies have been conducted on the petroleum geology (e.g., Demirel and Şahbaz, 1994), sedimentology, stratigraphy, structural geology, and the geologic history of the region (e.g., Ünalán *et al.*, 1976; Amirov, 2008; Okay and Altner, 2016). Taxonomic palaeontology studies date back to the 1960s. In the earliest studies, Dizer (1964, 1968) described a few species of the large foraminifers *Alveolina* and *Nummulites*. Later, many studies on microforaminifera, especially on planktonic foraminifera, the biostratigraphy of Upper Cretaceous deposits and the K-Pg boundary (e.g.,

Toker, 1975; Vardar, 2018), larger benthic foraminifera of the Cretaceous to Palaeogene deposits (Meriç, 1979, 1984; Özcan and Özkan-Altner, 1997; Sirel, 1998; Dinçer, 2016), deep-sea benthic foraminifera (Tanık, 2017), ostracods (Duru and Gökçen, 1990), and molluscs (Hoşgör, 2012) were presented. Except for only a few macro trace fossils' data and a study of microboring activity in the larger, benthic foraminifera (Görmüş *et al.*, 2019), details on trace fossil have not yet been well documented for the Cretaceous–Palaeogene deposits in the Haymana Basin. The purpose of this paper is to describe and interpret the trace fossils of the Cretaceous–Palaeogene deposits of the Haymana and Yeşilyurt formations and provide some data on the foraminifers in them.

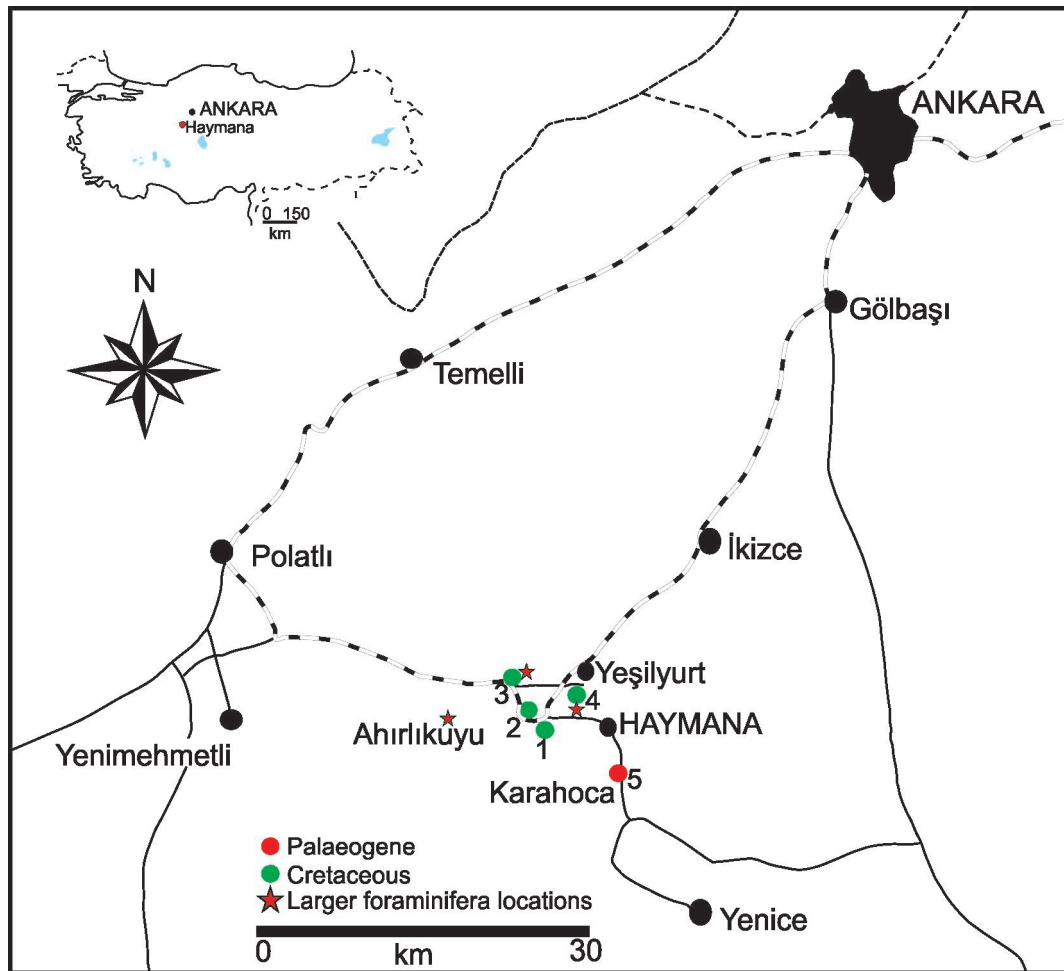


Fig. 1. Location map of the study area.

## GEOLOGICAL SETTING

In the Cretaceous–Palaeogene of the Haymana area, the lithostratigraphic units are as follows (from the bottom to the top): the Upper Cretaceous Haymana and Beyobası formations and the Paleocene Kartal, Çaldağ and Yeşilyurt formations (Ünalán *et al.*, 1976). The Cretaceous deposits unconformably overlie basement rocks, known as the Dereköy Mélange (Karakaya Complex) and carbonates of the Mollaresul Formation (Ünalán *et al.*, 1976; Okay and Altınér, 2016). The Paleocene carbonate deposits of the Çaldağ Formation conformably overlie siliciclastics of the shallow-marine Maastrichtian Beyobası Formation (Sirel, 1998), while the Paleocene rhythmic siliciclastics of the Yeşilyurt Fm cover the Campanian–Maastrichtian fine siliciclastics of the open-marine deposits, belonging to the Haymana Formation (Amirov, 2008; Esmeray, 2008; Esmeray–Senlet *et al.*, 2015; Karabeyođlu, 2017; Tanık, 2017; Vardar, 2018). The total thickness of the Cretaceous and Paleocene units reaches more than 2 km in the region (Okay and Altınér, 2016; Karabeyođlu, 2017). Deposits of the Maastrichtian Haymana and Beyobası formations and various deposits of the Paleocene Kartal, Çaldağ and Yeşilyurt formations display lateral and vertical facies changes (Ünalán *et al.*, 1976). In this study, trace fossil of the Haymana and Yeşilyurt formations are

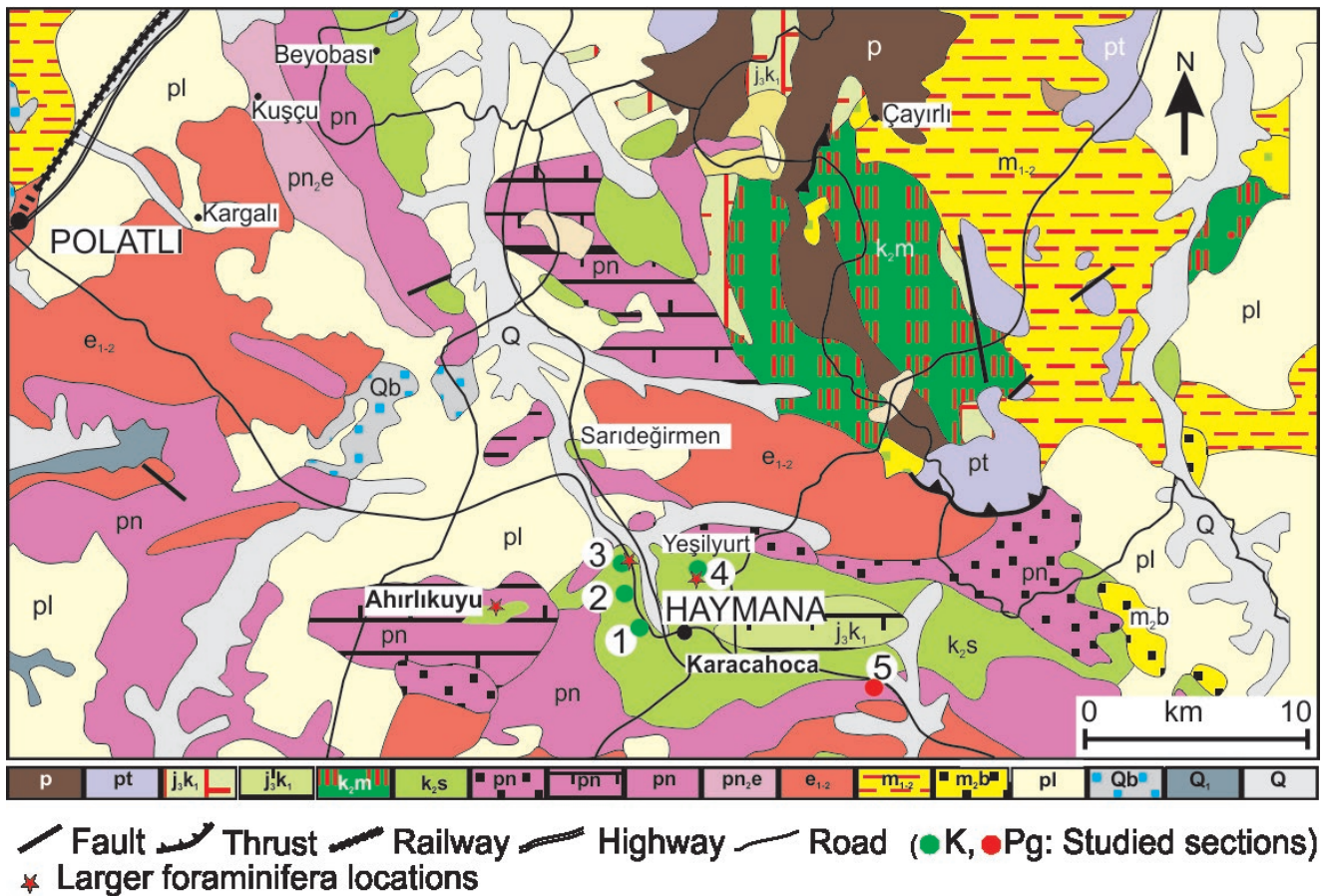
presented, whereas the data on larger benthic foraminifera refer to the Haymana, Beyobası and Çaldağ formations (Figs 2, 3).

## MATERIAL AND METHODS

Observations were made at five measured sections, containing Cretaceous to Palaeogene deposits. Sampling for foraminifers was based on changes in the lithology. The identification of trace fossils was made in the field from bedding surfaces, or on parting surfaces and in vertical sections, and from photographs and sketches. Foraminifers from the Haymana Formation were mainly microscopically identified; more than fifty thin sections were prepared at the Ankara University Geological Engineering Department. Single thin sections of *Loftusia* and *Orbitoides* from the weathered sediments (Haymana Fm) in the Ahırlıkuyu area (Fig. 2) and locality 3 were prepared.

## THE STUDIED SECTIONS AND THEIR ICHNOLOGICAL FEATURES

Five sections were studied in the area between Haymana (localities 1–4) and Yeşilyurt villages (locality 5), in the Haymana Basin (Figs 1, 2).



**Fig. 2.** Geological map of the Haymana district (modified from Atıcı *et al.*, 2014). Abbreviations: p – Palaeozoic, pt – Permo-Triassic,  $j_3k_1$  – Jurassic–Cretaceous of the Mollaresul Fm,  $k_2m$  – Dereköy Mélange,  $k_2s$  – Cretaceous of the Haymana Fm, pn – Paleocene of the Kartal Fm (coarse siliciclastics), pn – Çaldağ Fm (carbonates), pn – Yeşilyurt Fm (siliciclastics),  $pn_2e$  – Paleocene-Eocene siliciclastics,  $e_{1-2}$  – Çayraz Fm,  $m_{1-2}$ – $m_2b$  – Miocene fine to coarse clastics, pl – Pliocene, Qb – Quaternary basalt, Q1, Q – Quaternary. The numbers in circles refer to the studied localities. The asterisk indicates the larger foraminifera localities.

### Locality 1

The measured section, 18 m thick, was examined along the Haymana – Polatlı road (Fig. 1), approximately 1–1.2 km northwest of the centre of Haymana Province (Ankara J28b2-29a1 Quadrangle sheet; GPS coordinates: N39°26′18.52″, E 32°29′0.87″). The section represents the lower part of Unit B (Fig. 3). It is composed of yellow, medium-fine-grained sandstone, greenish-grey siltstones and greenish marl. The sandstones are 3–5 cm thick, mostly yellow but brown at the upper part of the section. The greenish-grey siltstones are parallel-laminated and the marls have a cleavage structure (Fig. 4A–C). Larger benthic foraminifera were not observed. The positions of trace fossils (*Chondrites* isp., *C. intricatus*, *C. affinis*, *Nereites* isp., *Phycosiphon incertum*, *Palaeophycus* isp., *Thalassinoides* isp., *Trichichnus* isp., and ?*T. linearis*) in the section is shown in Figure 5.

### Locality 2

The measured section at locality 2 is 9 m thick and was examined on the Haymana – Polatlı road, about 2 km northwest of the Haymana city center, at the Yeşilyurt road

junction (Ankara J28b2-29a1 Quadrangle sheet; GPS coordinates: N39°26′46.74″, E32°28′45.10″). It represents a fragment of the middle part of the Haymana Formation (Figs 1, 3; top of the Unit B and the lower part of the Unit C) and starts with intercalations of greenish-grey marl, siltstones, yellowish fine and coarse sandstones (Fig. 4D–F). The section contains ammonites.

Larger benthic foraminifera were not found in this section. The trace fossils include cf. *Asteriacites* isp., ?*Bergaueria* isp., *Chondrites intricatus*, ?*Cochlichnis* isp., *Helminthopsis* isp., *Helminthorhapha flexuosa*, *Ophiomorpha rudis*, *Paleodictyon minimum*, *P. strozzii*, *Scolicia vertebralis*, *Thalassinoides* isp., cf. *Thorichnus* isp., and *Zoophycos* isp. (Fig. 6).

