

GORTANIA - Atti Museo Friul. di Storia Nat.	20 (1998)	41-58	Udine, 31.X.1998	ISSN: 0391-5859
---	-----------	-------	------------------	-----------------

G. TUNIS, A. UCHMAN

ICHTHOLOGY OF EOCENE FLYSCH DEPOSITS IN THE CARNIAN PRE-ALPS (NORTH-EASTERN ITALY)

STUDIO ICNOLOGICO DEI DEPOSITI DI FLYSCH DELLE PREALPI CARNICHE (ITALIA NORD-ORIENTALE)

Abstract - The Eocene thin- and medium-bedded flysch deposits of the Carnian pre-Alps display abundant and diverse trace fossils, including graphoglyptids and forms produced by echinoids. They represent the *Nereites* ichnofacies. The ichnoassemblage is typical of moderately oligotrophic, well oxygenated environments. This type of flysch environments is common in Late Paleocene-Middle Eocene of the Alpine realm and is related to world-wide oligotrophy at that time.

Key words: Trace fossils, Flysch, Eocene, Carnian pre-Alps, Italy.

Riassunto breve - *I depositi di flysch caratterizzati da strati sottili e medio-sottili delle Prealpi Carniche presentano varie ed abbondanti tracce fossili, inclusi grafogliptidi ed alcune forme prodotte da echinidi. Essi rappresentano l'ichnofacies a Nereites. L'associazione icnologica è tipica di ambienti ben ossigenati, moderatamente oligotrofici. Questo tipo di ambienti in successioni flyschoidi, di età tardo paleocenica-eocenica media, è tipico del dominio alpino e può essere posto in relazione a fenomeni di oligotrofia a scala globale verificatisi in questo periodo.*

Parole chiave: *Tracce fossili, Flysch, Eocene, Prealpi Carniche, Italia.*

Introduction

The flysch deposits of the North-eastern Italy, Slovenia, and partially of Croatia have been ichnologically investigated during the latest 5 years (TUNIS & UCHMAN, 1992; 1994a; 1994b; 1996a; 1996b; LÖFFLER & GEYER, 1994). Trace fossils were used there for documentation of benthic life and better characteristics and interpretation of palaeo-environment. However, the flysch of the Carnian pre-Alps, which is located in a narrow zone joining the Belluno Flysch, and the Flysch of the Julian pre-Alps, is hitherto not ichnologically investigated.

The object of this paper is to document and interpret trace fossils from the Carnian pre-Alps. Investigations have been made in the Almadis quarry, in the old quarry in Maniago, and along the road in the Valle dell'Acqua, east of Maniago (fig. 1). The illustrated specimens

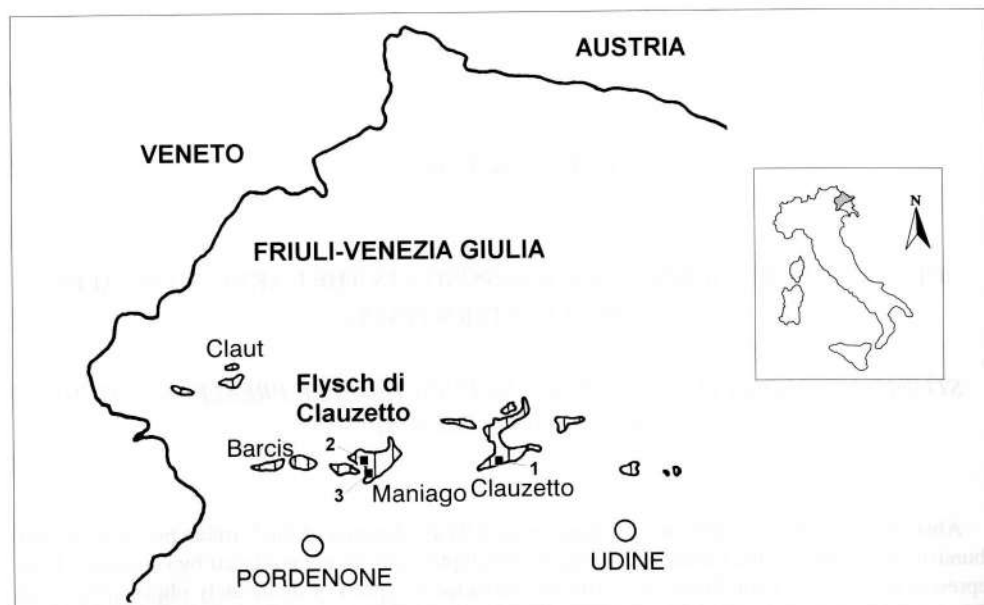


Fig. 1 - Index map with location of the examined section. 1) Almadis quarry; 2) old quarry near Maniago; 3) Valle dell'Acqua.

- Carta indice con ubicazione delle sezioni esaminate. 1) cava di Almadis; 2) vecchia cava presso Maniago; 3) Valle dell'Acqua.

are housed in the Institute of Palaeontology of Würzburg University (acronym PIW1993X) and in the Institute of Geological Sciences of the Jagiellonian University in Kraków (acronym TFAU). Data on sedimentology and general geology were provided by the first author (G.T.), while the ichnological work was done by the second author (A.U.).

Geological setting

From a geological point of view, Eocene Flysch of Carnian pre-Alps has received little attention in comparison with the turbiditic deposits of the Southern Julian pre-Alps. Rarity of good exposures due to wooded cloak, the scarce continuity of the outcrops, its very limited aerial extension and the complicated tectonics may explain the little progress in the geological knowledge of the forementioned region.

Eocene turbiditic deposits of the Carnian pre-Alps (fig. 1) are known under the term "Flysch di Clauzetto" (Cuvillier et al., 1968) which correspond to "strati marnosi a facies di flysch", according to Stefanini (1915) and to "complesso arenaceo marnoso a facies di Flysch con lenti e banchi di brecciole nummulitiche", according to Zenari (1929). "Flysch di Clauzetto" commonly overlies typical facies of "scaglia rossa" formation which nearby

the margin of the basin (Valle dell'Acqua, etc.) is characterised by intercalations of bioclastic beds deriving from the neighbouring carbonate platform. The molassic succession, the base of which is upper Chattian-Aquitainian, unconformably rests on the flysch deposits. From a lithological point of view, "Flysch di Clauzetto" is characterised by prevailing marls and hybrid arenites with subordinate fine breccias and by rare resedimented carbonate big beds (see also Richter, 1970; Stefani, 1982; Venturini & Tunis, 1992).

Turbiditic deposits outcropping nearby Claut, in the Pert valley and in Tremugna valley are characterised by thick graded carbonate megabeds which are composed by megabreccia in the lower part and graded calcarenite-marl in the upper part (see Sarti, 1979; Tunis & Venturini, 1992; Venturini & Tunis, 1992). Recently, Venturini & Tunis (1992), on the base of planktonic assemblages, sedimentological and lithological characteristics have attributed the examined sections of Claut, Pert and Val Tremugna to the upper part of the "Flysch del Grivò" which is a clastic unit of upper Paleocene-lower Eocene age widely outcropping in the Julian pre-Alps and in the neighbouring western Slovenia. Furthermore, in the forementioned paper the authors have found strong relationships between the "Flysch di Clauzetto" s.s. and Flysch di Cormons which overlies the "Flysch del Grivò" in the southern Julian pre-Alps. Grandesso & Stefani (1996) distinguished also the clastic deposits of the Carnian pre-Alps between "Flysch di Claut" and "Flysch di Clauzetto". The former and older unit is represented by proximal facies as proved by common pinching out of the beds, overturned slump folds and by presence of pebbly sandstone/mudstone with typical shallow water macrofaunas (Venturini & Tunis, 1992); the latter is dominated by distal turbiditic facies.

