Rivista Italiana di Paleontologia e Stratigrafia	volume 114	no. 1	1 pl.	pp. 161-167	March 2008

SHORT NOTE – NOTA BREVE

THE ICHNOFOSSIL GENUS *PARADICTYODORA* OLIVERO, BUATOIS & SCASSO (2004) FROM THE PLIOCENE OF THE NORTHERN APENNINES, ITALY

ENRICO SERPAGLI [1], PAOLO SERVENTI [1] & PAOLA MONEGATTI [2]

Received: July 11, 2007; accepted: December 13, 2007

Key words: Fodinichnion, *Paradictyodora*, Pliocene, Northern Italy.

Abstract. The ichnospecies *Paradictyodora flabelliformis* (D'Alessandro & Fürsich) is reported for the first time from the Pliocene "Argille Azzurre Formation" of Northern Italy. The horizon has an older age and is deeper than the shallow-water protected shoreface environment where the type specimens have been found. A narrow tubular structure exceptionally preserved on the specimen studied possibly supports the tellinid bivalve model instead of the *Arenicola* model for the origin of the trace fossil.

Riassunto. Viene segnalata per la prima volta l'icnospecie *Paradictyodora flabelliformis* (D'Alessandro & Fürsich) nei terreni pliocenici della "Formazione delle Argille Azzurre" dell'Italia settentrionale. L'importanza del ritrovamento risiede sia nell'età più antica del reperto rispetto a quella dei tipi, sia nella possibilità di spiegare l'origine della traccia in base ad una struttura particolarmente ben conservata.

Introduction

A Plio-Pleistocene unit known as "Formazione delle Argille Azzurre" (or more simple "Argille Azzurre"), tectonically belonging to the so called "Successione Padana di wedge top" (Barbacini et al. 2002), crops out along the north-eastern border of the Northern Apennine Chain and represents one of the units of the "Successione Neogenico-Quaternaria del Margine Appenninico-Padano" (Gasperi et al. 2005). This formation spans the Lower Pliocene (*Sphaeroidinellopsis seminulina* s.l. biozone) and Lower Pleistocene (*Globigerina cariacoensis* biozone) and is almost 1000 m thick.

At about 1 km from the village of San Valentino (municipality of Castellarano, Reggio Emilia province) two nearby sections, one of which up to 200 m thick, are exposed (Fig. 1). A well preserved specimen belonging to the newly established ichnogenus *Paradictyodora* Olivero, Buatois & Scasso, 2004, was discovered in the highest part of one of these sections. The aim of this note is to expand the known stratigraphic and geographic distribution of this genus, so far recorded only from the Lower Pleistocene of southern Italy.

The sections

In the area two sections (N 44°32'04", E 10°43'20"), very close to each other and informally named A and B, have been studied in detail by Catellani (1989) and by Campanini (1999), respectively. A composite section is shown in Fig. 2.

Section A

According to Catellani (1989) the section is about 180 m thick and continues in an almost vertical wall for at least 20 m. The extreme part (which, being inaccessible, was not studied) may be related to the "Membro di San Valentino" which might represent the base of the P2 cycle (Gasperi et al. 2005). The section was roughly divided into two intervals, informally named by Catellani DCSV1 and DCSV2.

1 Dipartimento del Museo di Paleobiologia e dell'Orto Botanico, Università di Modena e Reggio Emilia. E-mail: serpagli@unimore.it; paolo.serventi@unimore.it