### Locality 3

The measured section at locality 3 is 20 m thick. It is located approximately 2 km north of the Haymana city center, east of the Haymana–Yeşilyurt road (Ankara J28b2-29a1 Quadrangle sheet; GPS coordinates: N 39°26′55.90″, E32°29′11.43″). It represents the middle part of the Haymana Formation (Figs 1, 3, 7, 8; Unit C) and consists of medium- to coarse-grained siliciclastics and carbonates. While greenish-grey marls with sandstones are observed

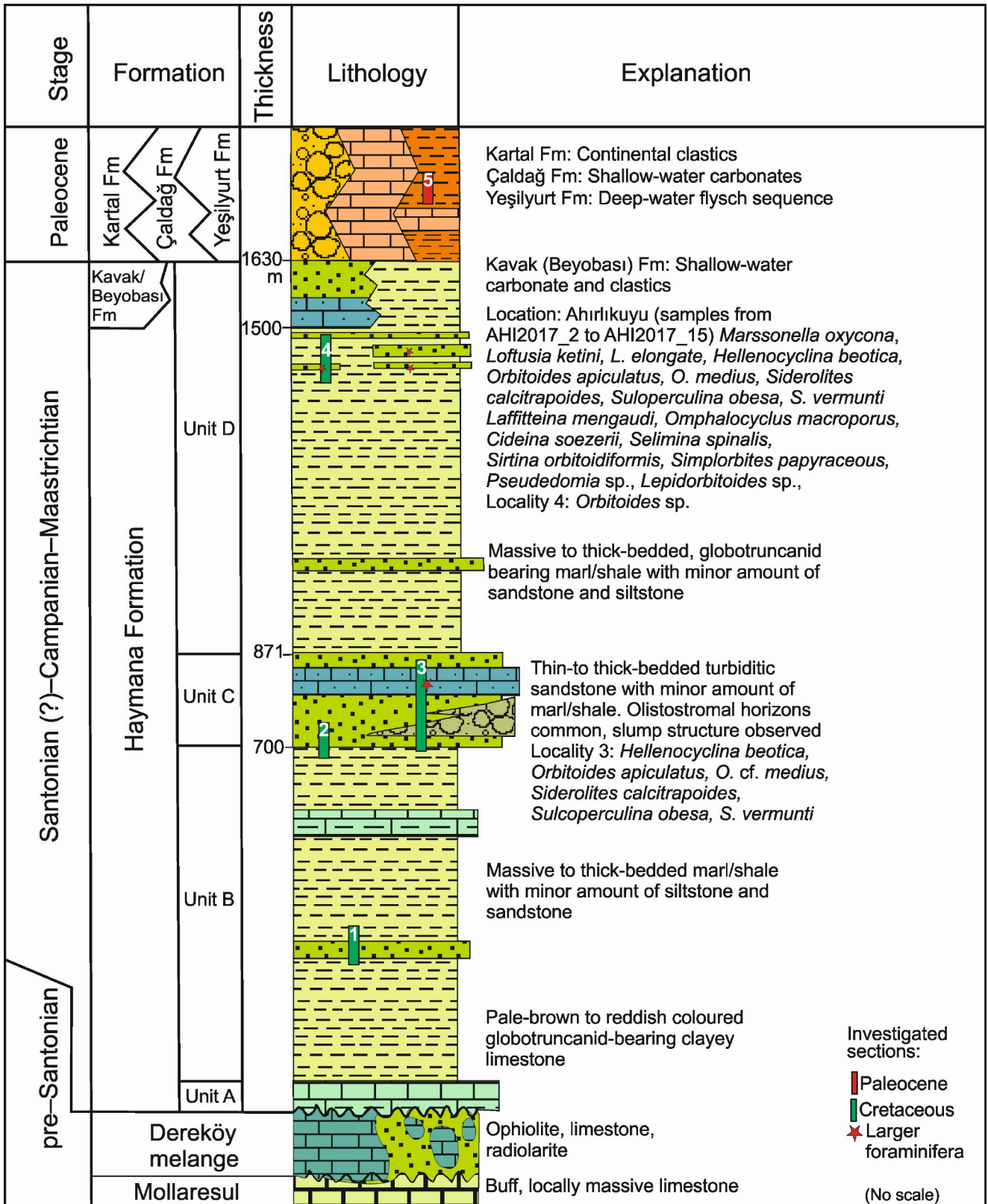
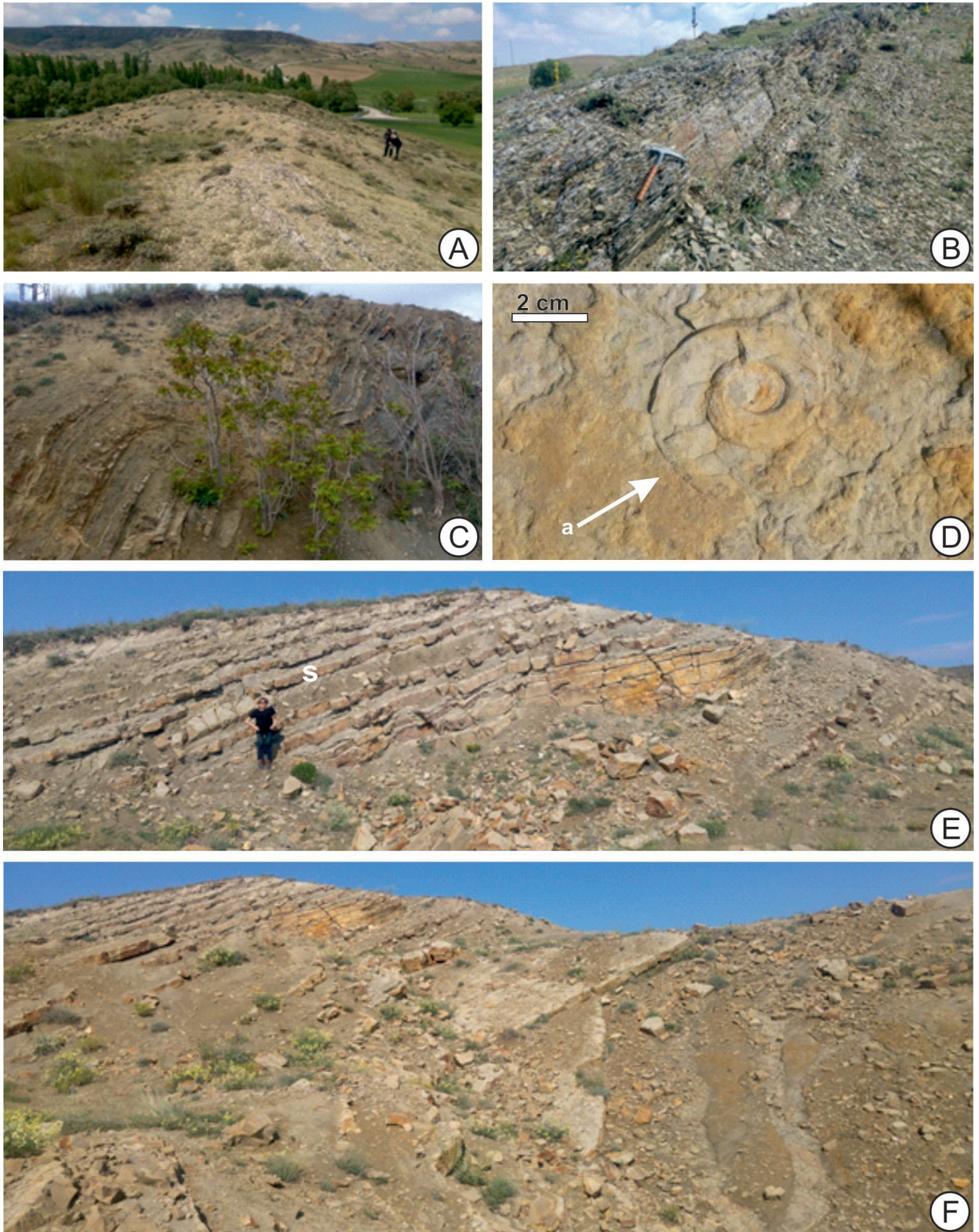


Fig. 3. Generalized measured section of the studied area (modified from Özcan and Özkan-Altner, 1997; Görmüş *et al.*, 2019).



**Fig. 4.** Outcrops of the lower–middle part of the Haymana Fm. **A.** Locality 1 measured section, northwest of Haymana. **B.** Locality 1 measured section, northeast of Haymana. **C.** Folded sandstone–mudstone deposits of the locality 1. **D.** Ammonite outer mould (a), 2 km of northwest Haymana, Locality 2. **E, F.** Locality 2 section showing of sandstone–mudstone alternations, northeast of Haymana.

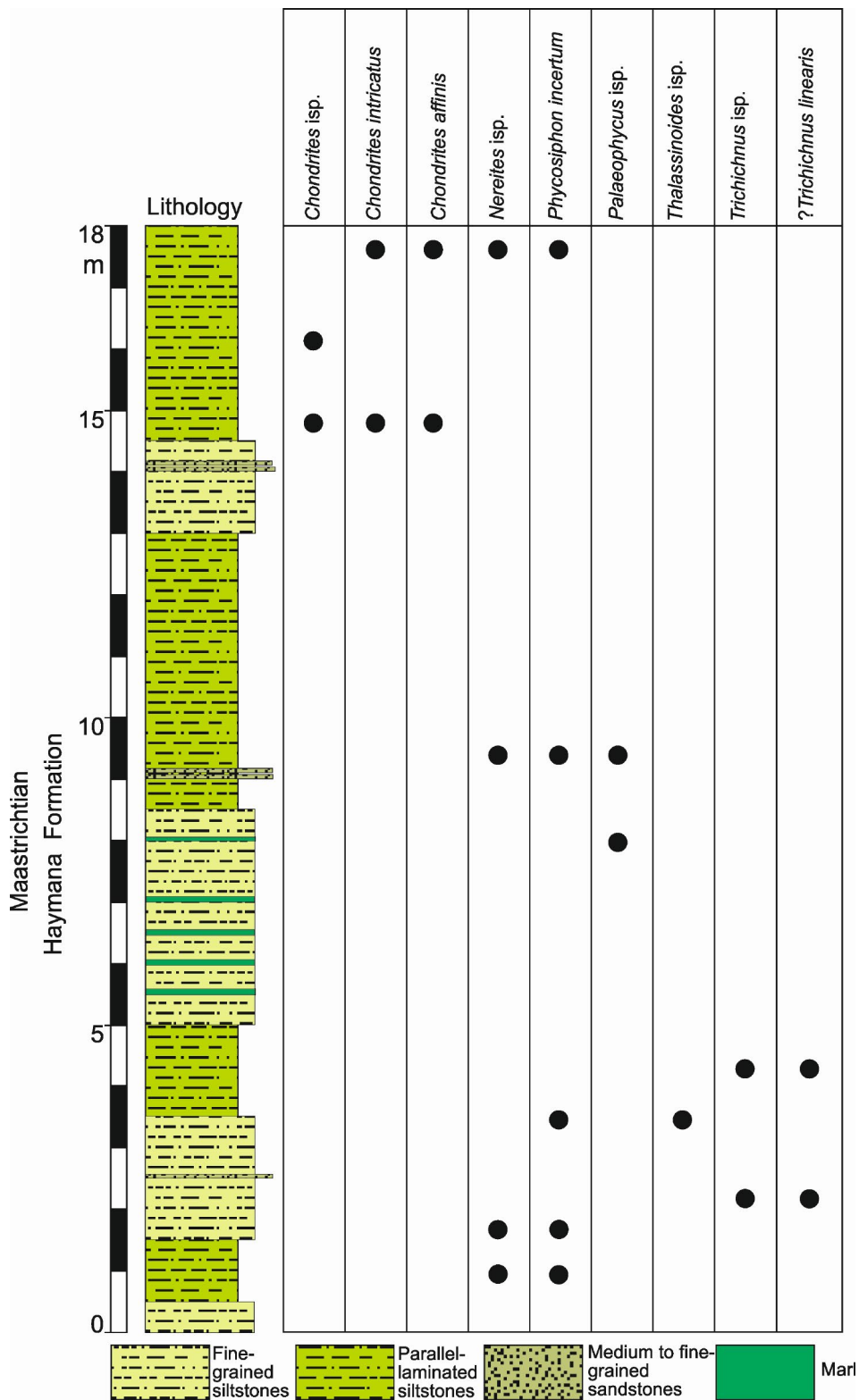


Fig. 5. Measured section of locality 1, Haymana Fm.

at the bottom of the measured section, the upper part of the section continues with similarly coloured laminated sandstones, siltstones and marl beds, containing ammonites. This part of the section also contains conglomerates of ophiolitic origin and coarse-grained sandstones, which are about 8 m thick and interpreted as a channel fill. *Orbitoides* is observed in the sandstones and limestones in the upper part of the section. Besides larger benthic

foraminifera (*Hellenocyclina beotica*, *Orbitoides apiculatus*, *Orbitoides* cf. *medius*, *Siderolites calcitrapoides*, *Suloperculina obesa*, *S. vermunti*, *Textularia* sp.), algae, bryzoa, coral, rudist and bivalves occur. Trace fossils were observed in greenish gray coloured, fine-medium grained sandstones along the channel-margin deposits (*Bergaueria* isp., *Halopoa* isp., *O. annulata*, *O. rudis*, *Planolites* isp., *Thalassinoides* isp.).