The three investigated sections in this paper pertain to "Flysch di Clauzetto" and, partly, to "scaglia rossa" unit.

At Almadis quarry (fig. 1) one may observe an excellent section about 250 m thick; it is characterised by turbidites made by terrigenous and bioclastic detritus, hemipelagic marls, rare arenitic couplets, a few carbonate big beds, in the coarsest part of which rudite-sized lithoclasts, marl chips and, occasionally, rather frequent chert pebbles occur (Palmieri, 1995). The turbidites are ascribed to the upper part of the lower Eocene as proved by the presence of assemblages with *Morozovella aragonensis*, *Acarinina pentacamerata* and *A. broedermanni*.

The old quarry of Maniago (fig. 1) shows a strongly tectonised section in which the *M. formosa*, *M. aragonensis*, *M. pentacamerata* and *Acarinina bullbrooki* biozones have been recognised (Nereo, 1971; Fornasari, 1995). The age ranges between lower Eocene p.p. and middle Eocene p.p. (as for as middle Eocene age of "Flysch di Clauzetto" see also Cousin, 1981; Tunis & Venturini, 1996). Individual turbidites explored are mostly classical or Bouma type (Bouma, 1962). They do not show any trends of thickening or thinning upward, so termination of their occurrence is abrupt, however thin bedded turbidites predominate (Fornasari, 1995).

Ichnotaxa	outcrops		
	1	2	3
? <i>Laevicyclus</i> isp.			VR
<i>Planolites</i> isp.	C	F	F
? <i>Skolithos</i> isp.	F	F	F
<i>Palaeophycus tubularis</i>			R
<i>Chondrites intricatus</i>		VR	R
<i>Trichichnus linearis</i>			C
<i>Ophiomorpha annulata</i>	F	F	F
<i>Ophiomorpha</i> isp.			R
<i>Halymenidium oraviense</i>			VR
<i>Thalassinoides</i> isp.	R	C	R
<i>Zoophycos</i> isp.	R		
<i>Lorenzinia pustulosa</i>			VR
<i>Glockerichnus alata</i>			VR
<i>Scolicia prisca</i>	C	R	C
<i>Scolicia striata</i>			C
? <i>Nereites</i> isp.			VR
<i>Cosmorhaphis ?sinuosa</i>			VR
<i>Belocosmorhaphis aculeata</i>			VR
<i>Helminthorhaphis flexuosa</i>		VR	VR
<i>Saerichnites</i> isp.			VR
<i>Urohelminthoida dertonensis</i>			R
<i>Protopaleodictyon submontanum</i>		R	R
<i>Protopaleodictyon incompositum</i>			VR
<i>Megagraption irregulare</i>			R
<i>Paleodictyon minimum</i>			VR
<i>Paleodictyon strozzii</i>			R
<i>Paleodictyon majus</i>			VR

Tabl. I - Occurrence of trace fossils in the flysch of the Maniago region. Frequency: VR - very rare; R - rare; C - common; F = frequent; VF = very frequent. Outcrops: 1 - Maniago, the old quarry; 2 - Valle dell'Acqua; 3 - Almadis quarry.
 - Presenza di tracce fossili nel flysch della zona di Maniago. Frequenza: VR - molto raro; R - raro; C - comune; F - frequente; VF - molto frequente. Sezioni: 1 - Maniago, vecchia cava; 2 - Valle dell'Acqua; 3 - Cava di Almadis.

The well exposed section of Valle dell'Acqua (fig. 1) is equally tectonised and overturned as the previous section; different stumps of the succession may be attributed to scaglia rossa unit with prevailing bioclastic turbidites and to "Flysch di Clauzetto" (lower part). The turbidites within scaglia rossa are ascribed to the upper Paleocene as proved by the presence of assemblages with *Planorotalites pseudomenardii* and *Morozovella velascoensis*. Turbiditic interbeddings of the segments of "Flysch di Clauzetto" succession permit to detect assemblages of foraminifers of lower Eocene age, probably *M. formosa* and *M. aragonensis* biozones.

Systematic description of trace fossils

Extended description and discussion of taxonomy, taphonomy, and ethology of trace fossils is beyond the scope of this paper. In this paper, the classification of trace fossils by KSIĄŻKIEWICZ (1970, 1977) is applied. Occurrence of trace fossils is represented in tabl. I. For further descriptions of the ichnogenera the reader is referred to the publications of HÄNTZSCHEL (1975), KSIĄŻKIEWICZ (1977), SEILACHER (1977), FILLION & PICKERILL (1990), CRIMES & CROSSLEY (1991), CRIMES & MCCALL (1995) and UCHMAN (1995).

Circular and elliptical structures

?*Laevicyclus* isp. (fig. 2A-C) is a hypichnial, usually incomplete elliptical ring, 20-30 mm long, 17-25 mm wide, and about 2-3 mm thick, with a central knob.

Simple structures

?*Skolithos* isp. occurs as circular to oval, convex hypo- and rarely epireliefs, 2-8 mm in diameter, forming various knobs, or as empty hollows on the upper surface of sandstone beds.

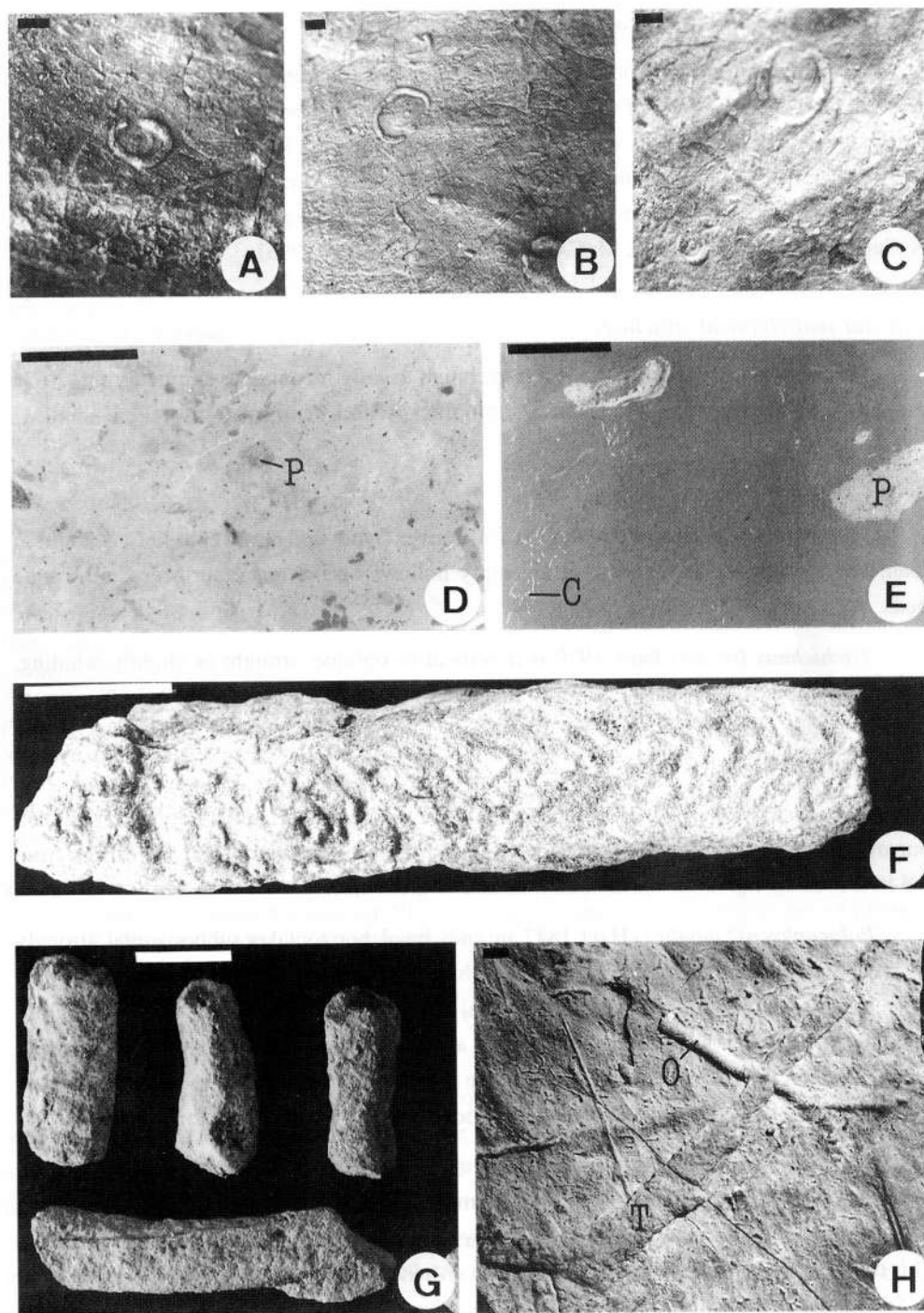
Trichichnus linearis FREY 1970 is a vertical to oblique, straight or slightly winding, rarely branching trace fossil, 0.2 mm in diameter, at least 10 cm long. The branches are at diverse angles. The trace fossils are filled with limonitic fine-grained material, probably weathered pyrite.