2 Dipartimento di Scienze della Terra, Università di Parma. E-mail: paola.monegatti@unipr.it

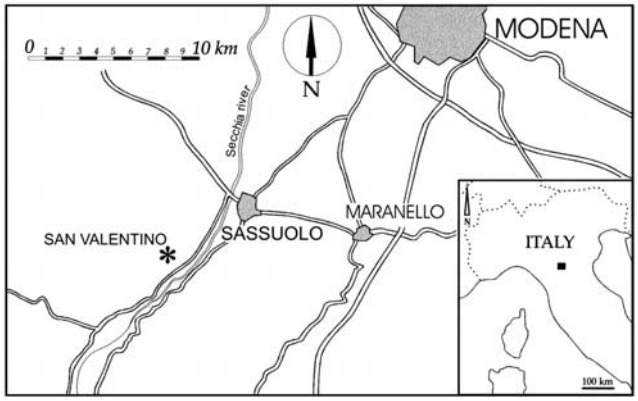


Fig. 1 - Location map of the site (asterisk) where *Paradictyodora flabelliformis* was collected.

Interval DCSV1 - A lithologically uniform sequence, about 140 m thick, of grey-blue massive pelites, with indistinct bedding, rich in fossils, whose sandy portion (mostly organic debris and pyrite granules) is always below 10%. This complex (partially shown in the lower part of the composite section of Fig. 2) is regionally well known as "Argille Azzurre". In this part of the section, 53 species of molluscs (gastropods, bivalves and scaphopods) have been identified by Catellani (1989).

Interval DCSV2 - This interval (not shown in Fig. 2) is about 40 m thick. According to Catellani (1989), the amount of sand increases between 140 and 145 m. At 145 m the first tempestite horizon, mostly made up of shell debris and disarticulated valves of bivalves, occurs. Marls bearing bivalve borings may be also be present in this horizon. The sandy pelites and the pelitic sands are usually bioturbated and rich in fossils, whereas the coarser part of the sandy portion is almost exclusively organogenic (forams, shell debris, bryozoans, etc.). Two hundred and forty seven species of benthic molluscs have been identified by Catellani (1989). Echinoids (*Schizaster* sp.), bryozoans, algae, cirripedes (barnacles) and the polychaete *Ditrupa arietina* (O. Müller, 1774), very abundant in sandy pelitic horizons, are also present. Vertebrate remains are dominated by small teeth of *Carcharodon* sp. and *Hexancus* sp. Whale bones belonging to cf. *Balaenula* sp. including a 2 m long mandibular arch, several ribs, three vertebrae as well as ulna and radius of the right limb have been found at about 13 m above the base of this interval.

Section B

Section B is very close to Section A and has been studied in great detail by Campanini (1999). It is about 100 m thick, and where sands and silty clays are prevalent, i.e. in its lower and middle part, it can be roughly correlated, in its middle and lower part, with the uppermost 80 m of Section A. It is wholly depicted in the upper half of the composite section (Fig. 2). The last 20 m, cropping out as an almost vertical wall and have been sampled with the help of a climber. They provided much palaeontological data for the stratigraphic and palaeoenvironmental reconstruction of the section. They are characterized by thick beds of grey and yellow well sorted medium-grained sands which become coarser towards the top of the section. In these sands, sedimentary structures are lacking and the palaeontological record is lower in abundance and preservation if compared with the underlying sediments.