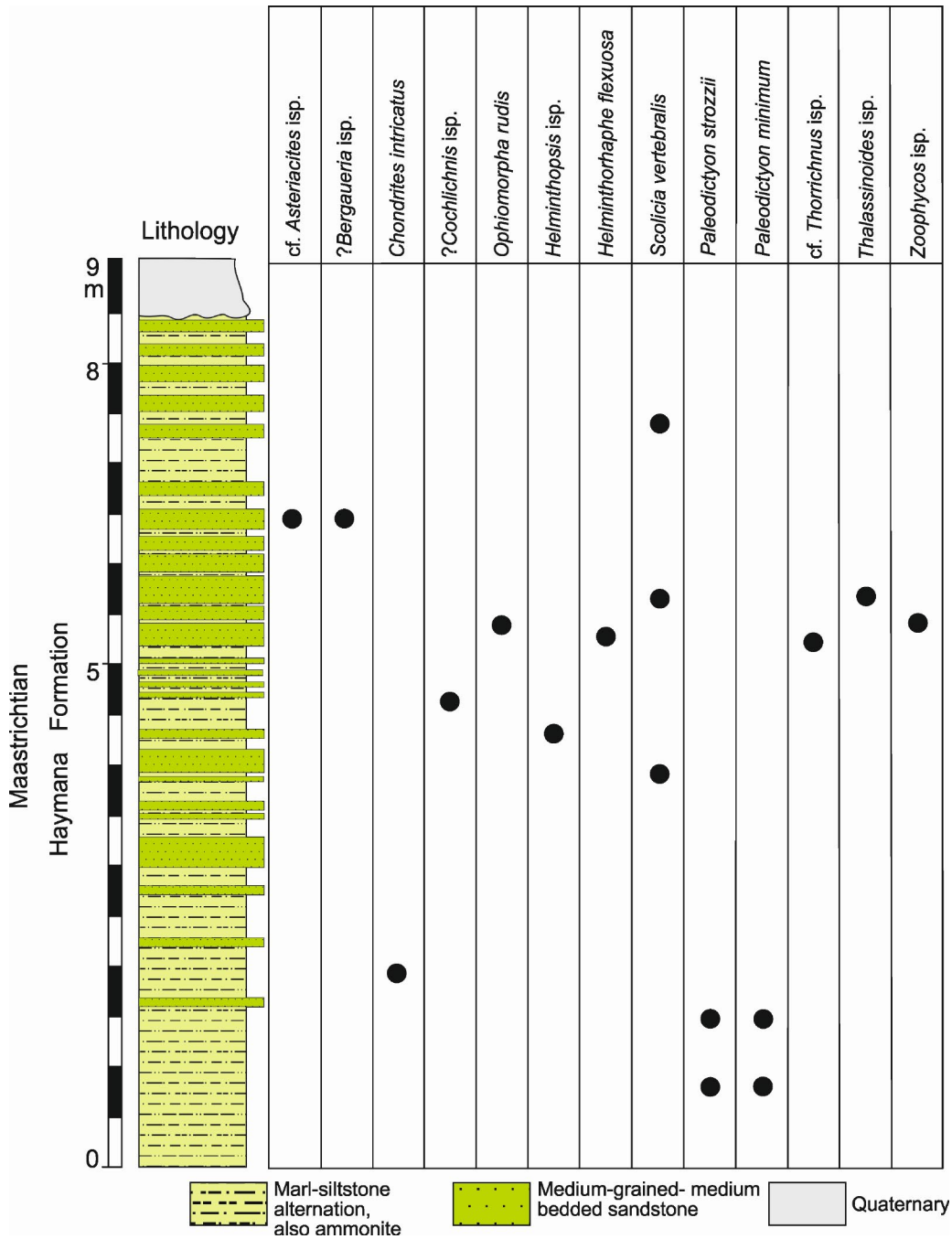


Fig. 6. Measured section of locality 2, Haymana Fm.

**Locality 4**

The section was measured on the side of the Haymana – Ankara road, approximately 4.5 km northeast of the Haymana city center (Ankara J28b2-29a1 Quadrangle sheet; GPS coordinates: N39°28'13.86", E32°31'38.05"). It is 17 m thick and contains medium- to coarse-grained siliciclastic channel deposits in the upper part of the Haymana Formation (Figs 1, 3, 9; Unit D). The section starts with yellow, medium-coarse grained, medium-bedded sandstone and siltstone intercalations, containing larger benthic foraminifera. The sandstones are interbedded with conglomerates towards the top. Bed thicknesses range from 20 to 30 cm. Several trace fossils (*Halopoa storeana*,

?*Halopoa* isp., *Planolites* isp., *Scolicia prisca*, *S. strozzii*, *Thalassinoides* isp.) have been identified on the lower bedding surfaces of medium- to coarse-grained sandstones. Grey, fossiliferous- sandy and silty-limestones overlie the fine- to medium-grained sandstones and continues with laminated sandstones up the sections (Fig. 10).

**Locality 5**

The section of the Yeşilyurt Formation studied is located 2.2 km north of Karacahoca village (Figs 1, 11), approximately 7.5 km southeast of the Haymana city center (Ankara J28b2 Quadrangle sheet; GPS coordinates: N39°25'37.57"; E 32°33'17.11"). The section is 60 m thick and consists of



Fig. 7. Outcrops of the middle part of the Haymana Fm. A, B. View of channel deposits, locality 3 (north of Haymana village).

siliciclastics. It starts with polymictic conglomerates with intercalations of coarse-grained sandstone and passes upward into fine- to medium-grained, medium-bedded, yellow, ichnofossiliferous marls. The deposits of the section contain (Fig. 12) *?Bergaueria* isp., *Chondrites* isp., *C. affinis*, *C. intricatus*, *?Desmograpton* isp., *?Halopoa* isp., *H. storeana*, *Helminthopsis* isp., *Helminthorhapha flexuosa*, *Lockeia* isp., *Megagraption submontanum*, *Ophiomorpha annulata*, *O. rudis*, *P. arvense*, *P. latum*, *P. majus*, *P. minimum*, *P. strozzii*, *Paleodictyon* isp., *Planolites* isp., *P. beverleyensis*, *P. montanus*, *Scolicia prisca*, *Scolicia strozzii*, *Thalassinoides* isp., and *Zoophycos* isp. Larger benthic foraminifera were not found in this measured section.

### FORAMINIFERA ASSEMBLAGES

The Maastrichtian and Paleocene deposits of the Haymana Basin are rich in benthic foraminifera (Table 1). Among the trace fossil localities studied, larger benthic foraminifera were recorded in thin sections from the section

at locality 3 (Fig. 8) and very rarely from the locality 4 section. Towards the upper part of the locality 3 section, sandy and silty limestones contain abundant larger benthic foraminifera, while the entire succession includes a rich macrobiota, such as algae, bivalves and corals. Larger benthic foraminifera include *Hellenocyclina beotica* Reichel, 1949, *Orbitoides apiculatus* Schlumberger, 1902, *Orbitoides* cf. *medius* (d'Archiac, 1837), *Siderolites calcitrapoides* Lamarck, 1801, *Sulcoperculina obesa* Cizancourt, 1949, *S. vermunti* Thiadens, 1937. These benthic index foraminifera support the Maastrichtian age of the Haymana Formation. They were derived from a shallow palaeoenvironment and were redeposited in sandy and silty limestone turbidites.

The Haymana Formation siliciclastics from the Ahırlıkuyu area contain a rare exposure of the K-Pg boundary interval (Fig. 2). The exposure shows vertical facies changes of the Haymana and Beyobası formations to carbonate-platform limestones of the Çaldağ Formation. In this area, shallow-water siliciclastics of the Haymana Formation contain



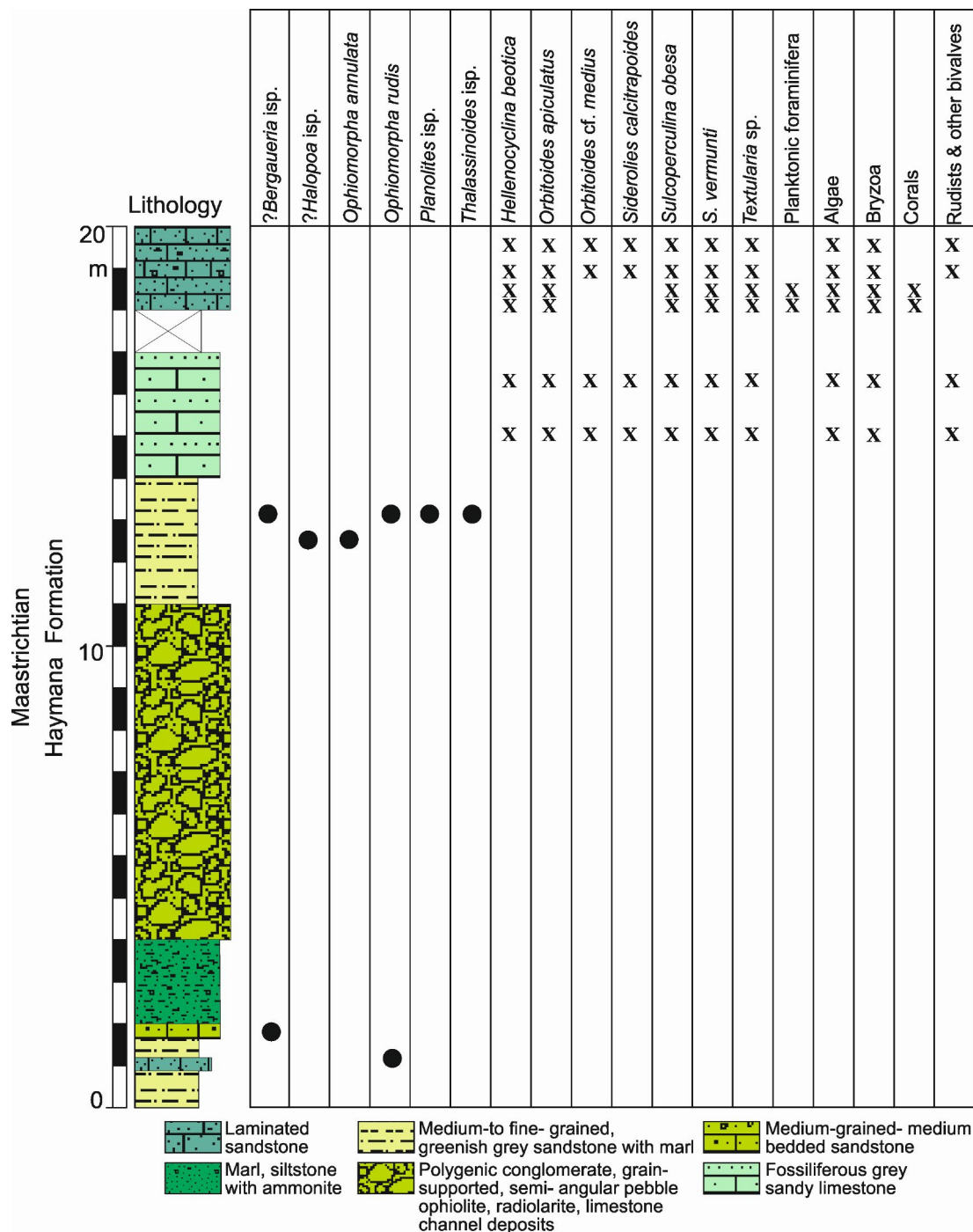


Fig. 8. Measured section of locality 3, Haymana Fm.

abundant, larger benthic foraminifera, while the Palaeogene carbonates contain Danian benthic foraminifera (Sirel, 1998, 2010). The larger benthic foraminifera of the Maastrichtian deposits include *Marssonella oxycona* Reuss, 1860, *Loftusia ketini* Meriç, 1979, *L. elongate* Cox, 1937, *Hellenocyclina beotica* Reichel, 1949, *Orbitoides apiculatus* Schlumberger, 1902, *O. medius* (d’Archiac, 1837), *Siderolites calcitrapoides* Lamarck, 1801, *Sulcoperculina obesa* Cizancourt, 1949, *S. vermunti* Thiadens, 1937, *Laffiteina mengaudi* (Astre, 1924), *Omphalocylus macroporus* (Lamarck, 1816), *Cideina soezerii* (Sirel, 1973), *Selimina spinalis* Inan, 1996, *Sirtina orbitoidiformis* Brönnimann and Wirz,

1962, *Simplorbites papyraceous* (Boubée, 1832), *Textularia* sp., *Pseudedomia* sp., *Lepidorbitoides* sp., and representative of Miliolidae, Textulariidae (Figs 13, 14). Sirel (1998, 2010) identified the following Paleocene benthic foraminifera from the Çaldağ Formation in the Ahırlıkuyu area: *Haymanella paleocenica* Sirel, 1999, *H. elongate* Sirel, 2009, *Ankaraella trochoidea* Sirel, 1998, *Kolchidina paleocenica* (Cushman, 1947), *Laffiteina mengaudi* (Astre, 1924), *Kayseriella decostroi* Sirel, 1999, *Planorbulina* sp., *Missisipina binkhorsti* (Reuss, 1862), *Thalmanita madrugensis* (Cushman and Bermudez 1947), *Akbarina primitive* (Rahaghi, 1983), *Bolkarina aksarayensis* Sirel, 1981,

Table 1

Distribution of benthic foraminifera fauna from the Cretaceous to Paleocene deposits  
 (\*1 – data from Sirel, 2010; \*2 – data from Merić, 1984; \*3 – data from Özcan and Özkan-Altın, 1997).

Stratigraphy	Benthic foraminifera		Textulariids		Miliolids											Rotaliids																																
	Paleocene	Maastrichtian	Marssonella oxycona	Loftusia ketini	Loftusia elongata	Textularia sp.	Valvulina sp.	Haymanella paleocenica <sup>1</sup>	H. elongata <sup>1</sup>	Kolchidina paleocenica <sup>1</sup>	Ankaraella trochoidea <sup>1</sup>	Kayseriella decasroi <sup>1</sup>	Pseudodonta sp.	Glomalveolina primaeva <sup>1</sup>	Pseudolacazina oeztemueri <sup>1</sup>	P. donatae	Scandonea sarmitica <sup>2</sup>	Miliolidae	Orbitoides apiculatus	O. gruenbachensis	O. megaliformis	O. medius	Simplorbites papyraceous	Lepidorbitoides bisambergensis <sup>3</sup>	L. campaniensis <sup>3</sup>	Siderolites calcitrapoides	Præsiderolites sp.	Cideina soezerii	Selimina spinalis	Laffiteina mengaudi	Sirtina orbitoidiformis	Sulcoperculina globosa	Sulcoperculina vermunti	Hellenocyclina beotica <sup>1</sup>	Pseudocuvillierina sireli <sup>1</sup>	Missipina cf. binkhorski <sup>1</sup>	Bolkarina aksarayensis <sup>1</sup>	Thalmanita madruagaensis <sup>1</sup>										
	Çaldağ Fm					X	X	X	X	X	X		X	X	X	X	X																															
	Yeşilyurt Fm																																															
	Beyobası Fm		X	X	X	X							X					X	X	X	X	X	X	X	X	X		X	X																			
	Haymana Fm		X	X	X								X					X	X	X	X	X	X	X	X	X		X	X																			

*Pseudocuvillierina sireli* (Inan, 1988), *Pseudolacazina oeztemueri* Sirel, 1981, *P. donatae* (Drobne, 1974), and *Glomalveolina primaeva* Reichel, 1936. Similar foraminifera have been found in carbonates of the Çaldağ Formation in the Sardeğirmen area.

**SYSTEMATIC DESCRIPTION OF TRACE FOSSILS**

The trace fossils presented are characterized by moderate diversity (21 ichnogenera, 35 ichnospecies). Their systematics is based on the morphological criteria, proposed mainly by Häntzschel (1975), Książkiewicz (1977), Seilacher (1977), Fillion and Pickerill (1990), Crimes and Crossley (1991), and Uchman (1995). They belong to six morphologic groups. The trace fossils are documented in field photographs. Their occurrences in the outcrops are listed in Table 2.