Planolites isp. (fig. 2D-E) is represented by cylindrical, horizontal to oblique, unlined burrows, circular to elliptical in cross-section, 2-6 mm in diameter. Their fill differs from the host rock by lighter or darker color, and/or in grain size.

Palaeophycus? tubularis HALL 1847 are endichnial, horizontal or subhorizontal, strongly flattened tunnels, 5-10 mm in diameter. For ichnotaxonomy see PEMBERTON & FREY (1982).

"Ferruginous cylinders" represent vertical or subvertical cylindrical, straight or slightly winding lined burrows, 3-5 mm in diameter, at least 10 cm long, filled with ferruginous, commonly coarser sediment. Occasionally, the burrows are surrounded by a ferruginous or manganiferous halo. They penetrate fine-grained sediment at the top of thick beds.

Spongeliomorpha oraviense (KSIĄŻKIEWICZ, 1961) (fig. 2F). Hypichnial, cylindrical, rarely branched full-relief trace fossils, 10-12 mm in the diameter, covered with short ridges oblique to the burrow axis. The ridges partially cross-cut themselves along the burrow axis. This trace fossil was described as *Halimenidium oraviense* by KSIĄŻKIEWICZ, but it was included in *Spongeliomorpha* (UCHMAN, in press).



Branched structures

Chondrites intricatus (BRONGNIART, 1823) (fig. 2E) is a system of tree-like sharp-angle branching, downward penetrating, flattened tunnels, 0.3-1.5 mm in diameter. In cross-section, it appears as patches of circular or elliptical small spots (cf. WERNER & WETZEL, 1981; and others), filled with lighter material.

Ophiomorpha annulata (KŚIAŹKIEWICZ, 1977) (figs. 2H, 3A) is an endichnial, straight, horizontal or subhorizontal, rarely branched, lined tubular trace fossil whose walls are commonly smooth or occasionally covered with mud pellets. The trace fossils are 3-4 mm in diameter. They are usually described as *Granularia* isp. (e.g. SEILACHER, 1964; LESZCZYŃSKI, 1991) or as *Sabularia simplex* (KŚIAŹKIEWICZ, 1977; TUNIS & UCHMAN, 1992), and was included in *O. annulata* by UCHMAN (1995).

?*Ophiomorpha* isp. (fig. 2G) is a fossil burrow system composed of endichnial or exichnial, chiefly vertical but also oblique and horizontal, rarely branched cylinders that are occasionally covered with pelletoidal knobs. The cylinders are 7-12 mm in diameter. Their horizontal parts are commonly flattened by compaction.

Thalassinoides isp. (fig. 2H) is represented by horizontal or oblique cylindrical trace fossils, having Y-shaped branches, 10-15 mm in diameter and swellings at the points of branching.

Fig. 2 - Trace fossils from the Carnian pre-Alps. A-C. ?*Laevicyclus* isp., soles of turbiditic sandstone beds, Almadis quarry, field photographs. D. Bioturbated marly mudstone at top of a turbiditic bed, horizontal section. *Planolites* isp. (P) penetrated by *Chondrites* isp., wet polished slab, Almadis quarry, PIW1993X302. E. Bioturbated mudstone at top of a turbiditic bed, horizontal section. *Chondrites intricatus* (C) and *Planolites* isp. (P). Wet polished slab, Almadis quarry. F. *Spongeliomorpha oraviense* separated from muddy sandstone, Almadis quarry, PIW1993X301. G. *Ophiomorpha* isp. separated from sandy mudstone, Valle dell'Acqua, TFAU163. H. *Thalassinoides* isp. (T) and *Ophiomorpha annulata* (O), sole of a turbiditic sandstone bed, Almadis quarry, field photograph. Scale bars = 1 cm.

- *Tracce fossili osservate nelle successioni del flysch delle Prealpi Carniche*. A-C ?*Laevicyclus* isp., controimpronta alla base di uno strato torbiditico, cava di Almadis, foto sull'affioramento. D. Sezione orizzontale alla sommità della porzione marnosa bioturbata di una torbidite. *Planolites* isp. (P) penetrato da *Chondrites* isp., sezione lucida, Cava di Almadis, campione: PIW1993X302. E. Sezione orizzontale alla sommità della porzione marnosa bioturbata di una torbidite. *Chondrites intricatus* (C) e *Planolites* isp. (P). Sezione lucida, Cava di Almadis. F. *Spongeliomorpha oraviense* isolata da un'arenaria marnosa, Cava di Almadis, campione PIW1993X301. G. Campioni di *Ophiomorpha* isp. isolati da un'arenaria marnosa, Valle dell'Acqua, TFAU163. H. *Thalassinoides* isp. (T) e *Ophiomorpha annulata* (O), controimpronta alla base di uno strato torbiditico. Cava di Almadis, foto in campo. Scala di riferimento = 1 cm.