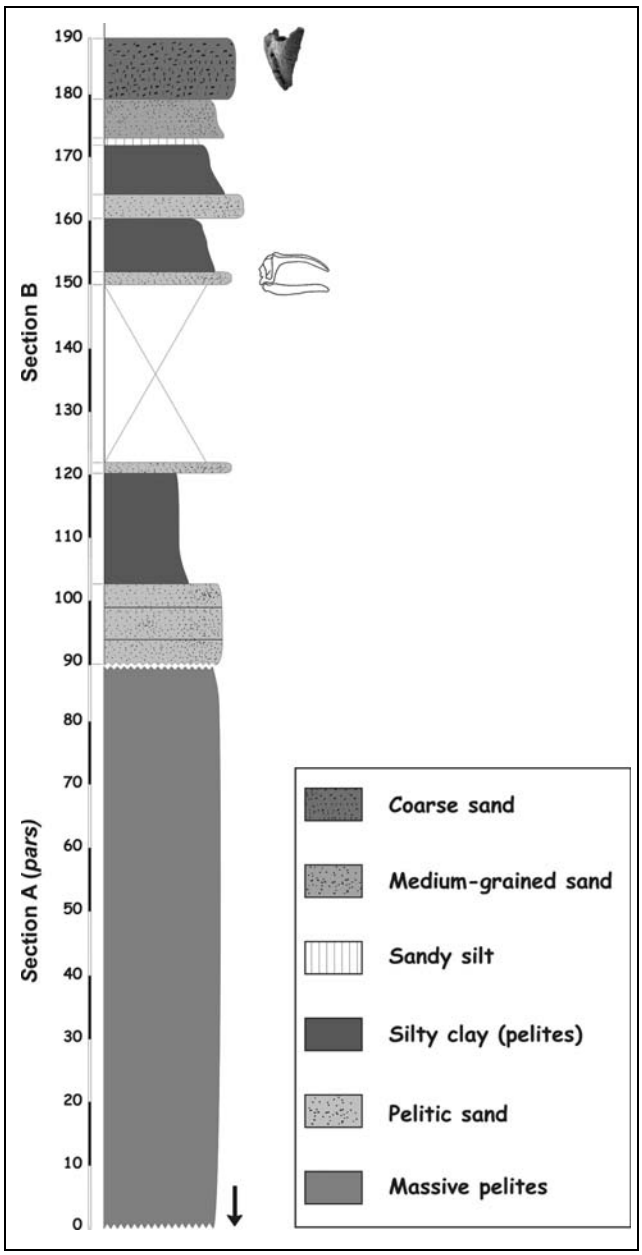


Fig. 2 - Composite section through the "Argille azzurre" (Pliocene) in San Valentino area, combining part of the lower portion of Section A and the whole of Section B. A *Balaena* skull indicates the "Whale level" and a silhouette of *Paradictyodora* the bed from which the trace fossil has been derived.

The difficulty in correlating the two sections lithologically is due to several factors:

(a) Catellani (1989) did not describe the lithology of Section A in detail except for the segment between 145 and 155 m.

(b) The almost 30 m thick covered interval shown by Campanini (1999), possibly fitting across the two intervals DCSV1 and DCSV2, does not occur in Section A, and seems therefore to be continuous.

(c) The 10 m of pelitic sands present in the lowermost part of Section B have not been seen in Section A.

(d) Section A does not continue in the wall and therefore the top 20 m are missing.

The fauna, despite being common, is poorly preserved, the specimens being often broken or abraded. 115 species of benthic mollusks (85 gastropods, 27 bivalves and 3 scaphopods) have been identified. Besides mollusks, four species of bryozoans, polychaetes [*Ditrupa arietina* (O. Müller, 1774)], cirripedes (*Balanus concavus* Bronn, 1831), brachiopods [(*Terebratula ampulla* (Brocchi, 1814)], and fragments of echinoids and stelleroids have been found. At about 60 m above the base of this section, an almost complete specimen of a whale [*Balaena glacialis* (P. L. S. Müller, 1776)] has been discovered.

Because the section shows the analogous faunistic features of interval DCSV 2 of Section A, including *Balaena* remains, a better correlation is achieved on a palaeontological basis.

Environmental interpretation

The several units of the sections have all been deposited on a continental shelf. Differences in lithology and in the taxonomic diversity of assemblages, can be referred to variations in the hydrodynamic regime and/or bathymetry.

According to Catellani (1989), the lack of distinct bedding in the lowermost part of his section (DCSV1) indicates that sedimentation was continuous and occurred in quiet waters without continuous wave action. The depositional environment was certainly below the storm-wave base. In the next unit (DCSV2), moderate hydrodynamic activity prevailed and the sandy pelites indicate episodic wave action, mainly in the basal part. The depositional environment was possibly located between the storm-wave base and fine-weather wave-base with recurring unstable conditions, as evidenced by the occurrence of *Corbula gibba* (Olivi, 1792) and *Ditrupa arietina* in the lower half of this interval of Section A.

