Bollettino della Società Paleontologica Italiana, 49 (2), 2010, 163-172. Modena, XXX 2010

Taphonomy of the graphoglyptid trace fossil *Desmograpton* Fuchs 1895 at the sole of Miocene thin-bedded turbidites, Northern Apennines

Paolo Monaco & Alessio Checconi

P. Monaco - Dipartimento di Scienze della Terra, Università di Perugia, Piazza dell'Università, I-06100 Perugia, Italy; pmonaco@unipg.it
A. Checconi - Dipartimento di Scienze della Terra, Università di Perugia, Piazza dell'Università, I-06100 Perugia, Italy; paleodot@unipg.it

KEY WORDS - Ichnology, Desmograpton, *graphoglyptids, taphonomy, Miocene, Northern Apennines*

ABSTRACT - The trace fossil Desmograpton *Fuchs 1895 belongs to the biramous meanders group of grapholyptids. It is composed of hypichnial, thin strings and shafts that vary in the spatial arrangement for different ichnospecies. 47* Desmograpton *specimens from soles of thin-bedded turbidites in flysch and hemipelagic deposits of Miocene formations (Cervarola, Marnoso-arenacea, Verghereto and Vicchio Marls and associated facies, Northern Apennines) were taphonomically analyzed in order to describe six main aspects: a) system preservation, b) meander preservation, c) axial system, d) string pattern, e) obstacle interference and f) fluting. The pattern of the axial system can be straight, divergent and curved and it seems to be related to the environmental conditions and to the preservation processes. In these deposits obstacles or irregularities in the substrate can be very common and they can strongly influence the string pattern producing local deviations in the burrowing system. The observations on the studied specimens also indicate that the development of* Desmograpton *immediately precedes the turbiditic event.*

RIASSUNTO - [Tafonomia della traccia fossile grafogliptide *Desmograpton* Fuchs 1895 alla base di torbiditi sottilmente stratificate nell'Appennino settentrionale] - *La traccia fossile* Desmograpton *Fuchs 1895 appartiene al gruppo dei grafogliptidi meandranti e biramosi. La traccia è caratterizzata da stringhe sottili a sviluppo principalmente orizzontale con rari pozzi verticali e organizzate in gruppi di stringhe parallele preservate come rilievi convessi alla base di depositi torbiditici. Questo lavoro si concentra sulla caratterizzazione tafonomica di 47 esemplari di* Desmograpton *collezionati alla base di torbiditi sottilmente stratificate in depositi di flysh ed emipelagiti del Miocene (Cervarola, Marnoso-arenacea, Marne di Verghereto e di Vicchio e facies associate, Appennino Settentrionale). Le analisi d'immagine, oltre a quelle macroscopiche e microscopiche, hanno consentito di caratterizzare i principali parametri di ciascun esemplare di* Desmograpton*: a) preservazione del sistema di burrow, b) preservazione dei meandri, c) sistema assiale, d) pattern delle stringhe, e) interferenza degli ostacoli, f) fluitazione. I dati raccolti suggeriscono che la preservazione delle stringhe e dei meandri dipende principalmente dall'erosione indotta dagli agenti fisici che caratterizzavano l'ambiente deposizionale. Il pattern del sistema assiale può essere parallelo, divergente o curvo e sembra essere influenzato sia dalle condizioni ambientali che dai processi tafonomici sin- e post-burrowing. In tale tipo di depositi gli ostacoli all'interno del substrato potevano essere anche molto frequenti e questi influenzavano notevolmente il pattern degli esemplari di* Desmograpton *producendo deviazioni delle stringhe e compromettendo il riconoscimento specifico. Le osservazioni sugli esemplari presi in esame indicano inoltre che lo sviluppo di* Desmograpton *precede immediatamente l'evento torbiditico alla cui base la traccia viene rinvenuta.*