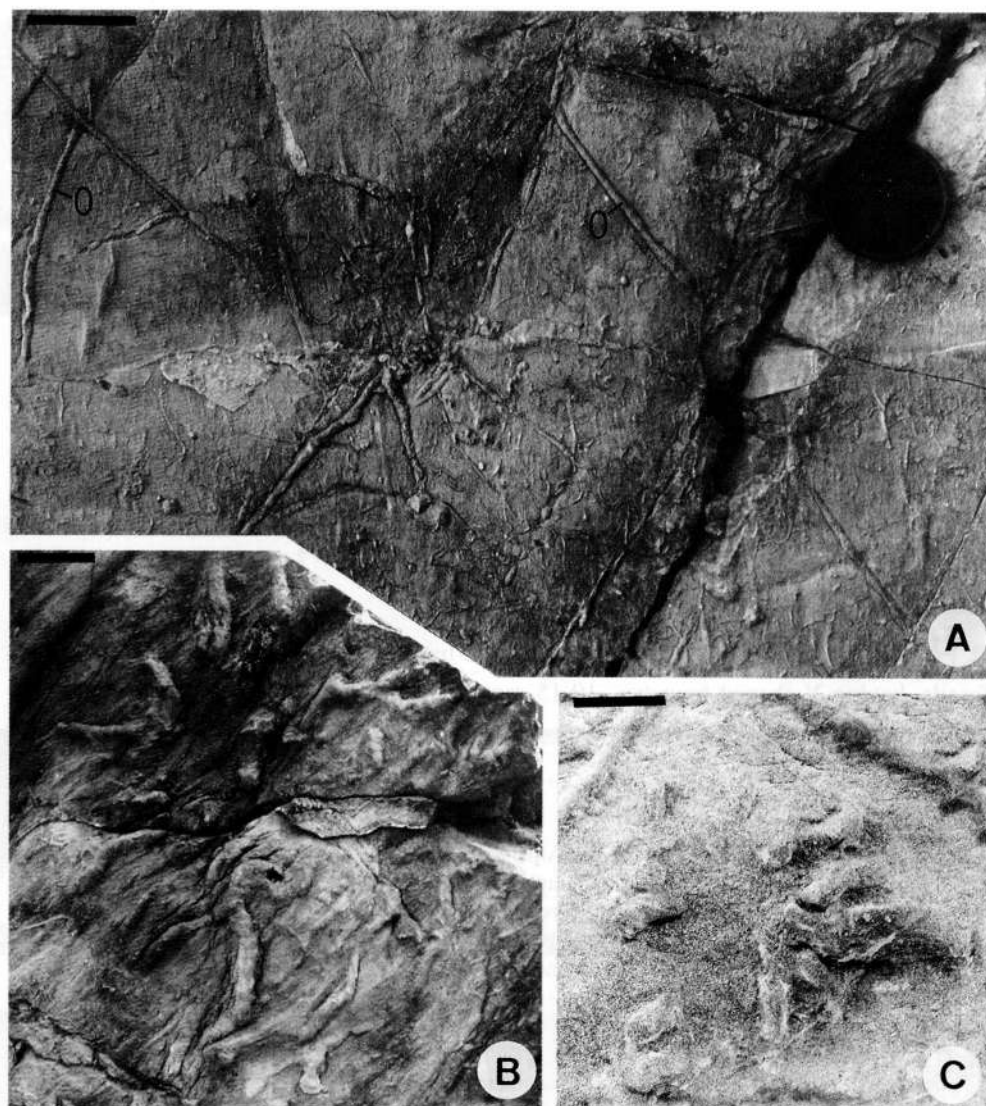


Fig. 3 - Trace fossils on soles of turbiditic sandstones from the Almadis quarry. A. ? *Ophiomorpha* isp. (O), field photograph. B. *Glockerichnus alata*, field photograph. C. *Lorenzina pustulosa*, PIW1993X320. Scale bars in A and B = 5 cm, in C = 1 cm.

- Controimpronte di tracce fossili alla base di strati torbiditici. Cava di Almadis. A. ? *Ophiomorpha* isp. (O), foto di campagna. B. *Glockerichnus alata*, foto di campagna. C. *Lorenzina pustulosa*, PIW1993X320. Scala di riferimento in A e B = 5 cm, in C = 1 cm.

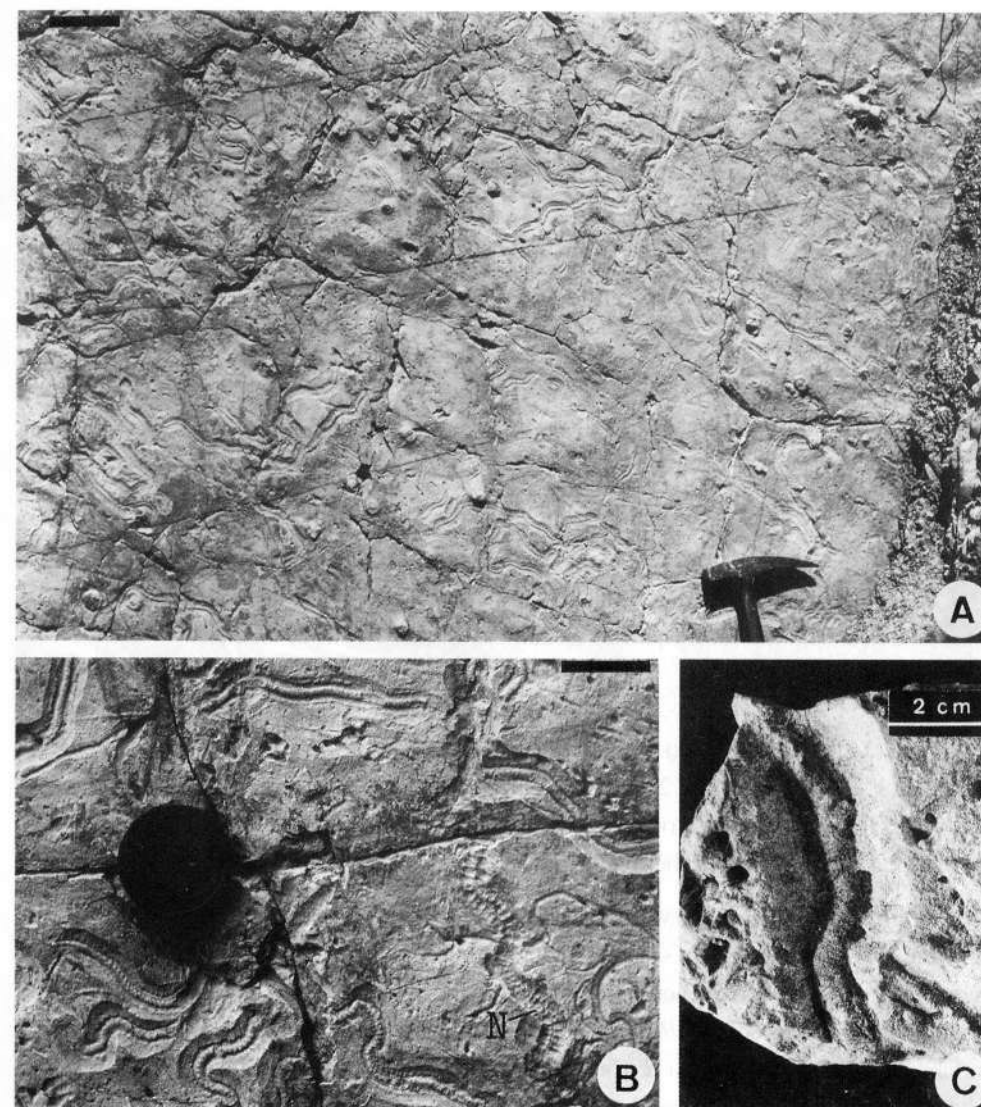


Fig. 4 - Trace fossils from the Carnian pre-Alps. A. *Scolicia striata*, sole of turbiditic sandstone, Almadis quarry, field photograph. B. *Scolicia striata* and *Nereites* isp. (N) on sole of a turbiditic sandstone bed, Almadis quarry, field photograph. C. *Scolicia prisca*, top of a turbiditic sandstone bed, the old quarry of Maniago. TFAU162. Scale bars in A = 10 cm, in B = 5 cm.

- Tracce fossili degli affioramenti di flysch delle Prealpi Carniche. A. *Scolicia striata*, controimpronta alla base di una torbidite. B. *Scolicia striata* e *Nereites* isp. (N), controimpronta alla base di una torbidite, Cava di Almadis, foto di campagna. C. *Scolicia prisca*, sommità di uno strato torbiditico, vecchia cava di Maniago TFAU162. Scala di riferimento in A = 10 cm, in B = 5 cm.

