

TRACE FOSSILS OF MIOCENE DEEP-SEA FAN FRINGE DEPOSITS FROM THE CINGÖZ FORMATION, SOUTHERN TURKEY

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Abstract: Fan fringe deposits of deep-sea fans are characterised by the *Nereites* ichnofacies, but in the Miocene Cingöz Formation in southern Turkey they contain 17 ichnospecies typical of the *Nereites*, *Skolithos* and *Cruziana* ichnofacies, including vertical “shallow-water” horn-like forms and *Ophiomorpha rudis*. Tracemakers of *Ophiomorpha rudis* have been probably imported by stronger turbidity currents from the inner part of deep-sea fan or occurred as a result of gradual colonisation of fan fringe deposits. Similar trace-fossils occurs in related facies of the coeval Marnoso-arenacea Formation in the Northern Apennines. Comparisons with other Cretaceous–Neogene flysch formations show that ichnoassemblages of fan fringe facies are very diverse in general.

Abstrakt: Ichnofacja *Nereites* charakteryzuje utwory otoczenia stożka głębokomorskiego, jednak w utworach otoczenia stożka miocenijskiej formacji Cingöz w południowej Turcji występuje 17 ichnogatunków z ichnofacji *Nereites*, *Skolithos* i *Cruziana*, w tym “płytkowodne” formy w kształcie rogu oraz formy z gatunku *Ophiomorpha rudis*. Twórcy śladów *Ophiomorpha rudis* byli prawdopodobnie transportowani przez silniejsze prądy zawieszinowe z wewnętrznej części stożka, lub zasiedlali oni stopniowo środowisko otoczenia stożka. Podobne skamieniałości śladowe występują w pokrewnych facjach równowiekowej formacji Marnoso-arenacea z Apeninów Północnych. Facje otoczenia stożków innych kredowo-paleogeńskich formacji fliszowych charakteryzują się bardzo różnicowanymi asocjacjami skamieniałości śladowych.

Key words: trace fossils, deep-sea fan, fan fringe, flysch, Miocene, Turkey.

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INTRODUCTION

Deep-sea fans are characterised by the *Nereites* ichnofacies, which comprises mostly horizontal pascichnia and agrichnia (e.g., Seilacher, 1967; Frey & Seilacher, 1980). However, the middle fan facies can contain also the so-called “shallow-water” ichnotaxa, for instance *Ophiomorpha*, *Thalassinoides*, *Skolithos*, which occur together with the ichnotaxa typical of the *Nereites* ichnofacies (e.g., Crimes, 1973, 1977; Crimes *et al.*, 1981). It is believed, that the “pure” *Nereites* ichnofacies is present in the distal fan facies. Nevertheless, this ichnofacies is diverse in different fan systems. Distal facies of some fans contain also the “shallow-water” ichnotaxa (Uchman, 1991, 1995), but this phenomenon is still not well explained, partly because of insufficient number of data documenting this situation in different fan systems.

Well-exposed fan fringe facies, which lateral position in two partially overlapping fan systems is clear, occur in the Cingöz Formation in the southern Turkey. They contain highly diverse trace fossil assemblage, which include the “shallow-water” forms. Several ichnotaxa from the Cingöz Formation were mentioned earlier by Demircan & Toker

(1997), but without relation to different parts of depositional system. The aim of this paper is to document and discuss the assemblage in two representative sections (Fig. 1). Majority of the specimens illustrated in this paper were left in field, however some are housed in the Department of Geological Engineering in Ankara and in the Institute of Geological Sciences of the Jagiellonian University in Kraków.

GEOLOGICAL SETTING

The Cingöz Formation constitutes a part of the Adana Basin fill. The Adana Basin is a part of the Çukurova Basin, which includes also the Iskenderun Basin and the separating them Misis Structural High (Fig. 2). These structures are located between NE–SE trending Taurus orogenic belt and the Amanos Mountains, which are a part of the Cyprus Arc. The Cyprus Arc is thrust generally to south and to the south-east in the discussed region (Biju-Duval *et al.*, 1978). Formation of the basins is related to collision of the Afro-Arabian and Eurasian continents resulted in closure of the Neo-Tethys. Formation of the basins was influenced by major fault systems, which include the East Anatolian, Dead