INTRODUCTION

The study of graphoglyptids – a large group of small, patterned trace fossils – represents a new tool for the ichnological characterization of deep-sea sedimentary environments (Seilacher, 1977; Ekdale, 1980; Miller, 1991; Gaillard, 1991; Rona et al., 2003). The term *Graphoglypten* has been introduced by Fuchs (1895), although previous observations on patterned trace fossils were made by Sacco (1888). Due to their abundance, graphoglyptid burrows are informally subdivided into several groups (Seilacher, 1977). Graphoglyptid trace fossils are known for a long time (see historical review of some forms in Baucon, 2010) from the Cretaceous to Cenozoic flysches of the Alps, Apennines, Pyrenees and the Carpathians (Ksiazkiewicz, 1970; Häntzschel, 1975; Leszczynski, 1991; 1993; Uchman, 1998; Heard & Pickering, 2008; Monaco, 2008; Monaco & Checconi, 2008).

Graphoglyptids are usually found at soles of mainly sandy turbidites of flysch deposits but they can occur also in carbonate gravity flow deposits (e.g., Monaco & Uchman, 1999). These trace fossils represents three-dimensional burrow systems which are preserved as bi-dimensional casts at the sole of thin turbiditic beds, not only in the distal basin plain but also in other more proximal settings (Seilacher, 1974, 1977; Heard & Pickering, 2008; Monaco, 2008; Monaco & Checconi, 2008; Milighetti et al., 2009). They are considered to be pre-turbidite trace fossils (Seilacher, 1977, 2007) that develop in the background mud as agrichnial burrow systems for microbial farming or trapping. Their different patterns and very different shapes are recorded in several ichnogenera and ichnospecies (Seilacher, 1977). The informal subdivisions of graphoglyptids (Seilacher, 1977) include: a) regular nets, b) radiating forms, c) irregular forms, d) continuous meanders, e) uniramous meanders and f) biramous meanders. The first three types are not considered in this paper and their characteristics can be found elsewhere (Ksiazkiewicz, 1977; Seilacher, 1977; Uchman, 1995; 1998; Monaco, 2008). The main difference in the meanders (forms d-e-f) is the presence/absence of the branching and their simple or double pattern at the apex of each undulation of the central axis

ISSN 0375-7633

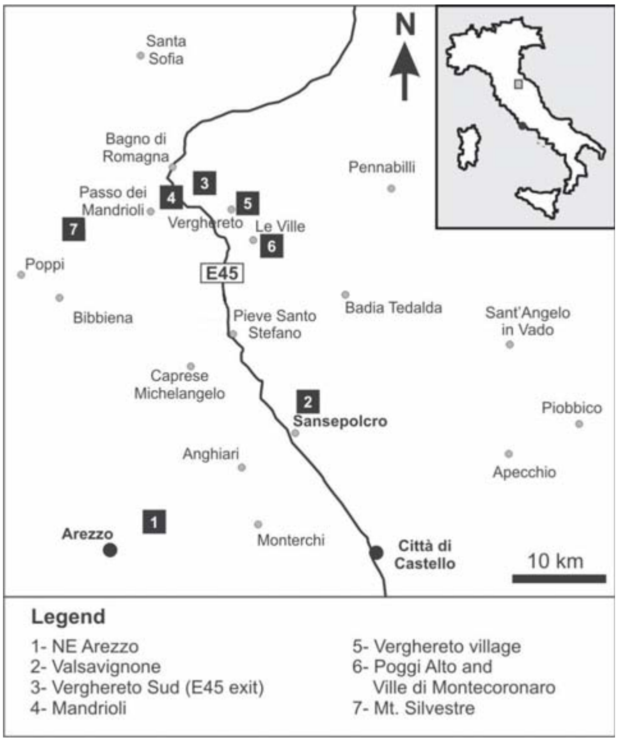


Fig. 1 - Study area and localization of *Desmograpton* specimens.

(Seilacher, 1977). In the biramous meanders, *Desmograpton* represents one of the most meaningful graphoglyptid, which occurs in flysch deposits from the Silurian (McCann, 1989) to the Miocene (D'Alessandro, 1980; Uchman, 1995). Other forms belong to the same biramous meanders group (e.g. *Paleomeandron*, *Oscillorhaphe* and *Protopaleodictyon*), some of which exhibit some similarities with *Desmograpton* (Seilacher, 1977). This work focuses on so-far poorly known taphonomic characteristics of *Desmograpton* at the soles of deep-water flysch turbidites in the Northern Apennines, which can be useful in palaeoecological analyses and interpretations.