Rosetted structures

Lorenzina pustulosa (KŚIAŹKIEWICZ, 1977) (fig. 3C) consists of indistinctly radiating short ridges which are 3-4 mm in diameter and 5-12 mm long. The ridges are scattered around indistinct areola.

Glockerichnus alata (SEILACHER, 1977) (fig. 3B) consists of hypichnial radiating anastomosing ridges with the characteristic U-shaped elements. The ridges are 12-18 mm wide. The whole structure is about 250 mm in diameter. This is the largest registered form of this ichnospecies.

Spreiten

Phycosiphon incertum FISCHER-OOSTER 1858 occurs on parting surfaces as small, strongly flattened spreite structures which are 0.7-1.0 mm wide. They form loops, 2-3 mm wide and up to 15 mm long. The tube fill is finer than the host sediment, the spreite consists of sorted material.

Zoophycos isp. Endichnial planar spreite structure in the upper part of turbiditic sandstone beds and the shaley part of turbidites, at least 10 cm in diameter.

Winding structures

Scolicia prisca DE QUATREFAGES 1849 (fig. 4C) is represented by a three-lobed, slightly meandering epichnial furrow, 20-30 mm wide. The furrow displays a convex, narrow (4-6 mm wide) floor that forms a ridge-like structure with perpendicular ribs. The walls of the furrow are covered with asymmetric ribs. The ribs are commonly not smoothed by weathering.

Scolicia striata (KŚIAŹKIEWICZ, 1970) (figs. 4A-B) is a trilobate, winding, full hypichnial structure that is expressed on soles of turbiditic sandstones as trilobate ridge with median, transversally striated furrow bordered by two narrow strings. The ridge is 20-30 mm wide. This form was described as *Subphyllochora striata*, but *Subphyllochora* is a preservational variant of *Scolicia* (e.g. SMITH & CRIMES, 1983) and has been included in this ichnogenus (UCHMAN, 1995). Morphological details of the ridges differ place by place along the same or adjacent ridges.

?Nereites isp. (fig. 4B). Hypichnial winding ridge, about 20 mm wide, composed of thin median string and symmetrically distributed elliptical mounds, which are densely packed along the string. The string locally disappear. Longer axes of the elliptical mounds are perpendicular to the median string. Similar forms were described by LÖFFLER & GEYER (1994) from the Eocene flysch of the Belluno region.

Saerichnites isp. consists of small cylindrical hypichnial mounds arranged in a single

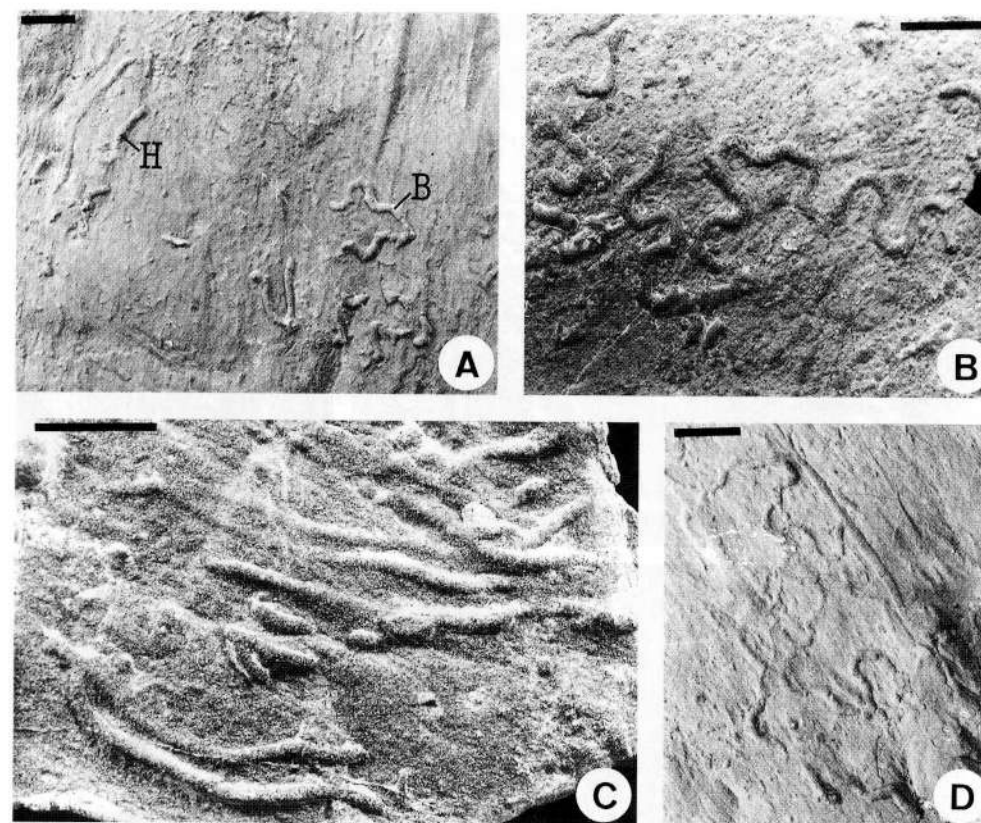


Fig. 5 - Graphoglyptid trace fossils on soles of turbiditic sandstone beds from the Almadis quarry. A. *Helminthorhapse flexuosa* (H) and *Belocosmorhapse aculeata* (B), PIW1993X308. B. *Cosmorhapse ?sinuosa*, PIW1993X312. C. *Urohelminthoida dertonensis*, PIW1993X304. D. *Protapaleodictyon incompositum*, PIW1993X306. Scale bars = 1 cm.

- Controimpronte di tracce fossili di grafoglitidi alla base di strati torbiditici. Cava di Almadis. A. *Helminthorhapse flexuosa* (H) e *Belocosmorhapse aculeata* (B), campione PIW1993X308. B. *Cosmorhapse ?sinuosa*, campione PIW1993X312. C. *Urohelminthoida dertonensis*, PIW1993X304. D. *Protapaleodictyon incompositum*, campione PIW1993X306. Scala di riferimento = 1 cm.

row. The mounds display a flat top and are 4-5 mm in diameter, up to 2 mm high, and 10 to 20 mm apart. For taxonomy of this ichnogenus see UCHMAN (1995).

Meandering structures

Belocosmorhapse aculeata (KŚIAŹKIEWICZ, 1977) (fig. 5A) is a convex hypichnial semi-relief, 2.0-2.5 mm wide, with incompletely preserved first order meanders. The second order meanders are wide as high and display characteristic angular guidance and short protrusions