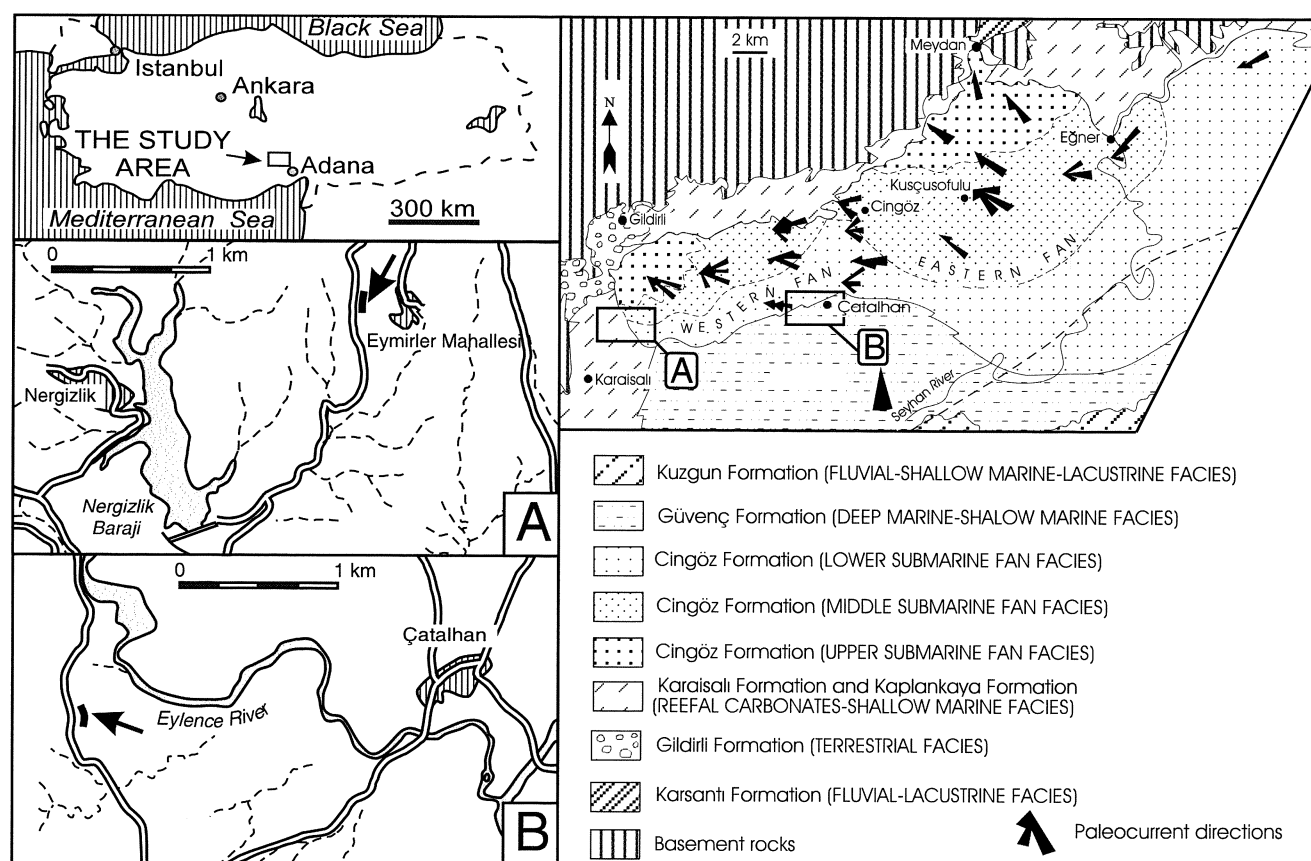


Fig. 1. Locality map showing two fans (geology based on Gürbüz & Kelling, 1992b). The studied outcrops in A and B are shown by arrows

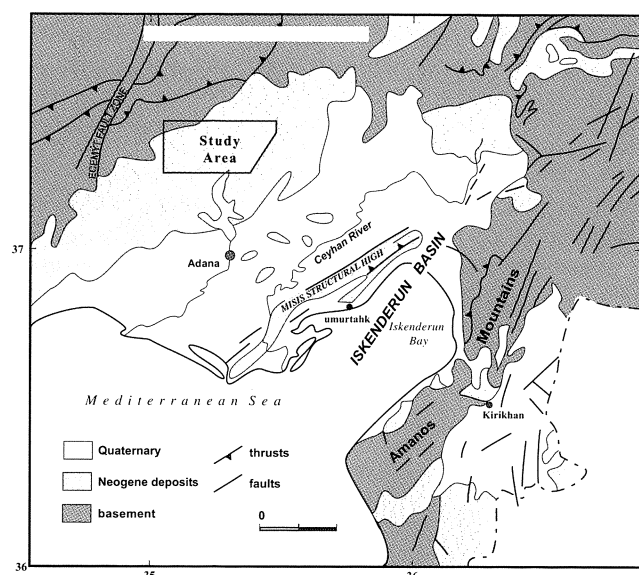


Fig. 2. Tectonic map of the Adana Basin (based on Gürbüz & Kelling, 1992b)

Sea, and the Ecemýt fault zones (Kelling *et al.*, 1987). The basement of the Adana Basin is formed by Paleozoic and Mesozoic carbonates, subordinate clastics and local ophiolitic rocks. The Cingöz Formation is underlain by shelf car-

bonates of the Karaisali Formation and fine-grained slope siliciclastics of the Kaplankaya Formation (Fig. 3). These formations belong to the Lower Miocene, mostly to the Aquitanian–Burdigalian. The Cingöz Formation passes upward into, and partially interfinger with, fine-grained deep marine, offshore, to shallow marine siliciclastics of the Güvenç Formation of Serravalian age (Yetiş & Demirkol, 1986; Yetiş, 1988; Ünlügenç *et al.*, 1991; Gürbüz & Kelling, 1992a, b).

The Cingöz Formation was dated as Lower-Middle Miocene (mostly Langhian–Serravalian) on the base of planktic foraminifers (Nazik & Gürbüz, 1992). Its lowermost part belongs probably to Burdigalian. The Cingöz Formation consists of thick deposits of two relatively small, partially overlapping deep-sea fans: the western fan (1250 m thick) and the eastern fan (2500 m thick), respectively. It is relatively easy to locate particular parts of the fans because of good exposures and only slight tectonic disturbances. Different flysch facies were recognised in the formation, including channel, levee, and depositional lobe facies. The channel facies are composed of conglomerates and thick-bedded sandstones. The lobe facies are dominated by coarsening and thickening upward cycles of sandstone beds (Gürbüz & Kelling, 1992a, b).