**Circular and elliptical structures**

The trace fossil cf. *Asteriacites* isp. (Fig. 15A) is a hypichnial, star-shaped mound, ca. 17 mm in diameter. It exhibits short, triangular arms, which are 3.4–4.5 mm long. *Asteriacites* von Schlotheim, 1820 is placed in the circular and elliptical structures by convention (cf. Riahi *et al.*, 2014). It is a resting trace (cubichnion) of asteroids and ophiuroids, which is known mostly from well-oxygenated,

shallow-marine (Müller, 1980; Twitchett and Wignall, 1996) and rarely from deep-sea deposits (Mikuláš, 1992; Riahi *et al.*, 2014). *Asteriacites* ranges from Cambrian to Holocene (Mikuláš, 1992).

?*Bergaueria* isp. (Fig. 15B, C) is a hypichnial, hemispherical mound, smooth with minor irregularities, circular or oval outline, 4.3–5 mm wide, preserved in sandstone beds.

*Bergaueria* Prantl, 1945 is a dwelling or resting trace of sea anemones (Pemberton *et al.*, 1988; Pickerill, 1989; Paczeńska, 2010). It is common in the softground siliciclastic deposits of beaches, tidal flats and shallow-marine to deep-sea settings (Knaust, 2017). *Bergaueria* ranges from the Ediacaran to Recent (Mángano and Buatois, 2016; Knaust, 2017).

*Lockeia* isp. (Fig. 15D) is a hypichnial, amygdaloidal mound, distinctly curved trace fossil, 3.5 mm wide and 6.4 mm long. *Lockeia* James, 1879 is a cubichnion (resting), produced mainly by bivalves (Seilacher and Seilacher, 1994) in various environments, but mostly in shallow-marine settings. It ranges from Ediacaran to Pleistocene (Fillion and Pickerill, 1990).

**Simple and branched structures**

*Chondrites affinis* (Sternberg, 1833) (Fig. 15E) is a system of tunnels, showing four or five branches, extending sideways, which are almost straight or distinctly curved, 8 mm wide. Up to three orders of branches are present. This ichnospecies was previously synonymised with *C. targionii* (Brongniart, 1828). After an analysis of the

Table 2

Distribution of trace fossils in the sections studied.

Stratigraphy		Trace fossils																																									
		cf. <i>Asteriacites</i> isp.	? <i>Bergaueria</i> isp.	<i>Lockeia</i> isp.	<i>Chondrites affinis</i>	<i>Chondrites intricatus</i>	<i>Chondrites</i> isp.	<i>Halopoa storeana</i>	? <i>Halopoa</i> isp.	<i>Ophiomorpha annulata</i>	<i>Ophiomorpha rudis</i>	<i>Palaephycus</i> isp.	<i>Planolites beverleyensis</i>	<i>Planolites montanus</i>	<i>Planolites</i> isp.	<i>Thalassinoides</i> isp.	cf. <i>Tnorichnus</i> isp.	? <i>Trichichnus linearis</i>	<i>Trichichnus</i> isp.	<i>Phycosiphon incertum</i>	<i>Zoophycos</i> isp.	? <i>Cochlichnis</i> isp.	<i>Helminthopsis</i> isp.	<i>Helminthorhapha flexuosa</i>	<i>Nereites</i> isp.	<i>Scolicia prisca</i>	<i>Scolicia strozzii</i>	<i>Scolicia vertebralis</i>	? <i>Desmograpton</i> isp.	<i>Megagrapton submontanum</i>	<i>Palaedictyon</i> isp.	<i>Palaedictyon arvanse</i>	<i>Palaedictyon latum</i>	<i>Palaedictyon majus</i>	<i>Palaedictyon minimum</i>	<i>Palaedictyon strozzii</i>							
Paleocene	Yeşilyurt Fm, Locality 5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X		X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X				
Upper Cretaceous	Haymana Fm, Locality 4						X	X						X	X											X	X																
	Haymana Fm, Locality 3	X						X	X	X				X	X																												
	Haymana Fm, Locality 2	X	X			X					X						X	X			X	X					X													X	X		
	Haymana Fm, Locality 1				X	X	X					X					X	X	X	X						X																	

well-preserved specimens from the Saraceno Fm (?Upper Cretaceous; Eocene–Miocene) in the southern Italy, it is considered to be a separate ichnospecies, recommended for further use (Uchman *et al.*, 2012). *Chondrites* Sternberg, 1833 has been interpreted as the chemichnion of an unknown deposit feeder (Bromley, 1996). *C. affinis* occurs in Upper Cretaceous to Neogene offshore, deep-sea sediments (Uchman *et al.*, 2012).

*Chondrites intricatus* (Brongniart, 1823) (Figs 15F, 19E) is a branching burrow system, composed of straight, unlined segments. The branches have acute angles, usually 25°–35°. The second-order branches predominate and the third-order branches are rare. The main (master) branches are 0.5–1 mm wide and 15 mm long; second-order branches are 0.3–0.4 mm wide and between 4.2–5.4 mm long. *C. intricatus* is a common trace fossil in deep-sea sediments (Uchman, 1995, 1998). It is distinguished by its straight and fine branches and acute angle of branching (Fu, 1991; Uchman, 1999). *Chondrites* is interpreted as a chemichnion (Bromley, 1996), produced by unknown organisms (Seilacher, 1990; Fu, 1991). It occurs from the Tommotian (Crimes, 1987) to the Holocene (Wetzel and Werner, 1981).

*Chondrites* isp. (Fig. 15G) is as root-like, branching tunnel systems. The tunnels branch at angles of 45°–90° and are 0.5–1.0 mm wide.

*Halopoa storeana* Uchman, 2001 (Fig. 15H, I) is a simple, cylindrical, hypichnial ridge, 4 mm wide, preserved in full relief and covered with wrinkles. The wrinkles are commonly 11 mm long, 3–4 mm wide. *H. storeana* differs from *H. imbricata* in the orientation of the surficial wrinkles. The wrinkles of *H. imbricata* are parallel to subparallel to the trace axis, whereas the wrinkles on *H. storeana* have a plaited pattern (Uchman, 2001). *Halopoa* Torell, 1870, including *H. storeana* is a pascichnion burrow (Uchman, 1998) and found in sandstone turbidites of deep-marine flysch deposits (Uchman, 1998). Its stratigraphic range

includes the Paleocene (Książkiewicz, 1977) and lower Oligocene of the Polish Carpathians (Uchman, 1998).

?*Halopoa* isp. (Fig. 15J) is a hypichnial, horizontal, straight to gently curved, cylindrical burrow, covered with oblique, irregular ridges or wrinkles. The ridges are 7–8 mm wide. *Halopoa* is usually horizontal, relatively long and unbranched, with continuous furrows and wrinkles. However, the ichnotaxa in question exhibits some, if not all the features of *Halopoa* – with very few wrinkles – therefore, it should be accompanied by question marks.

*Ophiomorpha annulata* (Książkiewicz, 1977) (Fig. 16A, B) occurs as a hypichnial, rarely branched, tubular cylinders with or without a wall, 3–4 mm in diameter. It is preserved in full relief along the bedding planes of sandstone beds. This ichnospecies is generally interpreted as a dwelling and feeding structure, produced probably by deeply burrowing crustaceans (Uchman, 2004). *Ophiomorpha* is very common in Mesozoic and Cenozoic deposits in shallow- and marginal marine environments, although some species have been recorded in deeper-marine settings (Frey *et al.*, 1978).

*Ophiomorpha rudis* (Książkiewicz, 1977) (Fig. 16C–F) is a horizontal, vertical, or oblique, sparsely branched, sand-filled cylindrical tunnel, 8–20 mm in diameter, with or without a wall. *O. rudis* generally is interpreted as a dwelling–feeding structure, produced by crustaceans searching for food in sediments rich in plant detritus (Uchman, 2009; Demirçan and Uchman, 2017). It is characteristic of deep-sea, sandy deposits (Uchman, 2009). *Ophiomorpha rudis* is known from the Tithonian to the Miocene (Tchoumatchenco and Uchman, 2001).

*Planolites beverleyensis* (Billings, 1862) (Fig. 16G–I) is a cylindrical, horizontal to oblique, smooth structure without a wall, 5–8 mm in diameter. It has the same filling as the surrounding rock. *P. beverleyensis* is interpreted as a feeding structure of vermiform animals (Howard and Frey, 1984). *Planolites* Nicholson, 1873 occurs in several facies



**Fig. 9.** Views of locality 4, Haymana Fm. **A.** Carbonates in the lower part. **B.** Limestones and conglomerates in the middle part. **C.** Limestones in the upper part.

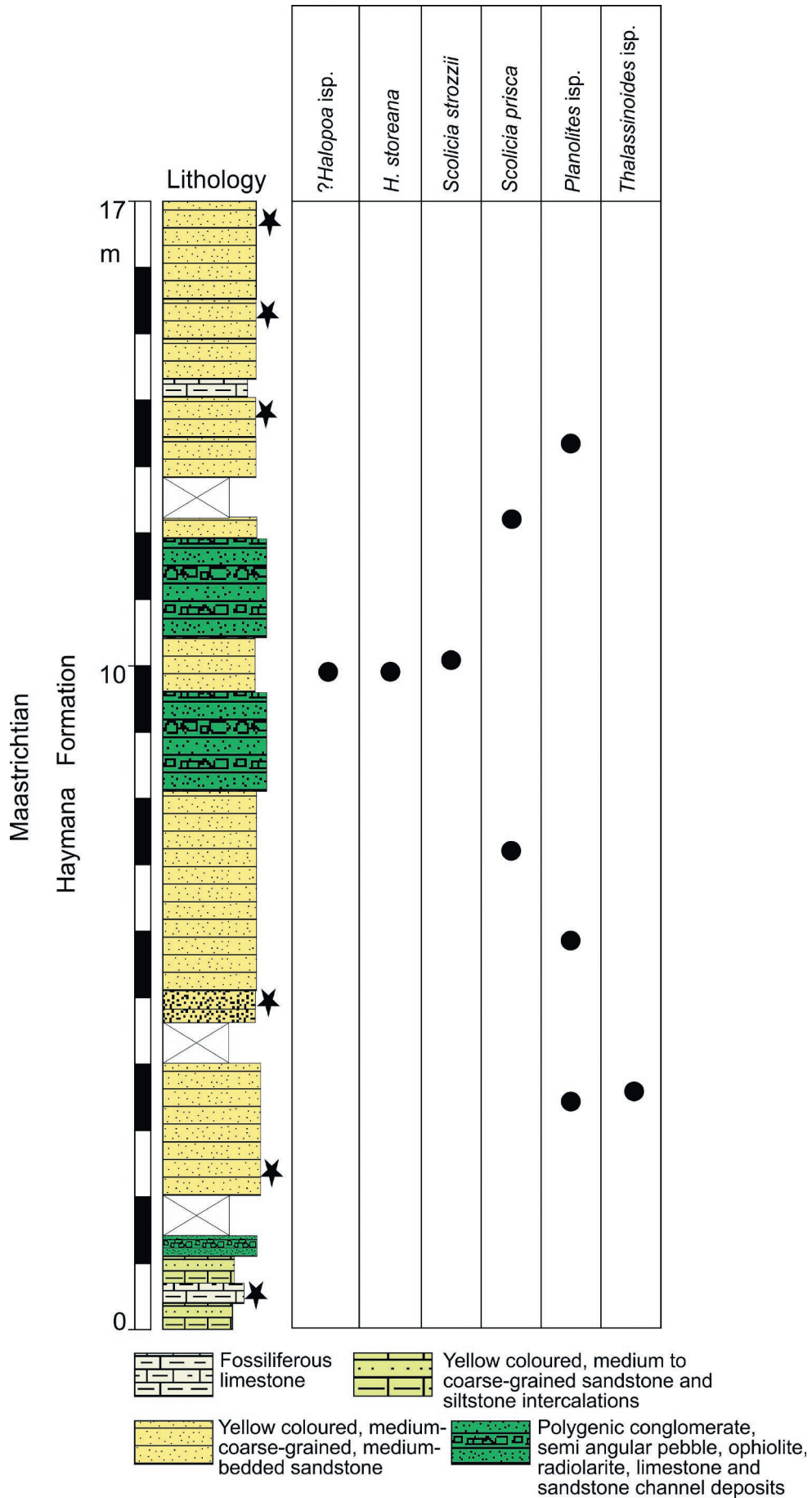


Fig. 10. Measured section of locality 4, Haymana Fm.



**Fig. 11.** Views of locality 5, Yeşilyurt Fm. **A.** Conglomerates in the lower part (western part). **B.** Deposits dominated by sandstones (southern side).

in their different palaeoenvironments, so their usefulness as palaeoenvironmental indicators is limited (Pemberton and Frey, 1982). This taxon is known from the Proterozoic to the Holocene (Häntzschel, 1975; McCann and Pickerill, 1988; Mángano and Buatois, 2016).

*Planolites montanus* Richter, 1937 (Fig. 16H) is a relatively small, straight to slightly curved, and horizontal to slightly inclined burrow, which is 2–3 mm wide. *P. montanus* differs from *P. beverleyensis* in that it is usually round and

shorter (Demircan and Uchman, 2016). It is a widespread trace fossil in different marine and non-marine environments (Pemberton and Frey, 1982).

*Planolites* isp. (Fig. 16I) is a horizontal to subhorizontal, unbranched, straight to slightly curved, cylindrical burrow, which is 3–4 mm wide.