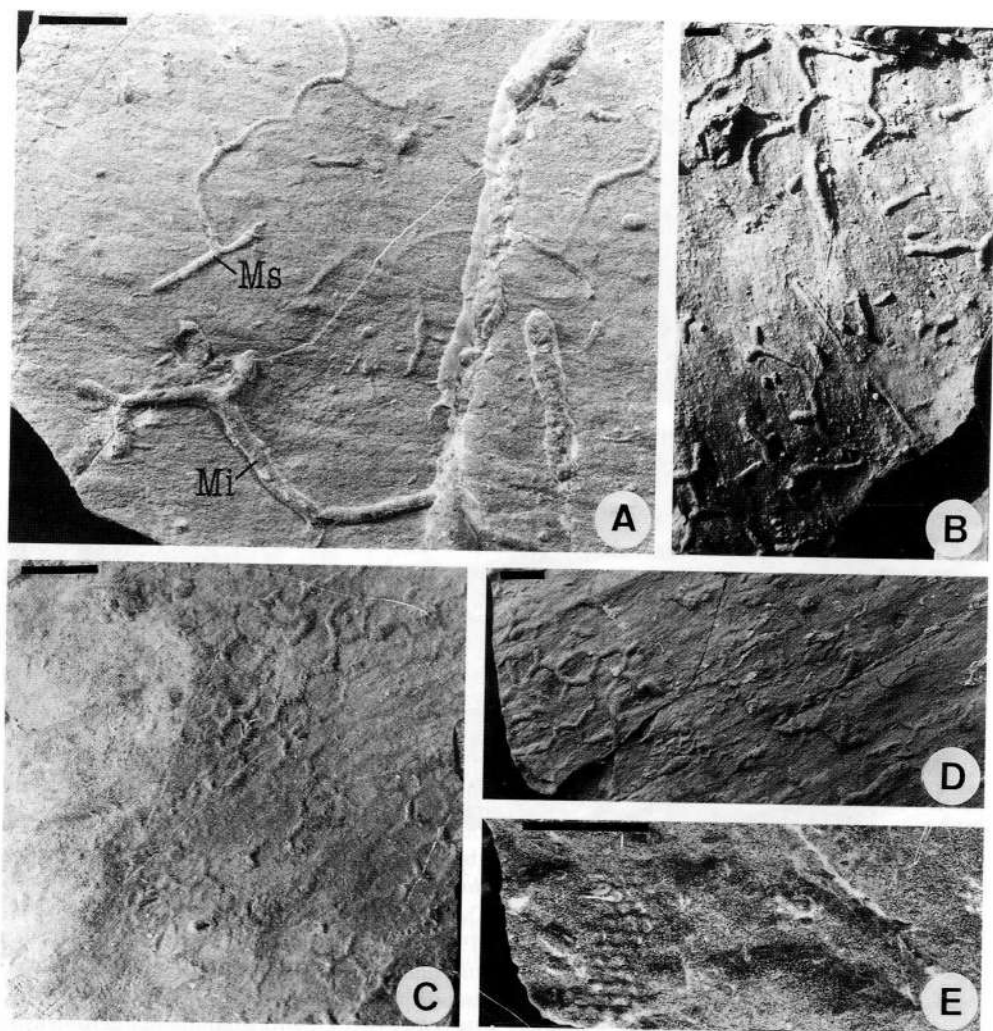


Fig. 6 - Graphoglyptid trace fossils on soles of turbiditic sandstone beds from the Almadis quarry. A. *Megagraption submontanum* (Ms) and *Megagraption irregulare* (Mi), PIW1993X313. B. *Megagraption irregulare*, field photograph. C. *Paleodictyon strozzii*, PIW1993X316. D. *Paleodictyon majus*, PIW1993X315. E. *Paleodictyon minimum*, PIW1993X317. Scale bars = 1 cm.

- Controimpronte di tracce fossili di grafogliptidi alla base di strati torbiditici dalla cava di Almadis. A. *Megagraption submontanum* (Ms) e *Megagraption irregulare* (Mi), campione PIW1993X313. B. *Megagraption irregulare*, foto di campagna. C. *Paleodictyon strozzii*, PIW1993X316. D. *Paleodictyon majus*, PIW1993X315. E. *Paleodictyon minimum*, PIW1993X317. Scala di riferimento = 1 cm.

or knobs. This form was described as *Helminthoida aculeata* (KŚIAŹKIEWICZ, 1977), but it displays first- and second-order meanders, which are typical of *Cosmorhaphe*. However, the angulate guidance and protrusions are not present in *Cosmorhaphe*. UCHMAN (in press) created ichnogenus *Belocosmorhaphe* for this form.

Cosmorhaphe ?sinuosa (AZPEITIA-MOROS, 1933) (fig. 5B) is a convex hypichnial semi-relief, 1.1-1.5 mm in diameter, showing densely or widely spaced first order meanders. Second order meanders are commonly lower than or equal to their wave length.

Helminthorhaphe flexuosa UCHMAN (1995) (fig. 5A) is a convex hyporelief, about 2 mm in diameter, forming deep, irregularly guided meanders of uneven width, without bulges at the curved segments of meanders.

Urohelminthoida dertonensis SACCO 1888 (fig. 5C) is a convex hyporelief consisting of narrow, deep zig-zag meanders. The turning points of the meanders have short outward directed appendages which are prolongations of oncoming meanders. String diameter is 0.5-1.2 mm.

Protopaleodictyon incompositum KŚIAŹKIEWICZ 1970 (fig. 5D) consists of hypichnial branched meanders. The branches originate from the convex side of turning points and have the tendency to meandering and further branching. String diameter is 1.4 mm.

Networks

Megagraption irregulare KŚIAŹKIEWICZ 1968 (fig. 6A-B) is a convex hypichnial semi-relief, 1.4-2.0 mm thick, forming an irregular net that displays more or less right angles. Mesh diameter is 20-25 mm.

Megagraption submontanum (AZPEITIA-MOROS, 1933) (fig. 6A) is a convex hypichnial semi-relief, 0.6 mm in diameter, irregularly winding and meandering, branching at various points and forming a network. The network consists of irregular meshes which are 14-16 mm in diameter. Commonly, this ichnospecies was described under *Protopaleodictyon* but it was included lately in *Megagraption* by UCHMAN (in press).

Paleodictyon (Glenodictyum) minimum SACCO (1888) (fig. 6E) is a very small *Glenodictyum* with mesh-size 1.0-1.3 mm and string diameter up to 0.3 mm.

Paleodictyon (Glenodictyum) strozzii MENEGHINI in SAVI & MENEGHINI 1850 (fig. 6C) is a net composed of regular to slightly irregular hexagonal meshes, 3.7-6.0 mm in diameter. String diameter is 0.7 mm.

Paleodictyon (Glenodictyum) majus MENEGHINI in SACCO 1888 (fig. 6D) is a relatively large, regular, hexagonal net 8-11 mm in diameter. String diameter is 1.1-1.3 mm.

Distribution of trace fossils

The shaley part of turbiditic-pelagitic couplets is totally bioturbated. The shales display totally bioturbated background and *Chondrites*, *Planolites*, and locally *Trichichnus* or *Phycosiphon*. In most cases, the shales display lightening of colour towards the top. The sandstone part of turbiditic beds is only locally cross cut by *Ophiomorpha annulata*. Sandy soles of turbidites are colonised by *O. annulata*, rarely by *Scolicia*, *Thalassinoides* or *Spongiomorpha*. The transition from sandstone to shale within turbidites (Tc-Td) is densely burrowed by *Scolicia prisca* in some beds. Other trace fossils are relatively rare.

In thick muddy turbidites only tops of the beds are bioturbated. In these, which display lightening toward the top, the "ferruginous tubes" extends at least 10 cm downwards the top. *Chondrites* and *Planolites* is observed within the 5 cm thick layer at the top. *Chondrites* cross cuts *Planolites*. Some thick muddy turbidites display dark marly mudstone shales, including the top layer. In this case, *Trichichnus* penetrates at least 10 cm downwards from the top. *Chondrites* occurs in shallower, 5-cm-thick layer.