The studied outcrops are road cuts located on the fringe of the western fan (Fig. 1). The section in the outcrop A is about 10 m thick, and in the outcrop B is about 50 m thick

AGE	FORMATION	LITHOLOGY	ENVIRONMENT
PLIO-QUATERNARY	KURANTA		FLUVIAL
LOWER PLIOCENE — MESSINIAN	HANDERE		LACUSTRINE- FLUVIAL
TORTONIAN — SERRAVALLIAN	KUZGUN		SHALLOW MARINE
SERRAVALLIAN — LANGHIAN	GÜVENÇ		DEEP MARINE- OFFSHORE- SHALLOW MARINE
	CINGÖZ		TURBIDITES
BURDIGALIAN — AQUITANIAN	KARAIŞALI		REEFAL CARBONATES
	KAPLANKAYA		SHALLOW MARINE
	GILDIRLI		TERRESTRIAL
OLIGOCENE	KARSANTI		ALLUVIAL- LACUSTRINE
		BASEMENT	

	VERY COARSE CONGLOMERATES		SILICICLASTIC FLYSCH
	FINE AND MEDIUM CONGLOMERATES		SANDY MUDSTONES AND SILTSTONES
	SANDSTONES		MUDSTONES
	MUDDY SANDSTONES		CARBONATES
			EVAPORATES

Fig. 3. Stratigraphic scheme and palaeoenvironmental approach of the Adana Basin with indication of predominant lithology (based on Gürbüz & Kelling, 1992b)

and exposed on a distance of a few hundred metres. Very thin beds (1–3 cm) of calcareous siliciclastic turbidites-hemipelagites interbedded with rare thick siliciclastic turbidites are exposed there (Fig. 4). Lower part of the turbidite beds consists of very fine-grained indistinctly ripple-cross laminated sandstones or siltstones (interval T_c according to Bouma, 1962). Hemipelagites and the upper part of turbidites are formed by light-grey calcareous, strongly weathered mudstones. Majority of beds display continuity and constant thickness on distance of at least 100 metres, however some of them change their thickness or pinch out. The thick beds of sandstones are fine-grained. They display T_{bc} or rarely T_{abc} Bouma intervals. The T_b division dominates, whereas the T_c divisions are very thin. Generally, the deposits resemble the facies C.2.3, and locally – facies D.2.3 (Pickering *et al.*, 1986), but the beds are thinner than in the typical examples of the mentioned facies. Moreover, the thick beds are thicker than in the facies C.2.3.

TRACE FOSSILS

Sixteen ichnotaxa have been recognised in the investigated sections. Trace fossils have been observed on bedding



Fig. 4. Deposits of the fan fringe facies in locality B

and on parting surfaces and in vertical sections. Taxonomic description is arranged according to morphological groups distinguished by Książkiewicz (1977), with further changes by Uchman (1995). For practical reason, the simple and branched structures are considered together (Uchman, 1998).

Simple and branched structures

?Planolites isp. (Fig. 5E-K) is preserved as hypichnial slightly winding ridges preserved in semi-relief. The ridges are 2.5–4.5 mm wide. Details of the trace-fossil margin are changed by erosion and therefore more detailed determination is not possible. This ichnogenus was discussed by Pemberton & Frey (1982), and by Keighley & Pickerill (1995).

Arthropycus cf. *tenuis* (Książkiewicz 1977) (Fig. 6A) occurs gregariously as semi-relief's of subhorizontal, hypichnial, convex ridges. The ridges are 1.0–1.5 mm wide and up to 35 mm long. They are straight, rarely branched, and oriented in different directions. *Arthropycus tenuis* was previously described under the ichnogenus *Sabularia* (Książkiewicz, 1977). Uchman (1998) did not recommend this ichnogenus for further use and included *Sabularia tenuis* in the ichnogenus *Arthropycus* Hall on the base of very fine perpendicular striae, which, however commonly

are not preserved. The described form is smooth, but it displays the characteristic geometry and size of *A. tenuis*. This ichnospecies was noted from the Valanginian (Książkiewicz, 1977) to the Lower Miocene (Alexandrescu & Brustur, 1984). The form described in this paper is, however, younger.

Chondrites intricatus (Brongniart 1823) occurs as a system of tree-like branching, downward penetrating, markedly flattened tunnels, less than 1.0 mm in diameter. The tunnels form acute angles. They are filled with light sediment. For a more extensive discussion of the ichnogenus *Chondrites* see Fu (1991).

Ophiomorpha rudis (Książkiewicz 1977) (Fig. 6B-D) is preserved as vertical to subvertical cylindrical, walled or unwalled, sand-filled, rarely branched tunnels, 8–15 mm in diameter. Some branches penetrate horizontally along bedding surfaces. The exterior part of tunnels is smooth or displays indistinct, irregular sandy granules. *Ophiomorpha rudis* penetrates through at least a few turbidites, which total thickness can exceed 28 cm.

Thalassinoides isp. is a hypichnial and exichnial horizontal, cylindrical, branched, walled or unwalled full relief, with smooth surface. The cylinders are 10–25 mm in diameter.

Horn-like forms (Fig. 6D-F) occur as L-shaped, simple, sand-filled, unwalled, smooth structures. They commonly penetrate through at least two turbidites. This trace fossil is composed of vertical or subvertical shaft that bends downwards into a horizontal, tapering, slightly flattened, blind tunnel. The lower part of the shafts is slightly enlarged in most specimens, and attains 35–40 mm in diameter. The remaining parts of the trace fossil are up to about 30 mm in diameter. The entire structure is ca. 250 mm high. The fill is structureless. The trace resembles *Rosselia* Dahmer, but it does not display convincing concentric internal structure. It is similar to some specimens of *Macanopsis* Macostay reported from the shallow-water Upper Miocene–Pliocene deposits of the southern Spain (Mayoral & Muñoz, 1997). The trace fossil, described here, can be interpreted as a domichnial shelter produced by crustaceans or fishes.

Spreiten structures

Echinospira isp. (Fig. 7A) is a large horizontal fan-like endichnial spreite structure, in which the spreite laminae converge in a stem-like bunch. It is at least 20 cm wide. The ichnogenus name *Echinospira* is proposed temporary for those members of the *Zoophycos* group, which display U-shaped causative burrow (Uchman & Demircan, 1999). The same trace fossil from the middle fan facies of the Cingöz Formation was discussed in paper cited above.