*Thalassinoides* isp. (Figs 17A–C, 19E) is straight or slightly winding, horizontal burrows, which is 6–22 mm wide, showing Y- or T-shaped branches. *Thalassinoides*,

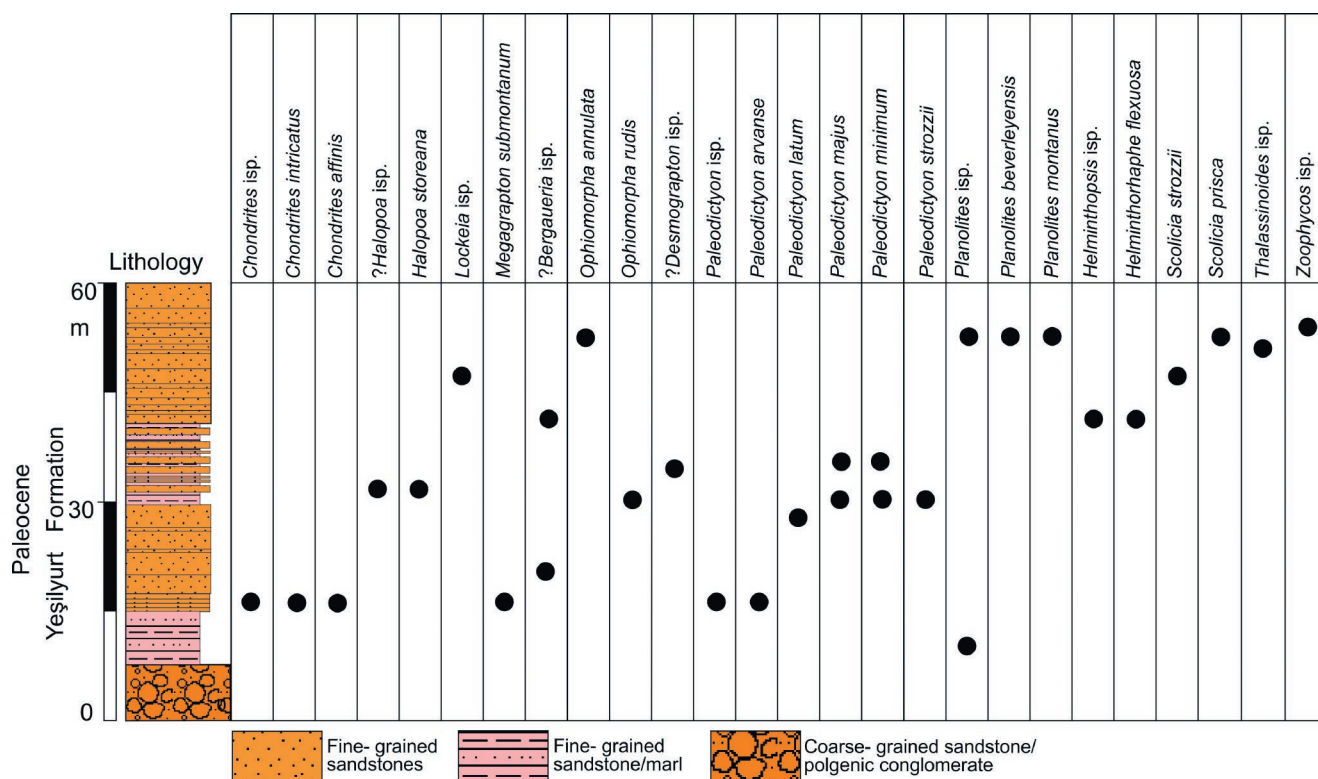


Fig. 12. Measured section of the Yeşilyurt Fm.

with its distinctive Y- or T- shaped branches, has been reported from deep-sea deposits (Kern and Warme, 1974; Uchman, 1995), since the Mesozoic (Bottjer *et al.*, 1987). It is also abundant in shallow-marine deposits. *Thalassinoides* Ehrenberg, 1944 mainly was produced by dwelling and/or feeding activity of crustaceans, shrimps and ghost shrimps, whereas it also was formed by shrimps, comparable to recent callianassids, in Mesozoic-Cenozoic sediments (Frey *et al.*, 1978).

cf. *Thorichnus* isp. (Fig. 17D, E) is a system of unlined burrows, preserved in positive hyporelief, consisting generally of the master burrow and laterally branches, which are 2–3 mm wide and up to 80 mm long. They form a dendritic or antler-like pattern. The branches are usually more abundant on one side. Originally, *Thorichnus* Pokorný, Krmíček and Sudo, 2017 was identified in subaquatic, lacustrine upper Miocene deposits in southeastern Iceland. Its characteristics indicate the dominance of a deposit-feeding ethology, less frequently the occurrence of surface grazing traces (pascichnia) and permanent dwelling structures (domichnia).

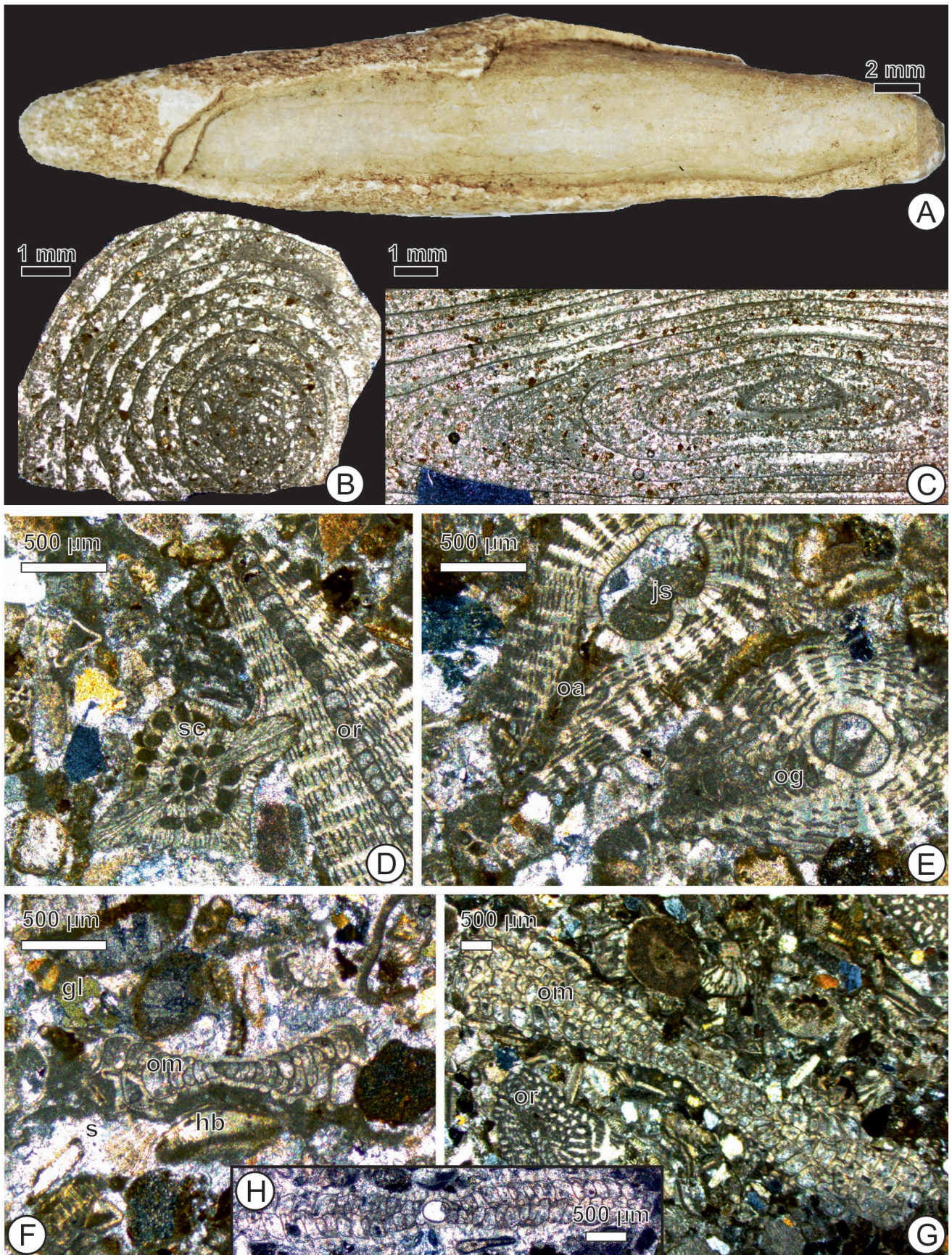
?*Trichichnus linearis* Frey, 1970 (Fig. 17F, H) is a vertical to oblique, unbranched, hair-like, very thin, cylindrical trace fossil, which is less than 1 mm in diameter. Its fill is usually pyritized. The most particular feature of *Trichichnus* is pyritization, which is not found in other trace fossils. *Trichichnus* Frey, 1970 is interpreted as a chemichnion structure (Uchman, 1999). It is produced by modern, large, sulphur bacteria, which live in the transition from anoxic to dysoxic sediments (Kędzierski *et al.*, 2015). *Trichichnus* is known from the marine, fine-grained deposits of different depths (Frey, 1970; Wetzel, 1983). It ranges from the Cambrian (Stachacz, 2012) to the Holocene (Wetzel, 1983).

*Trichichnus* isp. (Fig. 17G) is a cylindrical, straight or slightly winding structure, filled with pyrite or iron oxides, variably oriented and less than 1 mm in diameter. *Trichichnus* is observed winding ferruginous cylinder, which probably was produced by sulfur bacteria in the transition between anoxic-dysoxic sediments (Kędzierski *et al.*, 2015).

*Palaeophycus* isp. (Fig. 17I) is a horizontal, straight, cylindrical burrow with a wall, approximately 2 mm in diameter. The filling is different than the surrounding sediment. *Palaeophycus* Hall, 1847 differs from the morphologically similar *Planolites* in the presence of a wall (Pemberton and Frey, 1982). It is interpreted as a facies-crossing ichnogenus, produced by predeceous vermiform or suspension- and deposit-feeding (Schlirf, 2003) organisms. It ranges from the Ediacaran to Recent (Pemberton and Frey, 1982).

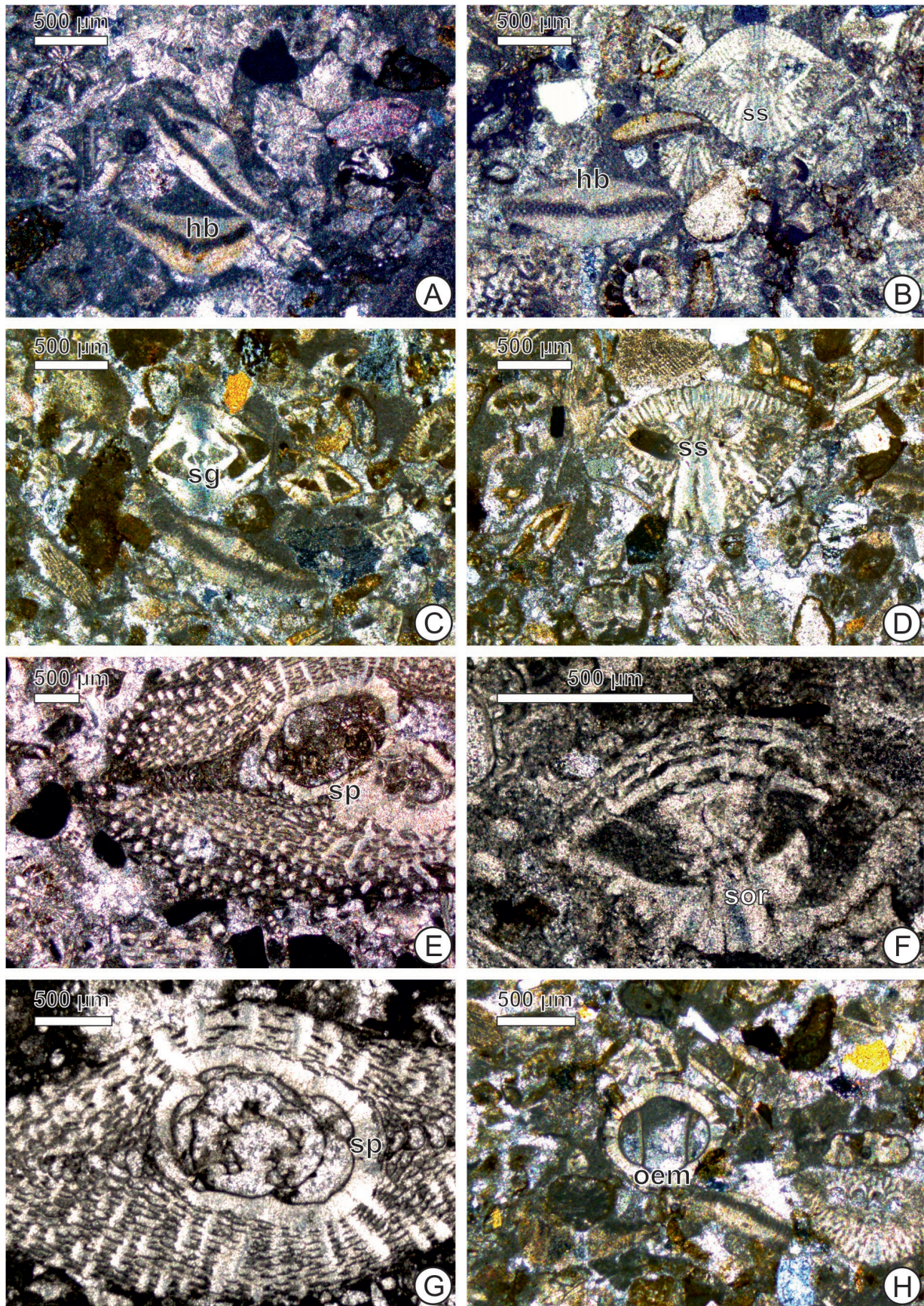
### Spreite structures

*Phycosiphon incertum* Fischer-Ooster, 1858 (Figs 17J, 18A, G, H) occurs as endichnial, horizontal lobes, encircled by a meandering, marginal tunnel. The lobes are 0.8–1 mm wide and up to 7 mm long. The marginal tunnel is about 1 mm wide. The tracemaker was an opportunistic, highly selective deposit-feeder (fodinichnion) and generally colonized sediments enriched in organic matter (Wetzel, 2010), probably a vermiform organism (Bednarz and McIlroy, 2009), but it remains unrecognized (Wetzel and Bromley, 1994; Wetzel and Uchman, 2001; Wetzel, 2008, 2010). *P. incertum* occurs from the Palaeozoic to the Holocene in deposits, ranging from continental shelves to submarine fans (Seilacher, 1978; Fu, 1991; Goldring *et al.*, 1991; Savrda *et al.*, 2001; Naruse and Nifuku, 2008).