Discussion

The trace fossil assemblage belongs to the deep-sea *Nereites* ichnofacies (SEILACHER, 1967). It is relatively diverse, with proportional contribution of shallow-tier, pre-depositional forms, mainly graphoglyptids (*Paleodictyon*, *Urohelminthoida*, *Helminthorhaphe*, *Protopaleodictyon*, *Belocosmorhaphe*, *Megagraption*) and deeper-tier post-depositional forms (*Ophiomorpha*, *Thalassinoides*, *Chondrites*, *Trichichnus*, *Spongiomorpha*, *Scolicia*). Some of the post-depositional forms occur in a great abundance (*Ophiomorpha*, *Chondrites*, *Trichichnus*, partially *Scolicia*). They probably displayed opportunistic, r-selected style of colonisation (cf. UCHMAN, 1992a). Such proportional contribution of the pre- and post-depositional forms, and common lightening beds toward the top of turbiditic-pelagitic couplets, suggest well oxygenated, mostly moderately oligotrophic environments. However, some periods of increasing accumulation of organic matter is indicated by isolated occurrences of dark shales in single beds (?eutrophic conditions). Occurrence of *Trichichnus* is commonly connected with such shales.

Analogical environment was interpreted for the similar flysch deposits in the Upper Paleocene-Lower Eocene "Flysch del Grivò" from the Julian pre-Alps (TUNIS & UCHMAN, 1992; 1994a; 1996a), the Eocene flysch of Istria (TUNIS & UCHMAN, 1994b; 1996b), the Eocene Beloveža beds in the Carpathians (UCHMAN, 1992b), or in the Miocene Marnoso-arenacea Formation of the Northern Apennines (UCHMAN, 1995). Thus, the discussed flysch deposits are an additional example of moderately oligotrophic flysch deposits in Eocene, with high contribution of K-selected graphoglyptids, typical of such environment (TUNIS & UCHMAN, 1996a).

The Late Paleocene-Middle Eocene oligotrophy is widely known from micropalaeontological investigations (HALLOCK et al., 1991). The oligotrophic conditions were caused by a global warming of climate in the Late Paleocene (SAVIN et al., 1975; BUCHARD, 1978; REA et al., 1990; BOERSMA & PREMOLI SILVA, 1991). SHACKELTON & BOERSMA (1981), BRASS et al. (1982) and SHACKELTON (1986) noted a rapid increase in temperature of deep-sea and surface waters at the beginning of the Eocene which resulted in microfaunal extinction and changes (KENNETT & SCOTT, 1991; CANUDO & MOLINA, 1992). The temperature increase resulted in replacement of cold-water communities by more diverse warm-water communities, causing increased exploitation of nutrients in all ecologic niches and an increased rate of decomposition of organic matter.

Manoscritto pervenuto il 23.VI.1998.

Acknowledgments

G.T. was supported by a MURST 60% grant (resp. G. Catani), A.U. was supported by the Alexander von Humboldt Foundation, the University of Würzburg, and the Jagiellonian University. We thank also H. Schirm (Würzburg) and P. Radzicki (Kraków) for preparation of the photographic illustrations.

References

- AZPEITIA-MOROS F., 1933 - Datos para el estudio paleontológico del Flysch de la Costa Cantábrica y de algunos otros puntos de España. *Bol. Inst. Geol. Min. de España*, 53: 1-65.
- BOERSMA A. & PREMOLI SILVA I., 1991 - Distribution of Paleogene planktonic foraminifera-analogies with the recent?. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 83: 29-48.
- BRASS G.W., SOUTHAM J.R. & PETERSON W.H., 1982 - Warm saline bottom water in the ancient ocean. *Nature*, 296: 620-623.
- BOUMA A.H., 1962 - Sedimentology of some flysch deposits: a graphic approach to facies interpretation. *Elsevier*: 1-168.
- BRONGNIART A.T., 1823 - Observations sur les Fucoids. *Soc. d'Hist. Nat. de Paris, Mem.*, 1: 301-320.
- BUCHARDT B., 1978 - Oxygen isotope palaeotemperatures from the Tertiary period in the North Sea area. *Nature*, 275: 121-123.
- CANUDO J.I. & MOLINA E., 1992 - Planktic foraminiferal faunal turnover and bio-chronostratigraphy of the Paleocene-Eocene boundary at Zumaya. Northern Spain. *Revista Soc. Geol. de España*, 5: 145: 157.
- COUSIN M., 1981 - Les rapports Alpes-Dinarides dans les confins de l'Italie et de la Yougoslavie. *Soc. Geol. du Nord*, 1+2, 521+521.
- CRIMES T.P. & CROSSLEY J.D., 1991 - A diverse ichnofauna from Silurian flysch of the Aberystwyth Grits Formation, Wales. *Geol. Jour.*, 26: 27-64.
- CRIMES T.P. & MCCALL G.J.H., 1995 - A diverse ichnofauna from Eocene-Miocene rocks of the Makran Range (S.E. Iran). *Ichnos*, 3: 231-258.
- CUVILLIER J., FOURY G. & PIGNATTI MORANO A., 1969 - Foraminifères nouveaux du Jurassique supérieur du Val Cellina (Frioul occidentale, Italie). *Geol. Romana*, 7: 141-156.
- DAVIDE N., 1971 - Studio geologico stratigrafico dei dintorni di Frisanco (provincia di Pordenone). *Tesi di laurea inedita*. Università di Trieste.
- FILLION 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.
- FISHER-OOSTER C., 1858 - Die Fossilen Fucoides der Schweizer-Alpen Nebst Erörterungen über deren Geologisches Alter. *Huber*, Bern, pp. 72.
- FORNASARI M., 1995 - Studio sedimentologico del Flysch di Clauzetto ad ovest del T. Meduna (Friuli occidentale). *Tesi di laurea inedita*, Università di Trieste.
- FREY R.W., 1970 - Trace fossils of Fort Hays Limestone Member of Niobrara Chalk (Upper Cretaceous), west-central Kansas. *University of Kansas, Paleontological Contributions*, 53: 1-41.
- GRANDESSO P. & STEFANI C., 1996 - I flysch paleogenici del Sudalpino Orientale (abs.) *Congresso S.G.I. Geologia delle Dolomiti*, San Cassiano: 78-79.
- HALL J., 1847 - Palaeontology of New York, v. 1. State of New York. *C. van Benthuyssen*, Albany, N. Y., pp. 338.
- HALL J., 1852 - Palaeontology of New York, v. 2. State of New York. *C. van Benthuyssen*, Albany, N. Y., pp. 362.
- HALLOCK P., PREMOLI SILVA I. & BOERSMA A., 1991 - Similarities between planktonic and larger foraminiferal evolutionary trends through Paleogene paleoceanographic changes. *Paleogeogr., Palaeoclimatol., Palaeoecol.*, 83: 49-64.
- HÄNTZSCHEL W., 1975 - Trace fossils and problematica. In: TEICHERT C. (ed.) - Treatise on Invertebrate Paleontology, part W, Miscellanea Supplement I. *Geol. Soc. of America and Univ. of Kansas Press*, pp. 269.
- KAIHO K., 1991 - Global changes of Paleogene aerobic/anaerobic benthic foraminifera and deep-sea circulation. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 83: 65-85.
- KENNETT J.P. & SCOTT L.D., 1991 - Abrupt deep-sea warming, palaeoceanographic changes and benthic extinctions at the end of the Paleocene. *Nature*, 353: 225-229.
- KSIĄŻKIEWICZ M., 1961 - O niektórych problematykach z fliszu Karpat polskich, Część 1 (On some problematic organic traces from the Flysch of the Polish Carpathians. - Part 1). *Kwartalnik Geol.*, 4: 735-747.
- KSIĄŻKIEWICZ M., 1968 - O niektórych problematykach z fliszu Karpat polskich, Część 3 (On some problematic organic traces from the Flysch of the Polish Carpathians. Part 3). *Rocznik Polskiego Towarzystwa Geologicznego*, 38: 3-17.
- KSIĄŻKIEWICZ M., 1970 - Observations on the ichnofauna of the Polish Carpathians. In: CRIMES T.P. & HARPER J.C. (eds.) - Trace Fossils. *Geol. Journal, Special Issue*, 3: 283-322.
- KSIĄŻKIEWICZ M., 1977 - Trace fossils in the Flysch of the Polish Carpathians. *Palaeontol. Polonica*, 36, pp. 208.
- LESZCZYŃSKI S., 1991a - Trace-fossil tiering in flysch sediments: examples from the Guipuzcoan flysch (Cretaceous-Paleogene), northern Spain. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 88: 167-184.
- LÖFFLER S.-B. & GEYER O.F., 1994 - Über Lebensspuren aus dem eozänen Belluno-Flysch (Nord-Italien). *Paläont. Zeitschr.*, 68: 491-519.
- PALMIERI A., 1995 - Studio sedimentologico del Flysch di Clauzetto ad est del T. Meduna. *Tesi di laurea inedita*, Università di Trieste.
- PEMBERTON G.S. & FREY R.W., 1982 - Trace fossil nomenclature and the *Planolites-Palaeophycus* dilemma. *Journ. Paleontol.*, 56: 843-881.
- QUATREFAGES DE M.A., 1849 - Note sur la *Scolicia prisca* (A. de Q.) annelide fossile de la Craie. *Ann. Sc. Natur., Zoologie*, 3 sér., 12: 265-266.
- REA D.K., ZACHOS J.C., OWEN R.M. & GINGERICH P.D., 1990 - Global change at the Paleocene-Eocene boundary: climatic and evolutionary consequences of tectonic events. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 79: 117-128.
- RICHTER D., 1970 - Flysch und Molasse an der südalpen-Dinariden Grenze zwischen Brenta und Isonzo. *Geol. Mitteil.*, 96: 371-417.