Winding and meandering structures

Scolicia plana Książkiewicz 1970 (Fig. 7A-C) is an en-

dichnial form observed as a composite winding, horizontal furrow on the top of the sandstone layers. The furrow is 20–35 mm wide, and is composed of ribbed smooth convex part which is dissected by a narrow central furrow. For discussion of this ichnospecies see Książkiewicz (1977) and Uchman (1998).

Scolicia strozzii (Savi & Meneghini 1850) (Fig. 7D) is a hypichnial double smooth ridge preserved in semi-relief. The ridge is 30–35 mm wide. It is divided by a median furrow. For discussion of this ichnospecies see Uchman (1995, 1998).

Nereites irregularis (Schafhäutl 1851) (Fig. 7E) is preserved as endichnial, meandering ribbon-like, strongly flattened full-reliefs composed of a distinct central string and poorly preserved, thin, side lobes of reworked sediment. Filling of the central string is lighter in colour and more fine-grained than the surrounding sediment. It is indistinctly meniscated. The central string is about 3 mm wide. For discussion of this ichnospecies see Uchman (1995).

Helminthorhapha flexuosa Uchman 1995 (Fig. 7F, G) is a hypichnial string with relatively deep, commonly irregular and poorly guided meanders lacking distinct bulges in the curved portions. The string is 1.0–1.5 mm wide. The meanders are 4–80 mm deep and 1–10 mm wide. The string displays very low, irregular second-order undulations.

Cosmorhapha sinuosa (Azpeitia & Moros 1933) (Fig. 5A) is a hypichnial semicircular, smooth string with two orders of meanders, preserved in semi-relief. First-order meanders are widely spaced. The second-order undulations are very diverse. Some of them display greater wave length than amplitude, but other *vice versa*. The string is about 2 mm wide.

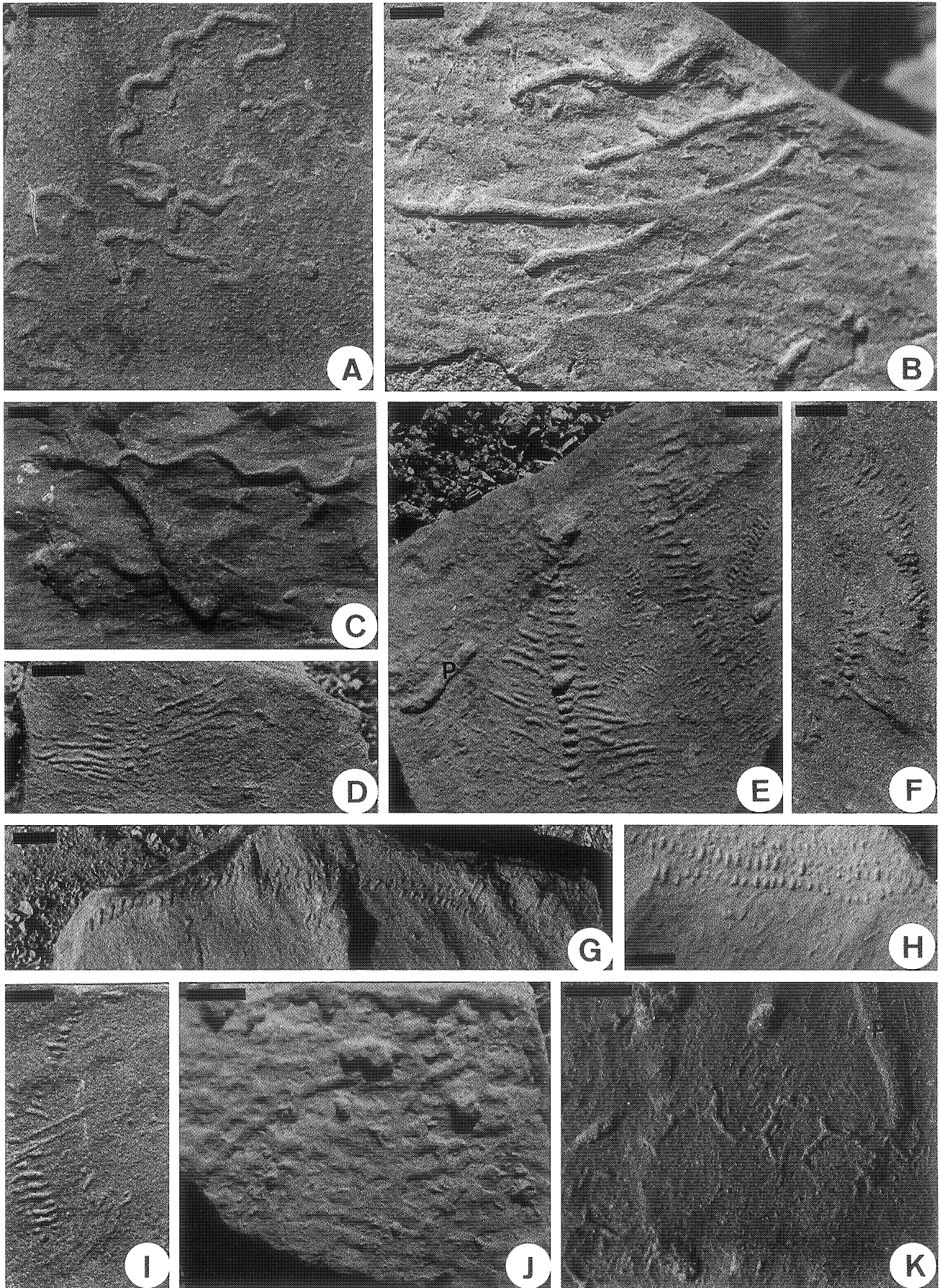
?*Cosmorhapha* isp. (Figs 5C, 7F) is a hypichnial, regularly meandering string. The string is about 2 mm wide. The wave length of the meandering undulations is about two times greater than the amplitude. The structure is incomplete and can be rather a part of eroded *Cosmorhapha* than *Cochlichnus* Hitchcock.