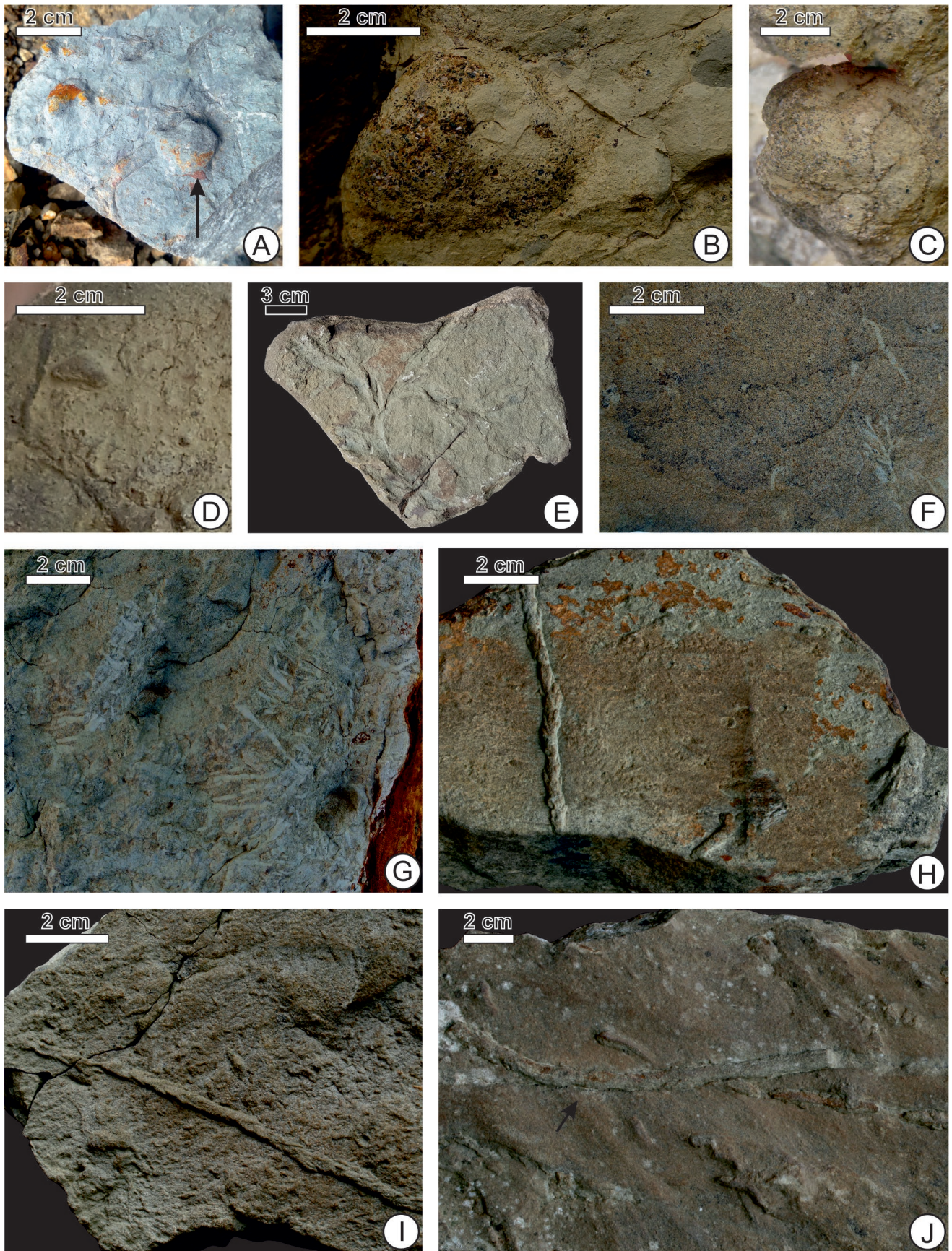


**Fig. 13.** Larger foraminifera views from the Haymana Formation (Maastrichtian) at Ahırlıkuyu. A–C. *Lofusina ketini*, A – external view, B – equatorial section, AHI2017\_13, C – tangential section, AHI2017\_9. D. *Siderolites calcitrapoides* (sc) and *Orbitoides* sp. (or), AHI2017\_2. E. *Orbitoides apiculatus* (oa) and *O. gruenbachensis* (og), geopetal structure (js), AHI2017\_2. F. *Omphalocyclus* sp. (om), *Hellenocyclina beotica* (hb), glauconite (gl), sparite, AHI2017\_3. G. H. *Omphalocyclus macroporus* (om), *Orbitoides* sp. (or), 6. AHI2017\_3; 7. AHI2017\_15.

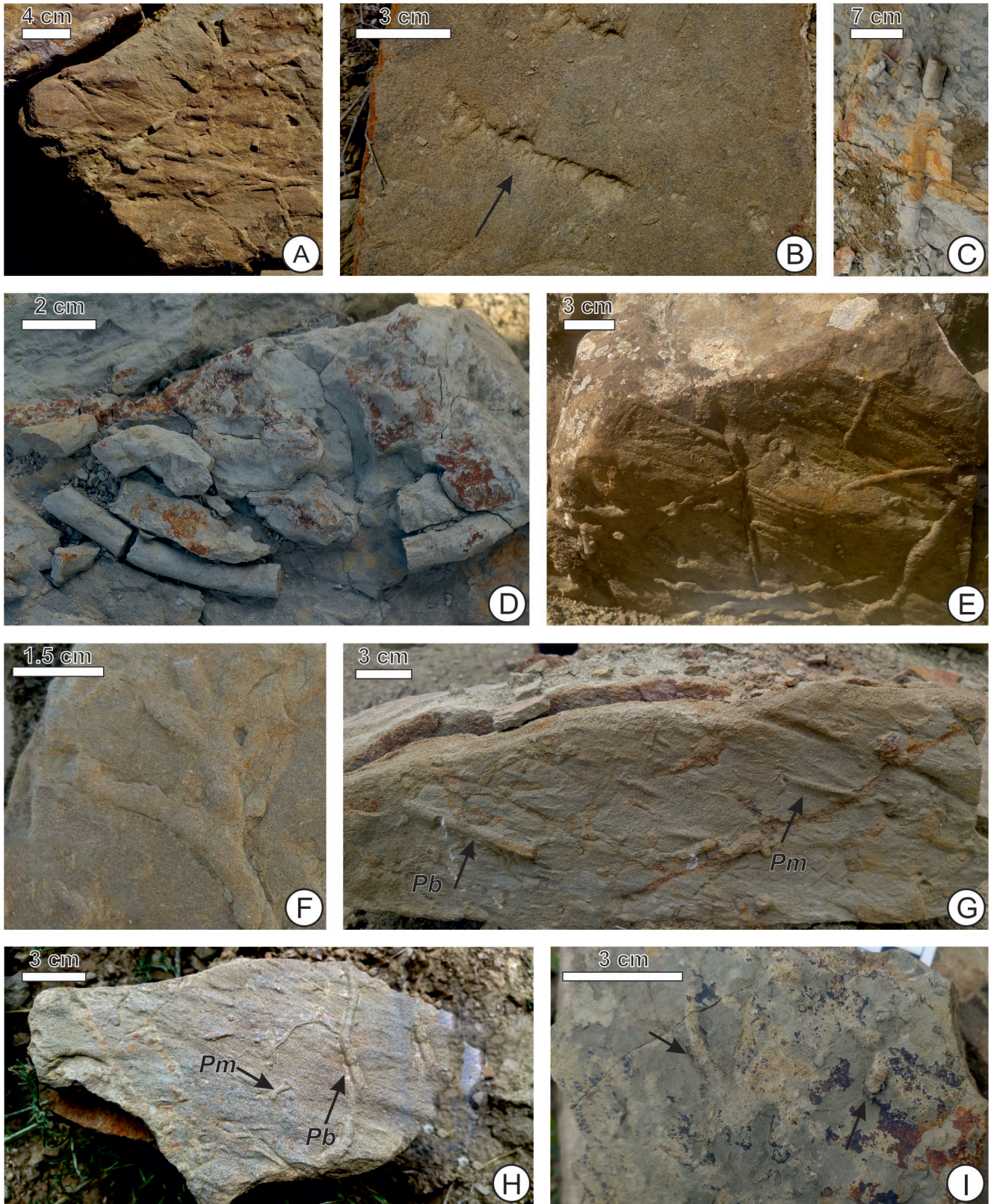




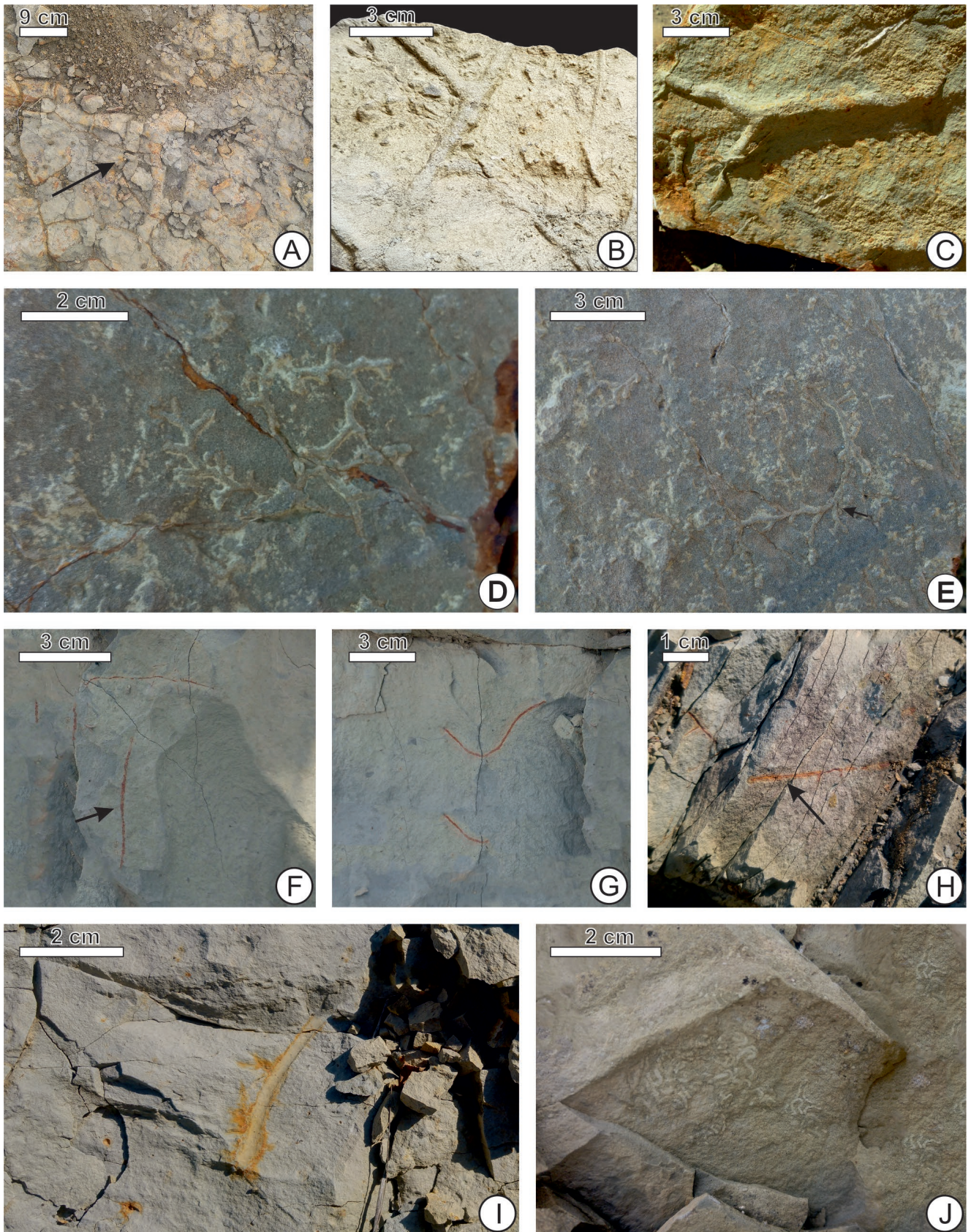
**Fig. 14.** Selected larger benthic foraminifera in thin sections from the Haymana Formation (Maastrichtian) at Ahırlıkuyu. **A.** *Hellenocyclina beotica* (hb), AHI2017\_14. **B.** *Cideina soezerii* (cs), *Hellenocyclina beotica* (hb), AHI2017\_14. **C.** *Sulcoperculina globosa* (sg), AHI2017\_2. **D.** *Selimina spinalis* (ss), AHI2017\_2. **E.** *Simplorbites papyraceus* (sp), reproduction view, AHI2017\_13. **F.** *Sirtina orbitoidiformis* (sor), AHI2017\_12. **G.** *Simplorbites papyraceus* (sp), AHI2017\_13. **H.** *Orbitoides* embryo within sandy limestones, *Hellenocyclina beotica* (hb), *Sulcoperculina vermunti* (sw), *Cideina soezerii* (cs), AHI2017\_2.



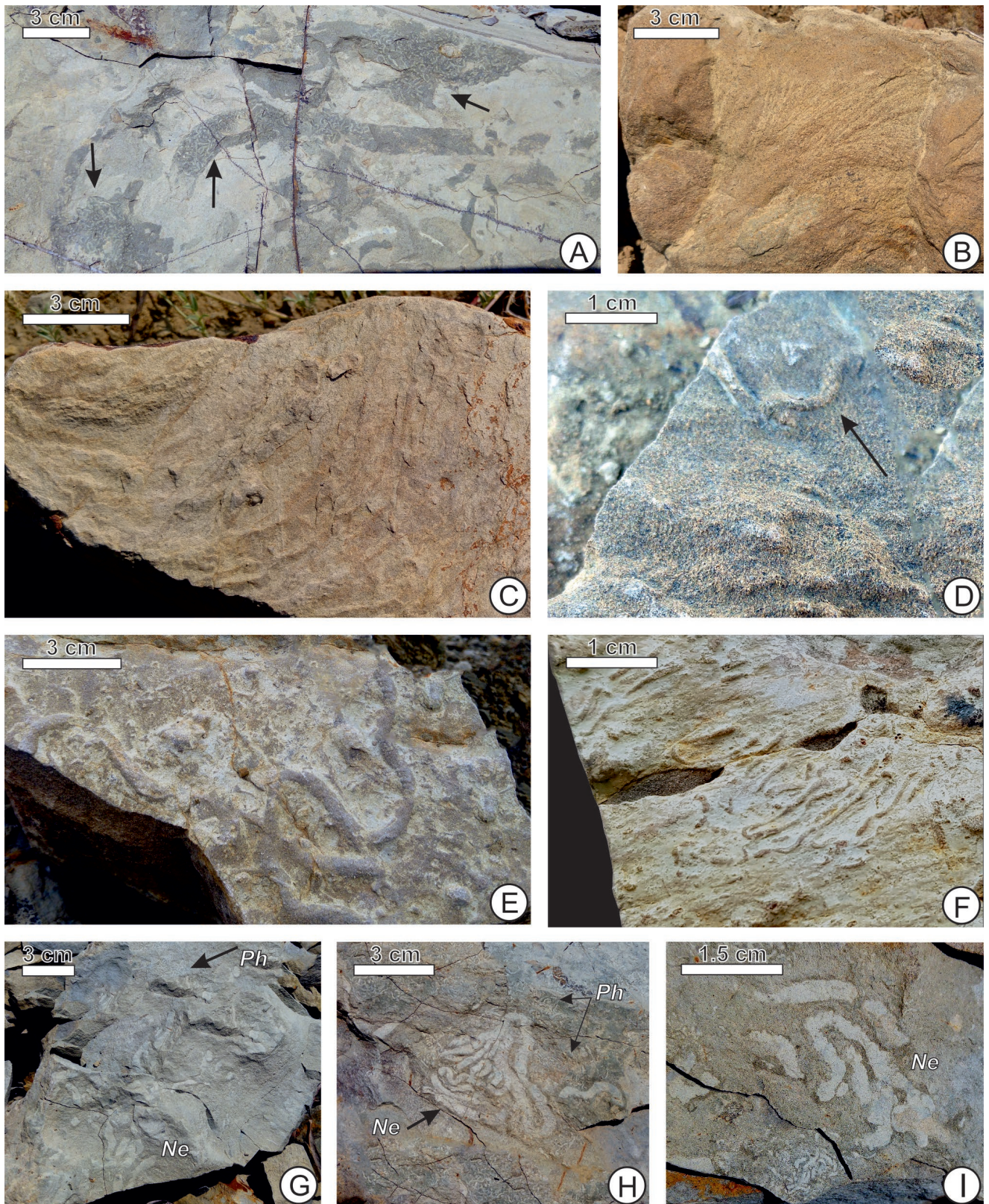
**Fig. 15.** Field photographs of trace fossils from the Haymana Fm (A–C, E–G, I, J) and Yeşilyurt Fm (D, H). **A.** cf. *Asteriacites* isp., locality 2. **B, C.** ?*Bergaueria* isp., locality 2. **D** *Lockeia* isp., locality 5. **E.** *Chondrites affinis*, locality 1. **F.** *Chondrites intricatus*, locality 1. **G.** *Chondrites* isp., locality 1. **H.** *Halopoa storeana*, locality 5. **I.** *Halopoa storeana*, locality 4. **J.** ?*Halopoa* isp., locality 3.