In agreement with this palaeoenvironmental interpretation, the molluscan assemblages recognized by Campanini (1999) allow the depositional environment to be referred to the proximal circalittoral, at the boundary with the infralittoral (*sensu* Peres & Picard 1964). The low bivalve diversity and the considerable diversity of turrid gastropods confirm a depositional environment of moderate hydrodynamic conditions alternating with episodes of instability as testified by the recurrence of opportunistic species such as *Corbula gibba, Ditrupa arietina,* and *Turbonilla rufa* (Philippi, 1836).

In the last 20 m of Section 2, cropping out in the wall, the distinct increase in medium to coarse-grained sand, the presence of reophilic taxa and the drastic reduction of opportunistic species indicate a depositional environment characterized by a constant and overall increase of water energy, probably related to slight shallowing (toward a distal infralittoral position). This hypothesis is supported by the presence of typical infralittoral species [e.g., *Spisula subtruncata* (Da Costa, 1778) and *Callista italica* (Defrance, 1818)] even if the taxonomic diversity of the assemblage does not show any significant difference from that of the underlying sediments.

Age of the unit

Both the authors that have studied the stratigraphy of the area agree on the age of the succession.

According to Catellani (1989) all of section A (except the last vertical part, not studied by him) is Early Pliocene in age based on both foraminifera and nannoplankton (data supplied to Catellani by Salvatorini and Mazzei). The lower part of the section (DCSV1) belongs to the *Globorotalia margaritae* biozone whereas the upper part (DCSV2) belongs almost entirely to the next *Globorotalia puncticulata* biozone, following the biostratigraphic scheme of Iaccarino (1985). A narrow transitional interval, where both *G.lia margaritae* and *G.lia puncticulata* co-exist, occurs in the lowest part of DCSV2.

Campanini (1999) confirms an Early Pliocene age for most of section B on the basis of ecobiostratigraphic data:

1) the occurrence, throughout the whole section, of the bivalves *Isognomon maxillatus* (Lamarck, 1801), *Callista italica* (Defrance, 1818), and *Circomphalus foliaceolamellosus* (Dillwyn, 1817), and of the gastropods *Murex spinicosta* Bronn, 1831 and *Mitra alligata* Defrance, 1824, all disappearing from the Mediterranean basin in connection with the first extinction event at the top of the faunal unit MPMU1, at about 3.0-2.9 My (Monegatti & Raffi 2001);

2) the occurrence of the gastropod *Gyrineum marginatum* (Gmelin, 1791) up to 75 m from the base of the section, whose disappearance, according to Mone-

gatti & Raffi (1996), approximates the LO of *Globorotalia puncticulata* at about 3.55 My.

It follows that all of section B is not younger than 3.0 My in age and that, the Zanclaen/Piacenzian boundary, as defined by Castradori et al. (1998) with the LO of *G.lia puncticulata,* probably can be placed at about 75 m above the base. In fact, the disappearance in the section of *Gyrineum marginatum* is not justified by changes of palaeoenvironmental features in the overlying sediments. Because *Paradictyodora* is supposed to occur in the uppermost sandy beds cropping out in the wall, just above the disappearance of *Gyrineum marginatum,* those beds can be referred to the lowermost Piacentian, at around 3.50 My.

Whale Level - Because in the San Valentino area where sections A and B are located, two whales (one referred to cf. *Balaenula* sp. and the other to *Balaena glacialis*, separated by a thickness of 70-90 cm, have been recovered, a "whale level" can justifiably be considered as marker-horizon of the area. This horizon can be placed in the uppermost part of *G.lia puncticulata* biozone (biostratigraphic framework of Cita 1975, emended).

Systematic Palaeontology

Ichnogenus *Paradictyodora* Olivero, Buatois & Scasso, 2004

1991 Vertical spreiten structure - Scasso, Olivero & Buatois, p. 260.
2005 *Tursia* - D'Alessandro & Fürsich, p. 67.

Type ichnospecies: *Paradictyodora antarctica* Olivero, Buatois & Scasso.