MATERIAL AND METHODS

The studied material consists of 47 *Desmograpton* specimens collected from the Northern Apennines (Fig. 1) and stored in the Biosedimentary Lab of Perugia University. They represent a part of the ichnologic collection (47 of 335 records in total) that constitutes the BSED-IDTB (biosedimentary-ichnofossil) database (Monaco et al., 2009). The *Desmograpton* specimens have been sampled at the soles of thin-bedded turbidites in flysch and hemipelagic deposits of Miocene formations (Cervarola, Marnoso-arenacea, Verghereto and Vicchio Marls and associated facies, see Monaco, 2008; Monaco & Checconi, 2008; Milighetti et al., 2009). Usually, *Desmograpton* can be found as a hypichnion in thin-bedded calcareous turbidites of basin plain, but it may occasionally occur also in overbank and levee deposits of more proximal settings (Milighetti et al., 2009; Monaco et al., 2010). Typical fine-grained and thin-bedded overbank deposits are represented by rhythmically arranged calcareous beds, 2-4 cm thick, interbedded with thick marls that were deposited in marginal sectors of the Marnoso-arenacea Basin (Inner Basin, at the transition with intrabasinal Verghereto High). In this area much diversified assemblages of trace fossils was found in an ichnologic-*lagerstätte* that exhibits 43 ichnotaxa (Monaco & Checconi, in press).

Each *Desmograpton* specimen was studied by means of magnifying glass and image analyses. String pattern organization, preservation and other macroscopic features were observed. High-resolution pictures were taken in order to measure smaller parameters as string diameter and distances between each string. When strings are not parallel, but externally slightly divergent, the distance between each string was measured in the inner parallel part. In each picture, England Finder Graticule was used as scale bar and it allowed to perform high resolution measuring (10^{-1} mm) by image analysis.

MORPHOLOGIC CHARACTERISTICS

For a detailed description of the ichnogenus *Desmograpton* Fuchs, 1895 and its ichnospecies (*D. dertonensis* Sacco 1888, *D. inversum* Seilacher 1977, *D. ichthyforme* Macsotay 1967, *D. alternum* Ksiazkiewicz 1977, *D. geometricum* Seilacher 1977 (= *D. alternum* in Uchman 1995) and *D. pamiricus* Vialov 1971) the papers by Seilacher (1977), McCann (1989) and Uchman (1995) are recommended. The graphoglyptid system exhibits a three-dimensional arrangement even though the horizontal development prominently prevails on the vertical one. The trace fossil is composed of thin, shorter and longer horizontal strings, mainly 0.7 to 2.2 mm thick (Fig. 2), usually forming groups of short or long strings in convex hypichnia. Strings are parallel or slightly divergent externally, and form irregular or regular patterns. The distance between strings, 0.3-3.3 mm, rarely up to 5-6 mm (Fig. 2), can vary between specimens and in same specimen too; this parameter ranges in the studied samples from 0.3 to 3.3 mm, but it can also reach sometimes 5-6 mm. Usually strings are short (1-3 mm) and form clusters aligned internally or may be very long (up to 50 mm) and appear as isolate strings aligned externally (Pl. 1, fig.1). Strings depart from a central axial zone where opposite meanders are disposed in characteristic undulations (Pl. 1, figs. 6-7). Morphology of these undulations is the crucial ichnotaxobase at ichnospecies level (see for example Pl. 1, figs. 7, 9). Externally, some short shafts connect the end of tunnels with the sediment surface; their outlets are preserved as plugs, which in general are very difficult for recognition (see drawings of Seilacher, 1977, fig. 7) and can be confused with plugs of other origin (e.g. plugs in Pl. 1, fig. 12). As indicated by the cited author, undulations of the central part may produce hair-pin like pattern because the apex can be down- or upward-bended; in some ichnospecies (e.g. *D. inversum* Seilacher, 1977, p. 312; included in *D. dertonensis* Sacco by Uchman, 1995), hair-pin structures are disposed in opposite directions