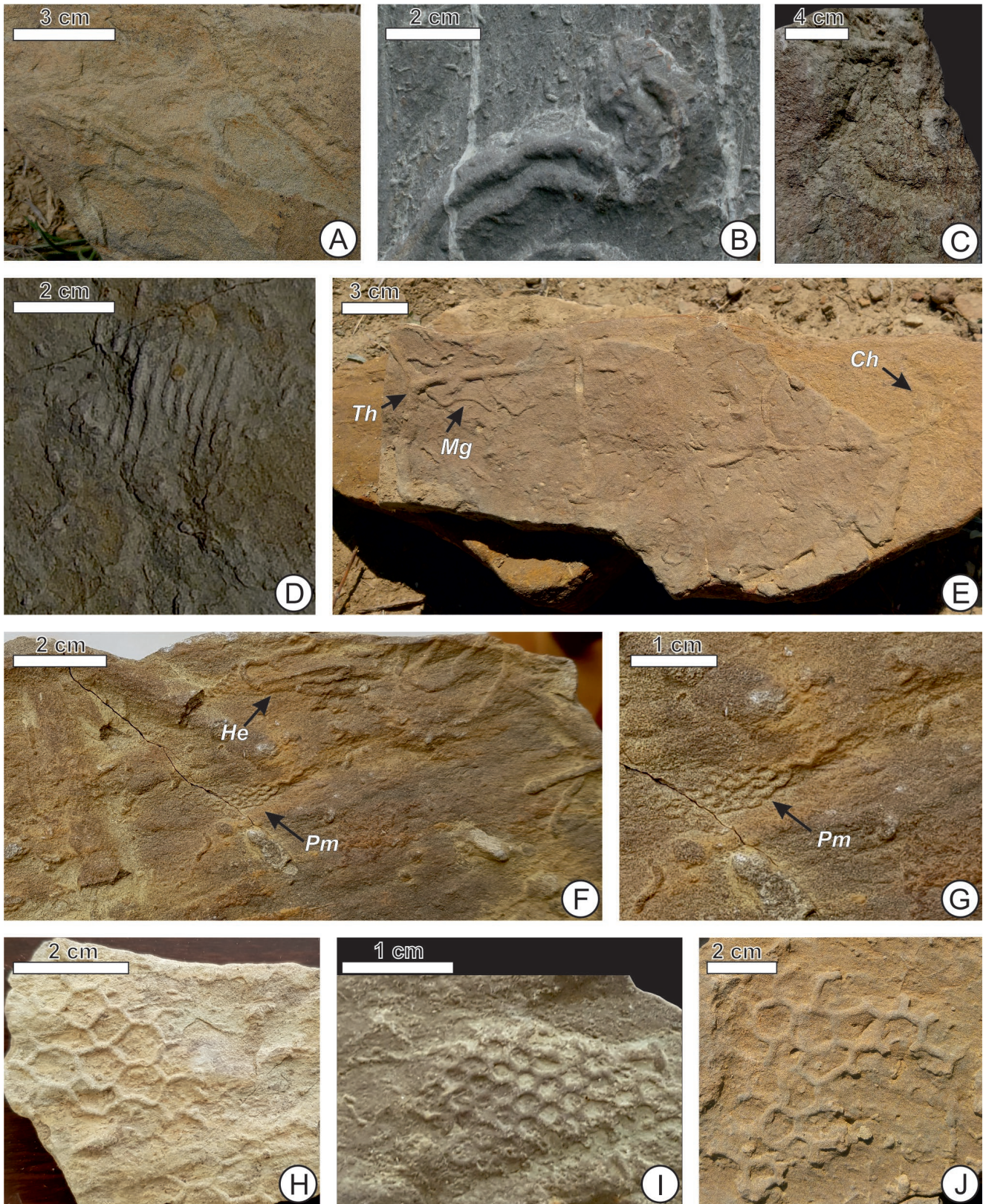
**Fig. 16.** Field photographs of other trace fossils from the Haymana Fm (A–F) and Yeşilyurt Fm (G–I). **A, B.** *Ophiomorpha annulata*, locality 3. **C–F.** *Ophiomorpha rudis*, locality 2. **G–I.** *Planolites beverleyensis* (Pb), *Planolites montanus* (Pm), locality 5. **H.** *Planolites montanus* (Pm), locality 5. **I.** *Planolites* isp., locality 5.



**Fig. 17.** Other trace fossils (field photographs) from the Haymana Fm from localities 3 (A–C) and 1 (D–J). A–C. *Thalassinoides* isp. D, E. cf. *Thorichnus* isp. F, H. *Trichichnus* cf. *linearis*. G. *Trichichnus* isp. I. *Palaeophycus* isp. J. *Phycosiphon* incertum.



**Fig. 18.** Field photographs of trace fossils identified in the Haymana Fm (A, B, D–I) and the Yeşilyurt Fm (C). **A.** *Phycosiphon incertum* (black arrows), locality 1. **B.** *Zoophycos* isp., locality 2. **C.** *Zoophycos* isp., locality 5. **D.** *?Cochlichnis* isp. (black arrows), locality 2. **E.** *Helminthopsis* isp., locality 2. **F.** *Helminthorhapse flexuosa*, locality 2. **G–I.** *Nereites* isp., locality 1.



**Fig. 19.** Field photographs of remaining Haymana Fm (A–C) and Yeşilyurt Fm (D–J). **A.** *Scolicia prisca*, Haymana Fm, locality 4. **B.** *Scolicia strozzii*, Haymana Fm, locality 4. **C.** *Scolicia vertebralis*, Haymana Fm, locality 2. **D.** *Desmograptus* isp., Yeşilyurt Fm, locality 5. **E.** *Megagraptus submontanum*, Yeşilyurt Fm, locality 5. **F, G.** *Paleodictyon minimum*, Yeşilyurt Fm, locality 5. **H.** *Paleodictyon majus*, Yeşilyurt Fm, locality 5. **I.** *Paleodictyon latum*, Yeşilyurt Fm, locality 5. **J.** *Paleodictyon arvense*, Yeşilyurt Fm, locality 5.

*Zoophycos* isp. (Fig. 18B, C) is an endichnial, planar structure, filled with spreite laminae. The spreites are concordantly arcuate. The spreite lamellae may contain pellets, elliptical in outline, up to 1.5 mm long. *Zoophycos* Massalongo, 1855 is interpreted as feeding structure, which was produced by unknown deposit feeders (Bottjer *et al.*, 1988; Olivero, 2003). Mostly, it occurs in deep-sea sediments in the Cenozoic (Zhang *et al.*, 2015).

### Winding and meandering structures

?*Cochlichnis* isp. (Fig. 18D) is a hypichnial, semi-cylindrical ridge, 2–3 mm wide and preserved in semi-relief, forming meanders up to 7 mm wide and 8 mm in amplitude. Only one incomplete first-order meander is visible. It is poorly recognizable owing to incomplete preservation. *Cochlichnus* Hitchcock, 1858 has been interpreted as a locomotion or grazing trace fossil, which was produced by insect larvae and nematodes (Buatois *et al.*, 1997; Metz, 1998). It has a wide facies range, including fluviatile and marginal-marine settings from the Precambrian to the Holocene (Häntzschel, 1975; Fillion and Pickerill, 1990; Buatois and Mángano, 1993).

*Helminthopsis* isp. (Fig. 18E) is a hypichnial, semi-cylindrical, loosely meandering, smooth, unbranched ridge, about 4–5 mm wide. *Helminthopsis* Wetzel & Bromley, 1996 is interpreted as a feeding or grazing trace fossil, produced by a vermiform endobiont detritus-feeder, probably a polychaete (Dam, 1990; Han and Pickerill, 1995; Uchman, 1998). It is a facies-crossing trace fossil, common in flysch (Książkiewicz, 1977). *Helminthopsis* occurs in the time interval ranging from the Cambrian to the Holocene in fully marine (Dam, 1990; Uchman, 1998; Uchman *et al.*, 2005; Sarkar *et al.*, 2009), deltaic (Bann and Fielding, 2004; Gani *et al.*, 2007; Buatois *et al.*, 2008) and non-marine settings (Buatois and Mángano, 1995, 2007; Mángano *et al.*, 1996; Buatois *et al.*, 1997; Krapovickas *et al.*, 2009; Wetzel and Bromley, 1996).

*Helminthorhapha flexuosa* Uchman, 1995 (Figs 18F, 19F) is a hypichnial meandering string, without bulges in the turns of the meanders, preserved in semi-relief in fine-grained sandstones. The string is 0.6–1 mm in diameter; the amplitude of meanders attains 25–30 mm, and their depth 2–3 mm. *H. flexuosa* is a graphoglyptid, produced by an unknown worm from mostly flysch deposits (Seilacher, 1977) and it can be a grazing trace fossil, which occurs in deep-sea sediments on the soles of fine-grained turbidites (Fan *et al.*, 2017). Its range is from Upper Cretaceous to Miocene (Fan *et al.*, 2017). *H. flexuosa* was also found in turbiditic sediments in the Polish Carpathians (Campanian–Palaeocene), in the Northern Apennines, Italy (Palaeocene), and in the deep-sea fan fringe deposits (Miocene) of southern Turkey (Uchman and Demircan, 1999).

*Nereites* isp. (Fig. 18G–I) is a horizontal, endichnial, irregularly meandering band, visible on parting surfaces. It is 3–5 mm wide. The band is lighter in colour than the host siltstone and its margins are uneven. *Nereites* MacLeay, 1839 is a typical pascichnion, produced by a worm-like sediment-feeder (Uchman, 1995; Mángano *et al.*, 2002; Martin and Rindsberg, 2007). It was formed just above the

redox boundary (Wetzel, 2002). *Nereites* occurs in shallow- to deep-marine deposits in the Palaeozoic (Conkin and Conkin, 1968; Hakes, 1976; Seilacher, 1983; Chaplin, 1985; Fillion and Pickerill, 1990; Rindsberg, 1994) and commonly in deep-sea Mesozoic and Cenozoic deposits (McCann and Pickerill, 1988; Crimes and McCall, 1995; Uchman, 1995; Wetzel, 2002). It ranges from from the late Precambrian–early Cambrian (Aceñolaza and Durand, 1973; Crimes and Germs, 1982) to the Miocene (Uchman, 1995) and the Quaternary (Ekdale and Lewis, 1991).

*Scolicia prisca* de Quatrefages, 1849 (Fig. 19A) is an epichnial, trilobate, curved or meandering furrow, 12–15 mm wide and up to 2 mm deep. The middle lobe is convex-up and 6.5 mm wide, covered with perpendicular ribs. The lateral lobes are covered by oblique ribs. *Scolicia* Quatrefages, 1849 is a pascichnion produced by spatangoid echinoids (Uchman, 1995). It is observed from shelf to deep-water environments and is known since the Late Jurassic to Recent (Tchoumatchenco and Uchman, 2001).

*Scolicia strozzii* (Savi and Meneghini, 1850) (Fig. 19B) is a hypichnial, loosely meandering, bilobate ridge, 13–22 mm wide, preserved in semi-relief in fine-grained sandstone turbidites. *S. strozzii* represents the washed-out remnants and casts of burrows of spatangoid echinoids. Straight to gently winding specimens are assigned to *S. strozzii* var. *vagans* (Książkiewicz, 1977) and may correspond to the locomotion activity of echinoids (Uchman, 1995).

*Scolicia vertebralis* Książkiewicz, 1970 (Fig. 19C) is an epichnial, three-lobed, winding and meandering, V-shaped furrow ridge, 15–25 mm wide, in medium-grained turbiditic sandstones. *S. vertebralis* is a locomotion and feeding burrow (pascichnion) of a spatangoid echinoid (Smith and Crimes, 1983; Uchman, 1995; Bromley *et al.*, 1997).

### Branched winding and meandering structures

?*Desmograpton* isp. (Fig. 19D) is a hypichnial, parallel to subparallel ridge, 1–1.3 mm wide, 30 mm long, semi-circular or asymmetrically oval in cross-section, preserved in semi-relief in fine-grained, turbiditic sandstones. *Desmograpton* Fuchs, 1895 is considered to be a typical pre-turbidite, graphoglyptid trace fossil (agrichnion), produced most likely by vermiform organisms, which occurs in flysch deposits from the Silurian (McCann, 1989) to the Miocene (D'Alessandro, 1980; Uchman, 1995).

### Networks

*Megagraption submontanum* (Azpeitia-Moros, 1933) (Fig. 19E) is a hypichnial, incompletely preserved irregular net, composed of a winding, semi-circular string. Meshes of the net are 17 mm wide, and the string is 2.5 mm wide. *Megagraption* Książkiewicz, 1968 typical graphoglyptid, is interpreted mainly as a farming (agrichnial) structure (Seilacher, 1977). It occurs in deep-water, mainly flysch deposits, from Cenomanian to Eocene (Uchman, 1998).