Stratigraphic range: Late Cretaceous to Pleistocene.

Ichnospecies *Paradictyodora flabelliformis* (D'Alessandro & Fürsich, 2005)

Pl. 1, figs 1a-e

1980 Curtain-like form - Bourgeois, p. 685, fig. 5A-C.
1980 V-shape trace - Bourgeois, p. 692, fig. 11B-C.
1993 Vertical bundled structure - D'Alessandro et al., p. 501, fig. 6A.
2005 *Tursia flabelliformis* - D'Alessandro & Fürsich, p. 67, 68, figs 5-7.

Examined material. One specimen (IPUM nº 27996) stored in the palaeontological collections of the Museum of Palaeobiology and Botanical Garden, Modena and Reggio Emilia University.

Locality and horizons. Rio della Rocca. San Valentino area, Castellarano municipality, Reggio Emilia Province, Northern Italy.

Description. The specimen consists of a vertical fan-like sheet with infolded margins axially anastomosing on one side to form a couple of slightly compressed cones of almost the same size. The structure is therefore bi-lobed and concave on one side and convex on the other side. The whole trace expands vertically, with an angle of about 30 degrees, from a central tube whose extreme basal part is not preserved. This tube is actually composed of three contiguous minor parts, two expanding in the main lobes and the third one continuing upwards on the convex side as a narrow tubular structure with an external diameter medially of 11 mm. The inner diameter of the tube is about 6 mm. The sheet is not flat but follows an irregular path which is quite evident in planar view (Pl. 1, Fig. 1e).

The whole structure is about 13.0 cm in height whereas its maximum width is about 9.5 cm. The thickness of the fan-like sheet, increasing where two opposite meander segments touch each other, ranges between 3-4 to 8-10 mm but it is not easy to confirm as it is controlled by the degree of cementation. In some areas of the lateral surfaces longitudinal ridges, striae or narrow grooves are present.

Age. Pliocene (lowermost Piacenzian).

Remarks. The sole specimen available, the general shape of which recalls some flabellate stalked corals (or sponges), fits in with the variability shown by D'Alessandro & Fürsich (2005) being very similar to the paratype PIW2003V 4. It was recovered as a loose specimen at the bottom of a steep wall and, on the basis of similar lithology, there are no doubts that it comes from the sandy levels cropping out in the wall (just) above the "whale horizon".