Branched winding and meandering structures

Urohelminthoida dertonensis Sacco 1888 (Fig. 5B) is a hypichnial, smooth meandering string with lateral appendages that protrude outwardly from the curved segments of the meanders. The appendages pass straight into one arm of meander, but form an angle with the second arm. The structure is preserved in semi-relief. The string is about 2 mm wide.

Desmograption ichthyforme (Macostay 1967) (Fig. 5D-I) is a hypichnial structure composed of subparallel, semicircular ridges which are elevated at the central part. The elevated parts form a central axis perpendicular to the ridges. The three-dimensional model of this ichnospecies was shown by Seilacher (1977). Elements of the axial part are preferentially preserved. This form displays several

Fig. 5. Trace fossils on soles of sandstone beds; locality B. Field photographs. A. *Cosmorhapha sinuosa*; hypichnial view. B. *Urohelminthoida dertonensis*. C. ?*Cosmorhapha* isp. D-I. *Desmograption ichthyforme* and cf. *Planolites* isp. (P) in E; D: 154P1, E: 1541P2. J. *Paleodictyon* cf. *strozzii*. K. *Paleodictyon majus* and *Planolites* isp. (P). Scale bar = 1 cm in all photographs



preservational variants, which depend on the depth of erosion of the burrow system. In some specimens, the burrow system is preserved as a double row of short bars (Fig. 5 G-I).

Networks

Paleodictyon cf. *strozzii* Meneghini 1850 (Fig. 5J) is a hypichnial subhexagonal net, preserved in convex semirelief. Maximum mesh size ranges from 3 to 6 mm. The string is distinctly flattened and is about 2.5 mm wide. The flattened strings are probably caused by collapse of the burrow system, and therefore width of the string reflects width of the exterior of the burrow, which include the burrow lumen and lining (for terminology see Bromley, 1996). For this reason, width of the strings is larger than in forms preserved due to scouring and casting. Taking this in account, the dimensions correspond to *P. strozzii* (see Uchman, 1995).

Paleodictyon majus Meneghini in Peruzzi 1880 (Fig. 5K) is a hypichnial, incomplete net. Maximum mesh attains about 9 mm, and the string is 1.2 mm wide.

Distribution

Distribution of most of the described trace fossils does not display any distinct rules. Only *Scolicia vertebralis* (locally common) and *Echinospira* isp. (locally common) show a tendency to occur in the thicker beds. Also *Ophiomorpha* and *Thalassinoides* occur usually in thicker beds. The remaining ichnotaxa are distributed more or less randomly in thinner beds, however some, single beds display characteristic assemblages of trace fossils. For instance, there are beds dominated by *Arthropycus* cf. *tenuis*. Locally, *Planolites* is more common.

DISCUSSION

The described trace fossil assemblage is dominated by ichnotaxa typical of the *Nereites* ichnofacies, represented by meandering pascichnia (*Nereites*, *Scolicia*) and different graphoglyptids (e.g., *Paleodictyon*, *Desmograptus*, *Cosmorhaphis*, *Helminthorhaphis*). Moreover, stationary fodinichnia (*Echinospira*) and ?chemichnia/fodinichnia (*Chondrites*) occur there as well. "Shallow-water" vertical forms (horn-like form and *Ophiomorpha*) typical of the *Skolithos* ichnofacies, and *Thalassinoides*, which is most characteristic of the *Cruziana* ichnofacies, are also present there.

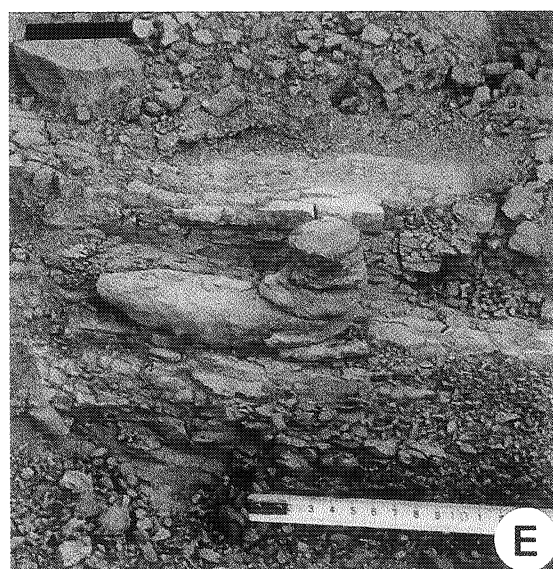
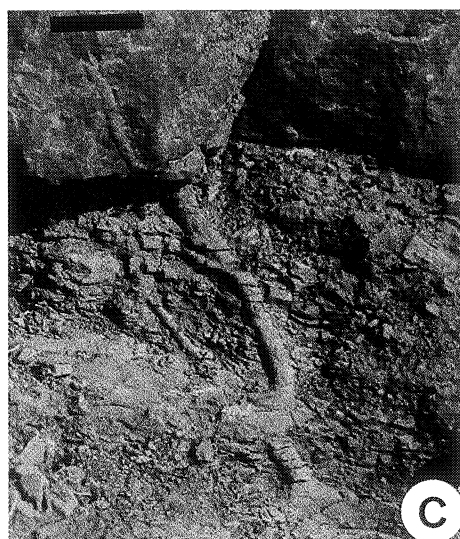
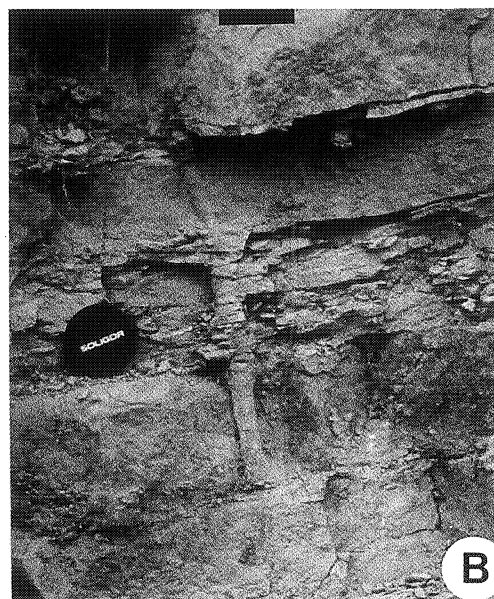
Occurrence of the "shallow-water" forms in the fan fringe deposits of the Cingöz Formation is striking. Such trace fossils were described from "proximal", mainly channel and proximal lobe facies of different Cretaceous–Paleo-