- SACCO F., 1888 - Note di paleoicnologia italiana. *Atti Soc. Ital. Sc. Nat.*, 31: 151-192.
- SARTI M., 1979 - Il Paleogene della Val Tremugna (Prealpi Carniche). *Boll. Soc. Geol. It.*, 98: 87-108.
- SAVI P. & MENEGHINI G.G., 1850 - Osservazioni stratigrafiche e paleontologiche concernenti la geologia della Toscana e dei paesi limitrofi. Appendix in: MURCHISON, R.L., 1850 - *Memoria sulla struttura geologica delle Alpi, degli Apennini e dei Carpazi*. Stamperia Granducale, Firenze, pp. 46.
- SAVIN S.M., DOUGLAS R.G. & STEHLI F.G., 1975 - Tertiary marine paleotemperatures. *Bull. Geol. Soc. of America*, 86: 1499-1510.
- SEILACHER A., 1967 - Bathymetry of trace fossils. *Marine Geology*, 5: 413-428.
- SEILACHER A., 1977 - Pattern analysis of *Paleodictyon* and related trace fossils. In: CRIMES T.P. & HARPER J.C. (eds.) - Trace fossils 2. *Geol. Journ., Special Issue*, 9: 289-334.
- SHACKLETON N.J., 1986 - Paleogene stable isotope events. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 57: 91-102.
- SHACKLETON N. & BOERSMA A., 1981 - The climate of the Eocene ocean. *Journal Geol. Soc. of London*, 138: 153-157.
- SMITH A.B. & CRIMES T.P., 1983 - Trace fossils formed by heart urchins - a study of *Scolicia* and related traces. *Lethaia*, 16: 79-92.
- STEFANI C., 1982 - Geologia dei dintorni di Fanna e Cavasso Nuovo (Prealpi Carniche). *Mem. Sc. Geol. Padova*, 35: 203-212.
- STEFANINI G., 1915 - Il Neogene Veneto. *Mem. Ist. Geol. R. Univ. Padova*, 3: 340-624.
- TUNIS G. & UCHMAN A., 1992 - Trace fossils in the "Flysch del Grivò" (Lower Tertiary) in the Julian pre-Alps, NE Italy: preliminary study. *Gortania*, 14: 71-104.
- TUNIS G. & UCHMAN A., 1994a - Trace fossils reflects facies changes and world-wide changes in the Maastrichtian-Paleogene flysch deposits of the Julian pre-Alps, Italy and Slovenia. *Internat. Ass. Sedimentol., 15th Regional Meeting, 13/15 April 1994, Ischia, Italy*: 417-418, De Frede, Napoli.
- TUNIS G. & UCHMAN A., 1994b - Ichnology of the Eocene flysch deposits in the Istrian Peninsula, Croatia and Slovenia In: *14th Internat. Sedimentol. Congress IAS 94, Recife, Agosto 94, S5-15-S5-16, Recife*.
- TUNIS G. & UCHMAN A., 1996a - Trace fossil and facies changes in the Upper Cretaceous-Middle Eocene flysch deposits of the Julian pre-Alps (Italy and Slovenia): consequences of regional and world-wide changes. *Ichnos*, 4: 169-190, Yverdon.
- TUNIS G. & UCHMAN A., 1996b - Ichnology of the Eocene flysch deposits in the Istria peninsula, Croatia and Slovenia. *Ichnos*, 5: 1-22, Yverdon.
- TUNIS G. & VENTURINI S., 1992 - Evolution of the southern margin of the Julian Basin with emphasis on the megabeds and turbidites sequence of the Southern Julian pre-Alps (NE Italy). *Geol. Croatica*, 45: 127-150.
- UCHMAN A., 1992a - An opportunistic trace-fossil assemblage from the flysch of the Inoceranian beds (Campanian-Paleocene), Bystrica zone of the Magura Nappe, Carpathians, Poland. *Cretaceous Research*, 13: 539-547.
- UCHMAN A., 1992b - Skamieniałości śladowe w eoceńskim cienko- i średnioławicowym fliszu strefy bystrzyckiej płaszczowiny magurskiej. *Przegląd Geologiczny*, 7: 430-435, Warszawa.
- UCHMAN A., 1995 - Taxonomy and palaeoecology of flysch trace fossils: The Marnoso-arenacea Formation and associated facies (Miocene, Northern Apennines, Italy). *Beringeria*, 15: 3-115.
- UCHMAN A., in press - Taxonomy and ethology of flysch trace fossils: Revision of the Marian Książkiewicz collection and studies of complementary material. *Ann. Soc. Geol. Poloniae*.
- VENTURINI S. & TUNIS G., 1992 - La composizione dei conglomerati cenozoici del Friuli: dati preliminari. *Studi Geol. Camerti. vol. spec. (1992/2), CROP 1*, 14: 285-295.
- WERNER F. & WETZEL W., 1981 - Interpretation of biogenic structures in oceanic sediments. *Bull. Inst. Geol. du Bassin d'Aquitaine*, 31: 275-288.

ZENARI S., 1929 - Note illustrative della carta geologica delle Tre Venezie. Foglio Maniago. Magistrato delle Acque, Padova. *Uff. Idrogr. R. Mag. delle Acque*, pp. 102, Venezia.

Authors' addresses - Indirizzi degli Autori:

- Dr. Giorgio TUNIS
Dip. di Scienze Geologiche, Ambientali e Marine
Università degli Studi di Trieste
Via E. Weiss 2, I-34127 TRIESTE
- Dr. Alfred UCHMAN
Institute of Geological Sciences
Jagiellonian University
Oleandry 2a, P-30-063 KRAKÓW (Poland)