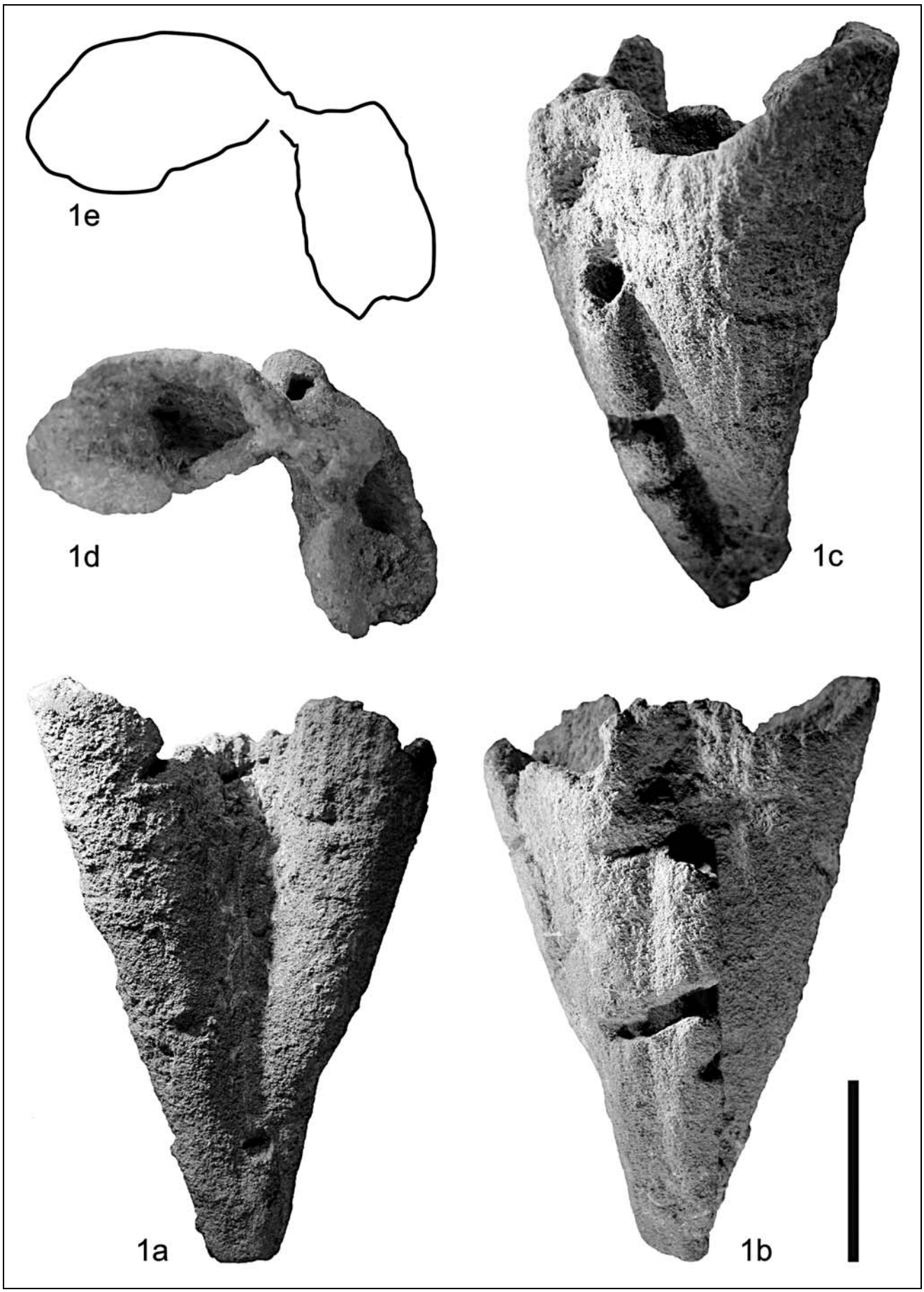
Paradictyodora flabelliformis from San Valentino was constructed in a deeper environment than the very shallow water protected shoreface environment where the type specimens have been found near Tursi in Southern Italy. It is also slightly older.

Behavioural notes

The trace has been interpreted by D'Alessandro & Fürsich (2005) as the feeding trace of an infaunal detritus-feeding organism such as a "worm" or tellinid bivalve.

PLATE 1

Paradictyodora flabelliformis (D'Alessandro & Fürsich). "Argille Azzurre" Formation; Pliocene of San Valentino. Scale bar: 40 mm.
Fig. 1a: view of the convex side; fig. 1b: view of the concave side where the tubular structure (= exhalant siphon) is evident in the middle part; fig. 1c: side view to show the tubular structure (= exhalant siphon); fig. 1d: top view to show the bilobate architecture and the position of the tubular structure (= exhalant siphon); fig. 1e: plan view to show the reconstruction of the irregular path of the sheet.