gene flysch formations (e.g., Crimes, 1977; Crimes *et al.*, 1981). This is also consistent with latter observations by Uchman (1991, 1995 for review) and Tunis & Uchman (1996a, b), who recognised that the "shallow-water" forms are also present in distal fan facies. The latest phenomenon is particularly typical of well-oxygenated upper Paleocene–middle Eocene and Miocene European flysch formations, which are characterised by increased ichnodiversity related to moderate oligotrophy caused by large-scale oceanographic and climatic changes (Uchman, 1995; Tunis & Uchman, 1996a).

Occurrence of *Ophiomorpha* in deep-sea environments is a matter of controversies for some geologists, who regard this form as an exclusively shallow-marine trace fossil. It must be stressed that *Ophiomorpha* should be considered in this matter at the ichnospecies level. Widely known *Ophiomorpha nodosa* is indeed shallow-marine form, but *Ophiomorpha rudis* is the deep-sea representative of the ichnogenus *Ophiomorpha*. Most of the flysch *Ophiomorpha*, described in the papers cited in the former paragraph, belongs to this ichnospecies. Its morphological features, such as the wall with sandy granules or common vertical orientation, are diagnostic for *Ophiomorpha* at the ichnogenus level (Uchman, 1998).

The occurrence of deeply penetrating vertical shafts of *Ophiomorpha* is not clear. In shallow-water environment, the deep *Ophiomorpha nodosa* burrows are connected with strong turbulence of water and shifting sandy substrate (Frey *et al.*, 1978). The only strong flows in the studied fan fringe facies are connected with episodic turbidity currents, which however, were relatively weak and acted very shortly. On the other hand, colonisation surfaces of most *Ophiomorpha* is located in sandstone beds, which are commonly thicker than 5 cm. It is possible that tracemaker of *Ophiomorpha* (probably a shrimp-like crustacean) was transported from more inner part of fan system by stronger turbidity currents. The transportation of shallow-water tracemakers by turbidity currents into deep-sea was proposed by Crimes (1977), and repeated by Wetzel (1981) and Föllmi & Grimm (1990). Such a transportation is possible, but it does not explain abundance of *Ophiomorpha* or *Thalassinoides* in some channel or lobe flysch facies. Uchman (1995) observed a broad size spectrum of *Ophiomorpha* in flysch channel and lobe facies of the Marnoso-arenacea Formation (Miocene; Northern Apennines), which was related to full ontogenic spectrum of tracemakers. These trace fossils penetrate very deep through thick beds, especially to turbidite sandy mudstones rich in plant detritus. *Ophiomorpha* tracemakers are able to use deeply buried food that is not available for shallower burrowers. The cited author concluded that the environment of the deep-sea fan facies is proper for the tracemakers of *Ophiomorpha*, which lived and reproduced there *in situ*. The deep, vertical burrows in

Fig. 6. Simple and branched trace fossils. Field photographs. A. *Arthropycus* cf. *tenuis*; hypichnial view of a sandstone slab, locality B. B–C. *Ophiomorpha rudis*; oblique view, locality A. D. Horn-like form and *Ophiomorpha rudis* (arrows); oblique view, locality B. E. Horn-like form; oblique view, locality B. F. Horn-like form; oblique view, locality A. Scale bar = 1 cm in A and 5 cm in B–F



fan fringe facies look rather like probes for proper feeding horizons than systematic reworking, typical of channel or lobe facies. It is impossible to recognize whether the occurrence of tracemaker of *Ophiomorpha* in the investigated fan fringe deposits is a kind of "planned" exploration of that area or results of a transport of the animal by turbiditic currents from more inner part of the fan system, where *Ophiomorpha* is common.

The occurrence of trace fossils typical of the *Skolithos* ichnofacies has rather not any bathymetric value. Geometric relations of the flysch lithosomes of the Cingöz Formation to shelf sediments of the Karaisali Formation suggest that the former was deposited on depths of rather hundreds than thousands metres.

The occurrence of the shelter horn-like forms is connected rather with biological predator-prey relations than with high energy of environment.