*Paleodictyon minimum* Sacco, 1888 (Fig. 19F, G) is a hypichnial net, composed of a string that is 0.1–0.3 mm wide and arranged in meshes which are 1–2 mm wide.

The taxonomy of *Paleodictyon* Meneghini in Savi and Meneghini, 1850 was classified by Uchman (1995), according to its morphometric parameters. In this study, Uchman's morphometric classification was taken into consideration for the identification of *Paleodictyon* ichnospecies. Röder (1971) and Seilacher (1977) interpreted *Paleodictyon* as agrichnial burrow systems, made to cultivate or trap microorganisms. Garlick and Miller (1993) suggested a small, elongate crustacean as the tracemaker. It occurs particularly in deep-water, mainly flysch deposits (Uchman, 1998), occasionally occurring in shelf sediments in the Palaeozoic (Archer and Maples, 1984; Paczeńska, 1985) and Mesozoic (Häntzschel, 1964; Gierlowski-Kordesch and Ernst, 1987; Hantzpergue and Branger, 1992). It ranges from the Cambrian (Crimes and Anderson, 1985) to the Holocene (Ekdale, 1980).

*Paleodictyon majus* Meneghini in Peruzzi, 1880 (Fig. 19H) is a hypichnial, sub-hexagonal network, preserved in convex-upward semi-relief. The string is no wider than about 1–1.5 mm and the maximum mesh size ranges from 7 to 12 mm. This is a common ichnospecies of *Paleodictyon* in Cenozoic turbidites (Książkiewicz, 1977).

*Paleodictyon latum* Vialov and Golev, 1965 (Fig. 19I) is a regular net, composed of polygonal to hexagonal meshes that are 1.8–1.6 mm wide. The meshes are formed by semi-circular ridges (strings), which are 0.5–0.4 mm wide. *Paleodictyon latum* is common in thin- to medium-bedded, turbiditic sediments (Uchman, 2007).

*Paleodictyon arvense* Barbier, 1956 (Fig. 19J) is preserved as a regular, hexagonal net, the meshes of which are 13.2–16 mm wide and string is 2.14–2.5 wide mm.

*Paleodictyon strozzii* Meneghini in Savi and Meneghini, 1850 (Fig. 20A) is a hypichnial sub-hexagonal network, preserved in convex-upward semi-relief. The string is 0.3–1 mm wide and the maximum mesh size ranges from 4 to 5 mm.

*Paleodictyon* isp. (Fig. 20B) is a hypichnial sub-hexagonal network, preserved in convex-upward semi-relief.

The string is flat and 3.18 mm wide, and the maximum mesh size ranges from 11 to 13 mm.

## DISTRIBUTION AND SIGNIFICANCE OF TRACE FOSSILS

Deposits of the section of locality 1 contain low diversity, post-depositional traces fossils (Table 3), dominated by non-graphoglyptid, including *Ophiomorpha annulata*, *Scolicia* isp. and *Nereites* isp. The trace fossils represent the *Ophiomorpha rudis* ichnosubfacies of the *Nereites* ichnofacies, which usually occurs in proximal depositional lobe and channel deposits of deep-sea fans (Uchman, 2009). Deposits of section of locality 2 contain a more diverse trace fossils, including non-graphoglyptid ichnotaxa (cf. *Asteriacites* isp., ?*Bergaueria* isp., *Chondrites intricatus*, ?*Cochlichnis* isp., *Helminthopsis* isp., *Ophiomorpha rudis*, *Scolicia vertebralis*, *Thalassinoides* isp., cf. *Thorichnus* isp.) and graphoglyptids (*Helminthorhapha flexuosa*, *Paleodictyon minimum*, *P. strozzii*). They represent cubichnia, repichnia, pascichnia, domichnia, fodinichnia and agrichnia (Table 3). Agrichnia dominante. This ethological category occurs mostly in deep-sea turbiditic environments and characterized the *Paleodictyon* ichnosubfacies of the *Nereites* ichnofacies, which is typical of distal and some middle parts of depositional system (Uchman and Wetzel, 2012). The obtained trace fossil data suggest that the deposits from the section of locality 2 are deeper than the deposits in section of locality 1.

The sections of localities 3 and 4 contain low-diversity, non-graphoglyptid trace fossils ?*Bergaueria* isp., *Halopoa storeana*, ?*Halopoa* isp., *Ophiomorpha annulata*, *O. rudis*, *Planolites* isp., and *Thalassinoides* isp. Trace-fossils in the locality 4 section are low diverse (*Halopoa* isp., *Planolites* isp., *Scolicia prisca*, *S. strozzii*, *Thalassinoides* isp.). They represent pascichnia, domichnia and fodinichnia

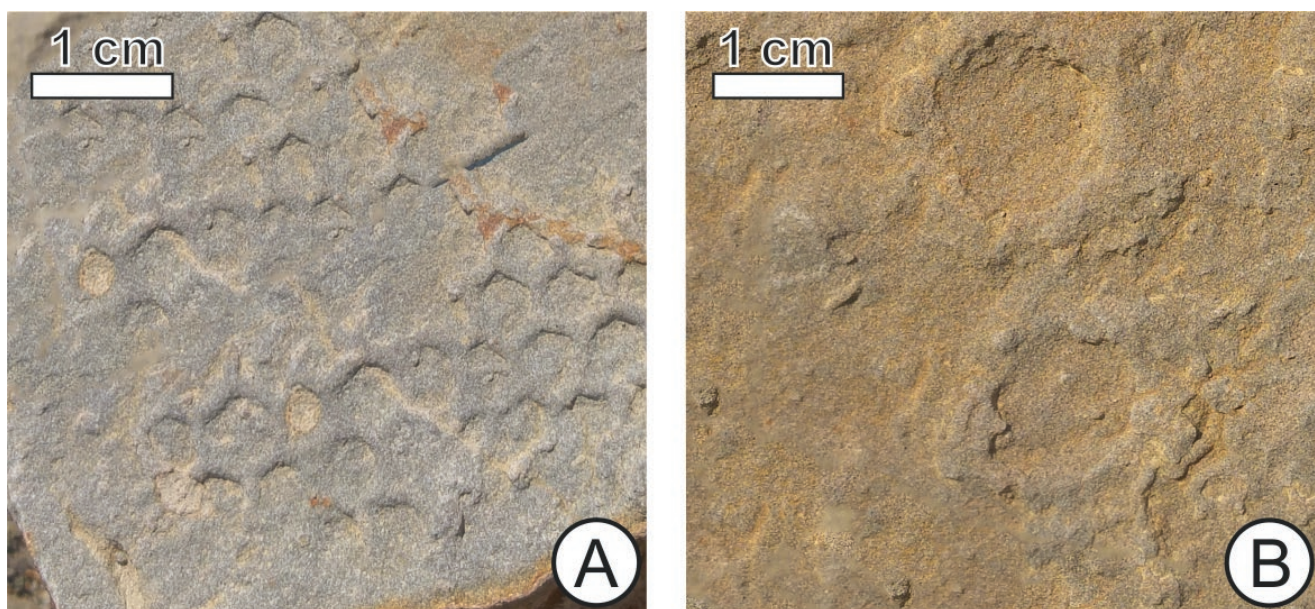


Fig. 20. Some *Paleodictyon* in the studied sections from the Yeşilyurt Fm, locality 5. A. *Paleodictyon strozzii*. B. *Paleodictyon* isp.



Table 3

Presence of ichnogenera in the Haymana and the Yeşilyurt formations, their ethology, relationship to turbiditic beds, morphological affiliation with indication of graphoglyptids.

BWM – branched winding and meandering; WM – winding and meandering.

Ichnotaxa	Pre-/Post-depositional	Ethological Category	Morphological Group	Graphoglyptids
cf. <i>Asteriacites</i> isp.	Post	Cubichnia	Radial structures	
? <i>Bergaueria</i> isp.	Pre	Cubichnia	Circular and elliptical	
<i>Chondrites</i> isp.	Post	Chemichnia	Simple and branched	
<i>Chondrites affinis</i>	Post	Chemichnia	Simple and branched	
<i>Chondrites intricatus</i>	Post	Chemichnia	Simple and branched	
? <i>Cochlichnis</i> isp.	Pre	Repichnia	WM	
? <i>Desmograpton</i> isp.	Pre	Agrichnia	BWM	X
? <i>Halopoa</i> isp.	Post	Fodichnia	Simple and branched	
<i>Halopoa storeana</i>	Pre	Fodichnia	Simple and branched	
<i>Helminthopsis</i> isp.	Pre/Post	Pascichnia	WM	
<i>Helminthorhapha flexuosa</i>	Pre	Agrichnia	WM	X
<i>Lockeia</i> isp.	Pre	Cubichnia	Circular and elliptical	
<i>Megagraption submontanum</i>	Pre	Agrichnia	Network	X
<i>Nereites</i> isp.	Post	Pascichnia	WM	
<i>Ophiomorpha annulata</i>	Post	Domichnia	Simple and branched	
<i>Ophiomorpha rudis</i>	Post	Domichnia	Simple and branched	
<i>Paleodictyon</i> isp.	Pre	Agrichnia	Network	X
<i>Paleodictyon arvense</i>	Pre	Agrichnia	Network	X
<i>Paleodictyon latum</i>	Pre	Agrichnia	Network	X
<i>Paleodictyon majus</i>	Pre	Agrichnia	Network	X
<i>Paleodictyon minimum</i>	Pre	Agrichnia	Network	X
<i>Paleodictyon strozzii</i>	Pre	Agrichnia	Network	X
<i>Palaeophycus</i> isp.	Post	Fodichnia/Domichnia	Simple and branched	
<i>Phycosiphon incertum</i>	Post	Fodichnia	Spreiten	
<i>Planolites</i> isp.	Post	Pascichnia	Simple and branched	
<i>Planolites beverleyensis</i>	Post	Fodichnia	Simple and branched	
<i>Planolites montanus</i>	Post	Fodichnia	Simple and branched	
<i>Scolicia prisca</i>	Post	Pascichnia	WM	
<i>Scolicia strozzii</i>	Pre	Pascichnia	WM	
<i>Scolicia vertebralis</i>	Post	Pascichnia	WM	
<i>Thalassinoides</i> isp.	Post	Fodichnia/Domichnia	Simple and branched	
cf. <i>Thorichnus</i> isp.	Post	Pascichnia	Simple and branched	
<i>Trichichnus</i> isp.	Post	Chemichnia	Simple and branched	
? <i>Trichichnus linearis</i>	Post	Chemichnia	Simple and branched	
<i>Zoophycos</i> isp.	Post	Fodichnia	Spreiten	

(Cummings and Hodgson, 2011). The abundance of domichnia and fodinichnia (*Ophiomorpha annulata*, *O. rudis*, *Halopoa* isp., *Thalassinoides* isp.) indicates a proximal part of the depositional system, with a high rate of deposition.

The section of locality 5 (Yeşilyurt Fm, Paleocene) contains pascichnia, domichnia, fodinichnia and especially agrichnia, which are more abundant than in the Haymana Formation (Table 3). The graphoglyptids (*?Desmograpton* isp., *Helminthorhapha flexuosa*, *Megagraption submontanum*, *Paleodictyon* isp., *P. arvense*, *P. latum*, *P. majus*, *P. minimum*, *P. strozzii*) are more abundant than non-graphoglyptids (*Chondrites* isp., *C. affinis*, *C. intricatus*, *?Halopoa* isp., *Halopoa storeana*, *Lockeia* isp., *O. annulata*, *Planolites* isp., *P. beverleyensis*, *P. montanus*, *Scolicia prisca*, *S. strozzii*, *Thalassinoides* isp., and *Zoophycos* isp.). The graphoglyptids are most characteristic for deep-sea, ichnological assemblages, typical of the *Paleodictyon* ichnosubfacies of the *Nereites* ichnofacies (Uchman, 2003; Uchman & Wetzel, 2012). The assemblage of the trace fossils does not show any significant difference with respect

to trace fossils of the same ichnosubfacies in the Cretaceous Haymana Formation. This indicates that the Cretaceous–Palaeogene extinction did not influence the tracemakers over longer time intervals (cf. Uchman, 2004).

## CONCLUSIONS

Trace fossils of the Haymana and the Yeşilyurt formations in the Haymana Basin are moderately diverse in both Maastrichtian and Paleocene deposits. Their main features are as follows:

1. Thirty-five ichnospecies, belonging to 21 ichnogenera and six morphologic groups, are recognized. The following ichnofossils were identified: cf. *Asteriacites* isp., *?Bergaueria* isp., *C. intricatus*, *C. affinis*, *Chondrites* isp., *?Cochlichnus* isp., *?Desmograpton* isp., *H. storeana*, *?Halopoa* isp., *Helminthopsis* isp., *Helminthorhapha flexuosa*, *Lockeia* isp., *Megagraption submontanum*, *Nereites* isp., *Ophiomorpha rudis*, *O. annulata*, *Palaeophycus* isp., *Paleodictyon* isp., *P. arvense*, *P. latum*, *P. majus*,

- P. minimum*, *P. strozzii*, *Phycosiphon incertum*, *P. beverleyensis*, *P. montanus*, *Planolites* isp., *Scolicia strozzii*, *S. prisca*, *S. vertebralis*, *Thalassinoides* isp., cf. *Thorichnus* isp., ?*Trichichnus linearis*, *Trichichnus* isp., *Zoophycos* isp. Among these *Chondrites intricatus*, *C. affinis*, *Chondrites* isp., ?*Halopoa* isp., *O. annulata*, *P. minimum*, *P. strozzii*, *Planolites* isp., *Scolicia strozzii*, *S. prisca*, *Thalassinoides* isp., and *Zoophycos* isp. are the most common. Most of the traces represent pascichnia, domichnia, fodinichnia and agrichnia (Table 3). They belong to the *Nereites* ichnofacies.
- In this study, the specimen of cf. *Thorichnus* isp. the Haymana Formation was described for the first time in deep-sea deposits.
  - According to the identified ichnosubfacies identified, the Haymana Formation (Maastrichtian) represents the proximal to middle and partly distal parts of deep-sea fans, while the Yeşilyurt Formation (Paleocene) indicates the middle to distal fan deposits.
  - The trace fossils do not show any significant change above the K-Pg boundary with respect to these below the boundary. However, the boundary interval was not examined.
  - The larger benthic foraminifera present in the formations studied were derived from nearby, shallow parts of the Haymana Formation. They were redeposited in a turbiditic environment.

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