1e
1d
1c
1a
1b

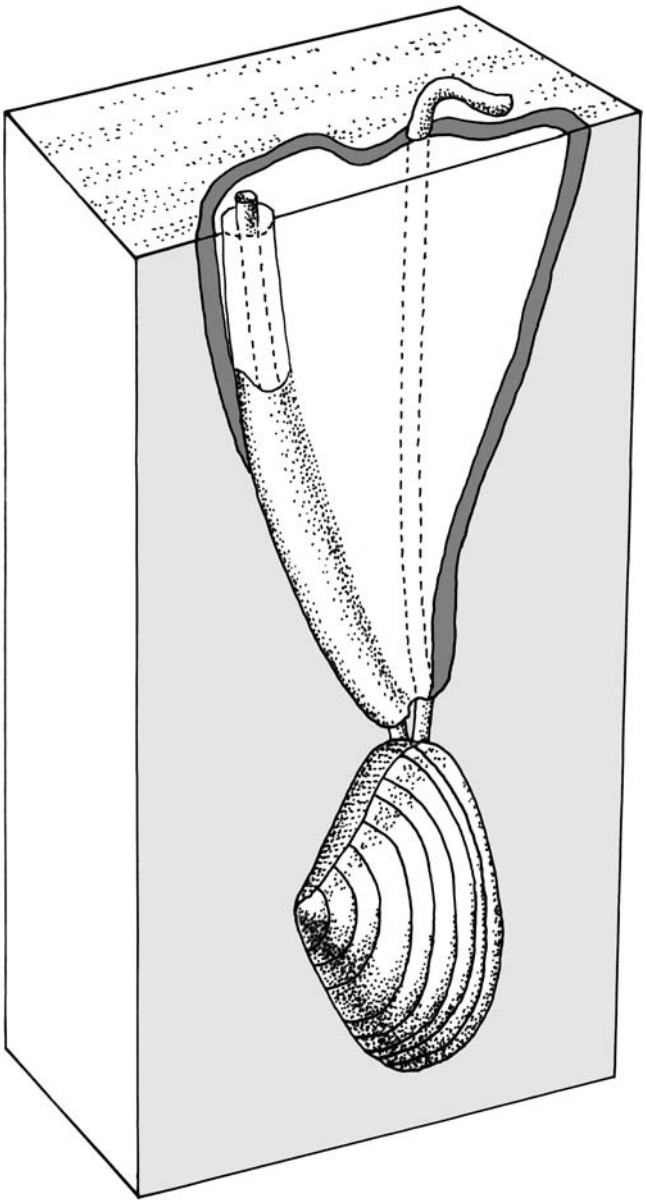


Fig. 3 - The ethological model of *Paradictyodora flabelliformis* favoured in the present paper is based on the preservation of a peculiar tubular "structure" (on the left) related to the selective cementation and infilling of a possible exhalant siphon of a tellinid bivalve. The inhalant siphon is also showed.

In our specimen, on the convex side, a peculiar tubular "structure" is preserved which can be interpreted as the selective cementation of the sediment surrounding the siphon (possibly the exhalant one), taking place while the siphon decayed. The inhalant siphon, on the contrary, shifting laterally, was responsible for the construction of the main bilobate fan (Fig. 3).

It is evident that this interpretation supports the tellinid bivalve model. This hypothesis is not confirmed by the presence of tellinids among the bivalves occurring in the sandy levels characterizing the last 20 m of Section B. However, it is worth considering that all the specimens from the same levels, are often broken or abraded and that the tellinids have a thin shell with a microstructure offering little resistance to biostratinomic processes. Therefore, the lack of tellinids in the fossil community is most probably related to poor preservation of their shells and not to their absence in the original biocoenosis. The palaeoenvironment features were infact suitable for some species of tellinids.

Acknowledgements. The authors wish to thank P. Rompianesi, collector of the specimen, for bringing the specimen to our notice. D. Catellani and R. Campanini are deeply acknowledged for allowing us the use of data from their unpublished theses. The drawing support given by G. Leonardi was very helpful and is deeply acknowledged. We would like to thank the reviewers F. T. Fürsich and S. Raffi for their constructive remarks. This paper was financially supported by FAR grants 2005 and 2006 and also represents a contribution to the subproject "Ichnology" with the CONISMA group (Consorzio Nazionale Interuniversitario per le Scienze del Mare).