A comparison of the described trace fossil assemblages with relevant assemblages from other formations is not easy. The literature on trace fossils from Mesozoic–Neogene fan fringe deposits is very scarce. Generally, detail determinations of flysch facies are not common in ichnological literature. Moreover, the distinguished flysch facies are commonly not comparable. Several publications are older than the concept of facies in deep-sea fan system, which arose in seventies (Mutti & Ricci Lucchi, 1972; Ricci Lucchi, 1975; Walker, 1977). The commonly distinguished distal flysch facies of the older hydrodynamic concept (Bouma, 1962; Walker, 1967) can embrace overbank, inter-channel, interlobe, and fan fringe facies of the deep-sea fan system. However, the distal flysch facies distinguished by Książkiewicz (1970, 1977), and Crimes (1973) roughly correspond to fan-fringe facies. This can be deducted from the local geological situation in the Carpathians and the northern Spain, respectively. Both the cited authors noted that the distal flysch facies are typified by the patterned trace fossils (e.g., *Paleodictyon*, *Desmograpton*), which passed into more distal turbidites characterised by the rosetted and meandering forms.

Crimes (1977) analysed distribution of trace fossils in the Eocene Monte Jaizkibel fan in the northern Spain. He showed that the middle fan facies are characterised by mixture of the *Nereites*, *Cruziana*, and *Skolithos* ichnofacies. The outer fan facies is typified by the *Nereites* ichnofacies, where, however, the so-called "shallow-water" forms (*Ophiomorpha*, *Skolithos*, *Phycodes*) are present in thick sandstones of the lobe facies.

McCann & Pickerill (1988) distinguished proximal and distal lobe fringe facies in the Cretaceous flysch of the Kodiak Formation in Alaska. They recognised six rare meandering or winding pasichnia or repichnia (*Helminthopsis*, *Helminthoida*, *Gordia*, *Neonereites*) and one circular form

(*Circulichnis*). It is striking that abundance and diversity of trace fossils is there lower than in channel levee or inter-channel facies.

Crimes *et al.* (1981) recognised fan fringe facies in the Paleocene flysch of the Fayaux quarry in the western Switzerland, where they reported meandering and network trace fossils. "Shallow-water" forms are absent there, however they are present in more "proximal" facies of the Paleocene–Eocene flysch in other localities.

Uchman (1995) described trace fossils from the Miocene Marnoso-arenacea Formation in the Northern Apennines. Basin plain through outer fan facies, which more or less correspond to fan fringe facies, are characterised by increased diversity of trace fossils, with small *Chondrites*, *Trichichnus*, *Planolites*, *Scolicia*, numerous graphoglyptids, and "shallow-water" *Ophiomorpha* and *Thalassinoides*. The latter are more abundant in lobe facies.

Tunis & Uchman (1996a, b) noted occurrence of some "shallow-water" trace fossils (*Ophiomorpha*, *Thalassinoides*) in distal fan facies of the upper Paleocene–lower Eocene Flysch del Grivó in the Julian Prealps and in the Eocene flysch of the Istria Peninsula. The facies display mostly features of fan fringe environment.

The closest equivalent of the here described trace fossil assemblage is in the coeval Marnoso-arenacea Formation from the Northern Apennines. However, the horn-like forms and *Echinospira* do not occur there. The fan fringe facies of the Marnoso-arenacea Formation contain common *Trichichnus*, which was not found in the Cingöz Formation. Moreover, *Chondrites* is more abundant in the Marnoso-arenacea Formation.

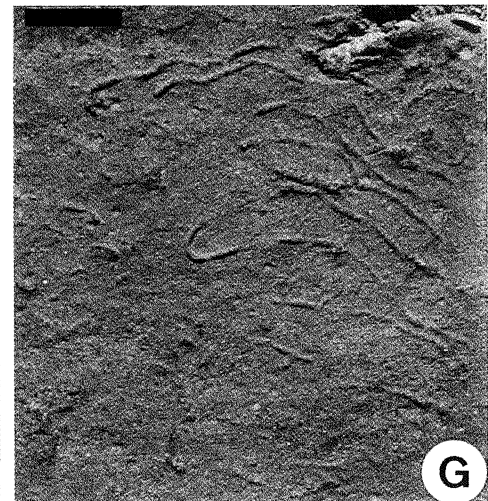
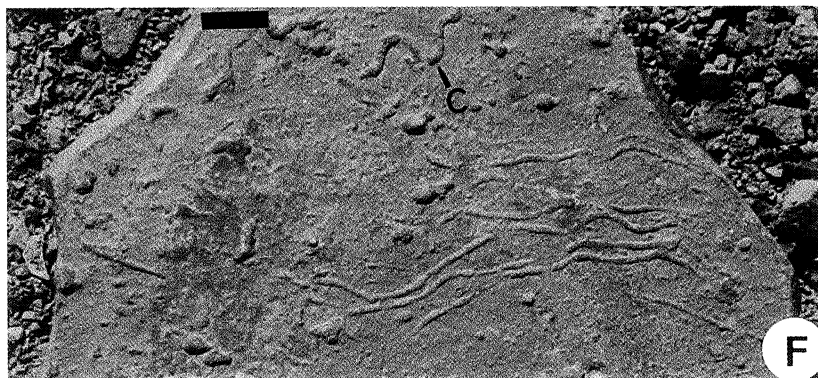
The presented above review shows that there is not a uniform model for the distribution of trace fossils in flysch facies. This is not only a result of inconsistencies of literature data, but mainly because of primary causes, which can be related to a broad spectrum of factors influencing benthic life. For instance, sedimentary processes, bathymetry, oxygenation, or trophic level influenced by palaeoceanographic and palaeoclimatological changes can be considered here. The evolutionary aspect of trace fossils can be also taken in account. For instance, *Scolicia* occurs in flysch deposits since Albian (Książkiewicz, 1977). These problems, however, are beyond the scope of this paper.

CONCLUSIONS

1. Fan fringe facies of the Cingöz Formation contain the deep-sea *Nereites* ichnofacies with admixture of the "shallow-water" *Skolithos* and *Cruziana* ichnofacies.