REFERENCES

Barbacini G., Bernini M., Papani G. & Rogledi S. (2002) - Le strutture embricate del margine appenninico emiliano fra il T. Enza e il T. Secchia - Prov. di Reggio Emilia (con carta geologica alla scala 1:50.000). In: Barchesi P. Angelelli A. & Forni S. (Eds) - Atti del terzo seminario sulla cartografia geologica, Bologna 26-27 febbraio 2002: 64-69, Bologna.

Bourgeois J. (1980)- A transgressive shelf sequence exhibiting hummocky stratification: the Cape Sebastian Sandstone (Upper Cretaceous), southwestern Oregon. *J. Sed. Petrol.*, 50: 681-702, Durham, North Carolina.

Campanini R. (1999) - Il Pliocene di San Valentino (RE): indagine paleoecologica e paleoclimatica con le faune a molluschi. Università di Parma, Tesi di laurea inedita: 1-145, Parma.

Castradori D., Rio D., Hilgen F.J. & Lourens L.J. (1998) - The Global Standard Stratotype-section and Point (GSSP) of the Piacenzian Stage (Middle Pliocene). *Episodes*, 21(2): 82-93, Bejing.

Catellani D. (1989) - Interpretazione paleoecologica di malacofaune plioceniche dell'Emilia (Appennino Settentrionale, Italia NE). Università di Modena, Dottorato di Ricerca in Paleontologia (II ciclo 1986-1989), Tesi di dottorato inedita: 1-338, Modena.

Cita M.B. (1975) - Studi sul Pliocene e gli strati di passaggio dal Miocene al Pliocene. VII. Planktonic biozonation of the Mediterranean Pliocene deep sea record. A revision. *Riv. It. Paleont. Strat.*, 81(4): 527-544, Milano.

D'Alessandro A. & Fürsich F.T. (2005) - *Tursia* - A new ichnogenus from Pleistocene shallow water settings in Southern Italy. *Ichnos*, 12: 65-73, Philadelphia, PA.

D'Alessandro A., Loiacono F. & Bromley R.G. (1993) - Marine and nonmarine trace fossils and plant roots in a regressional setting (Pleistocene, Italy). *Riv. It. Paleont. Strat.*, 98: 495-522, Milano.

Gasperi G., Bettelli G., Panini F. & Pizziolo M. (2005) - Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, foglio 219 - Sassuolo: 1-195, S.EL.CA. s.r.l. Firenze.

Iaccarino S. (1985) - Mediterranean Miocene and Pliocene planktic foraminifera. In: Bolli H.M., Saunders J.B. & Perch-Nielsen K. (Eds) - Plankton stratigraphy. Cambridge Univ. Press.: 283-314, Cambridge.

Monegatti P. & Raffi S. (1996) - Castell'Arquato ed i suoi dintorni. La culla degli studi sul Pliocene. Guida alle escursioni della Società Paleontologica Italiana, XII Convegno: 43-61, Parma.

Monegatti P. & Raffi S. (2001) - Taxonomic diversity and stratigraphic distribution of Italian Pliocene bivalves. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 165: 171-193, Amsterdam.

Olivero E.B., Buatois L.A. & Scasso R.A. (2004) - *Paradictyodora antarctica*: a new complex vertical spreite trace fossil from the Upper Cretaceous-Paleogene of Antarctica and Tiera del Fuego, Argentina. *J. Paleontology*, 78(4): 783-789, Norman.

Peres J.M. & Picard J. (1964) - Nouveau manuel de Bionomie Benthique de la mer Méditerranée, *Rec. Trav. St. Mar. Endoume*, 31: 47. 137, Endoume.

Scasso R.A., Olivero E.B. & Buatois L.A. (1991) - Lithofacies, Biofacies and Ichnoassemblages evolution of shallow submarine volcaniclastic fan-shelf depositional system (Upper Cretaceous, James Ross Island, Antarctica). *J. South Am. Earth Sci.*, 4: 239-260, Amsterdam.