2. Occurrence of *Ophiomorpha* in fan fringe environment can be explained by import of its tracemaker within

Fig. 7. Spreiten, winding and meandering trace fossils in sandstone beds; locality B. Field photographs. **A.** *Echinospira* isp. and *Scolicia plana* (S); epichnial view. **B–C.** *Scolicia plana*; epichnial views. **D.** *Scolicia strozzii*; hypichnial view. **E.** *Nereites irregularis*; epichnial view. **F.** *Helminthorhapha flexuosa* and ?*Cosmorhapha* isp. (C); hypichnial view. **G.** *Helminthorhapha flexuosa*; hypichnial view. Scale bar = 5 cm in A and 1 cm in B–G



stronger turbidity currents from inner part of deep-sea fan, or by normal "planned" colonisation.

3. The described trace fossil assemblage displays closest similarities to the coeval ichnoassemblage of the Marnoso-arenacea Formation in the Northern Apennines.

4. Trace fossil assemblages in fan fringe facies are very changeable. This resulted probably from different factors influencing benthic life in different fan systems.

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Streszczenie

SKAMIENTAŁOŚCI ŚLADOWE Z MIOCENSKICH UTWORÓW OTOCZENIA STOŻKA GŁĘBOKO- MORSKIEGO Z FORMACJI CINGÖZ W POŁUDNIOWEJ TURCJI

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Dotychczasowe badania paleontologiczne wskazują, że w utworach otoczenia stożka głębokomorskiego występuje przede wszystkim głębokomorska ichnofacja *Nereites*. Utwory otoczenia takiego stożka, należące do miocenkiej formacji Cingöz w południowej Turcji zawierają bogaty zespół skamieniałości śladowych, należących jednak nie tylko do ichnofacji *Nereites*, lecz także do ichnofacji *Skolithos* i *Cruziana*, znanych ze środowisk płytkomorskich.

Badana pod względem zróżnicowania ichnofacji formacja

Cingöz jest częścią wypełnienia basenu Adany (Figs 1–3), rozwinętego na przedpolu gór Taurus i powstałego w wyniku kolizji kontynentów afro-arabskiego i euro-azjatyckiego. Składa się ona z osadów dwóch, częściowo nakładających się na siebie, stosunkowo niewielkich stożków głębokomorskich. Badane odsłonięcia znajdują się w otoczeniu tak zwanego stożka zachodniego (Fig. 1). Utwory otoczenia stożka budują tutaj bardzo cienkie ławice turbidytowe (1–3 cm), przekładane nielicznymi ławicami grubszyymi (Fig. 4). Piaszczyste części cienkich ławic zawierają interwały T_c, a w grubszych ławicach występują interwały T_{bc}, rzadziej T_{abc}.

W badanych utworach rozpoznano następujące skamieniałości śladowe (Figs 5–7): *Planolites* isp., *Arthropycus* cf. *tenuis*, *Ophiomorpha rudis*, *Thalassinoides* isp., formy w kształcie rogu, *Echinospira* isp., *Scolicia plana*, *S. strozzii*, *Nereites irregularis*, *Helminthorhapha flexuosa*, *Cosmorhapha sinuosa*, *Cosmorhapha* isp., *Urohelminthoida dertonensis*, *Desmograption ichthyforme*, *Paleodictyon* cf. *strozzii* i *P. majus*.

Występowanie skamieniałości śladowych z rodzaju *Ophiomorpha* i *Thalassinoides* jest związane z grubszyymi ławicami. Wymienione skamieniałości śladowe należą głównie do ichnofacji *Nereites*, a niektóre z nich do ichnofacji *Skolithos* (formy w kształcie rogu i *Ophiomorpha*) i ichnofacji *Cruziana* (*Thalassinoides*).

Szczególnie intrygująca jest obecność pionowych form z ichnogatunku *Ophiomorpha rudis*, podobnych do znanych ze środowisk płytkomorskich form z ichnogatunku *Ophiomorpha nodosa*. Cechy sedimentacyjne badanych utworów wskazują, że środowisko sedimentacji formacji Cingöz było niskoenerygiczne, z wyjątkiem epizodycznych okresów spływów prądów zawieszinowych. Twórcy *Ophiomorpha*, których ślady działania znaleziono w tych utworach mogli być zatem przetransportowani przez silniejsze prądy zawieszinowe z wewnętrznych części stożka, gdzie forma ta występuje licznie. Wskazywać na to może związek *Ophiomorpha* z grubszyymi ławicami. Możliwa jest również stopniowa kolonizacja środowisk otoczenia stożka, gdzie twórcy *Ophiomorpha* poszukiwali osadów bogatych w sieczkę roślinną. Kanały żerowiskowe *Ophiomorpha* występują również licznie w tego typu ławicach, w kanałowych i lobowych facjach stożka.

Porównanie opisanej asocjacji skamieniałości śladowych z analogicznymi asocjacjami z utworów otoczenia stożka głębokomorskiego różnych kredowo-neogeńskich formacji natrafia na trudności. Literatura dotycząca tego problemu jest bardzo nieliczna, a wydzielane facje otoczenia stożka głębokomorskiego w różnych formacjach są często nieporównywalne. Największe podobieństwo ichnoasocjacji utworów otoczenia stożka formacji Cingöz wykazuje ichnoasocjacja z analogicznych utworów równowiekowej formacji Marnoso-arenacea z Apeninów Północnych. Przegląd innych kredowo-paleogeńskich formacji wskazuje na znaczne różnice ichnoasocjacji w utworach otoczenia stożka. Ma to związek z wieloma czynnikami kontrolującymi życie bentosu, takimi jak rodzaj procesów depozycyjnych, czy zmiany poziomu troficznego i natlenienia dna, które często się wiążą ze zmianami geograficznymi i klimatycznymi.