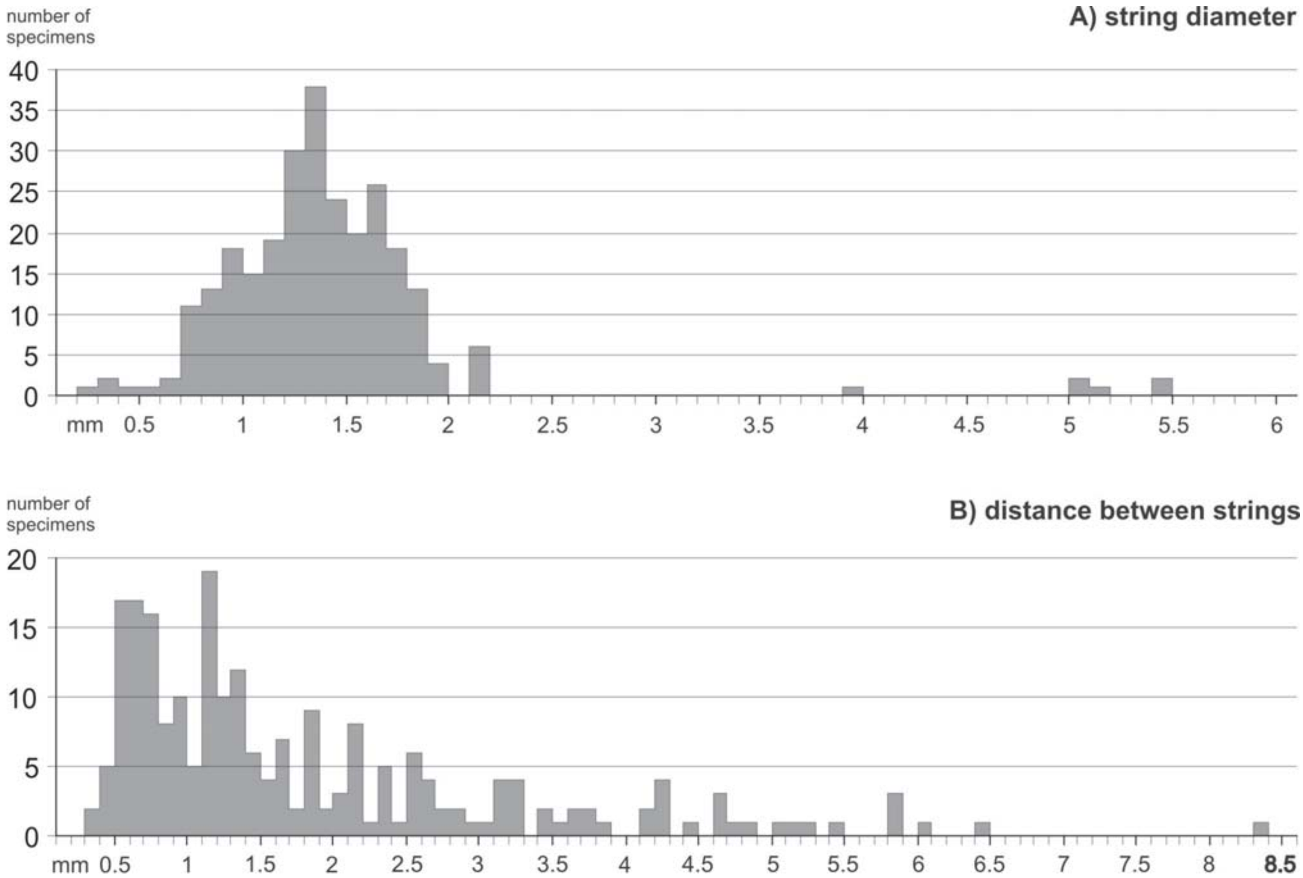


Fig. 2 - Bar chart with measurements of some morphologic characteristics of studied *Desmograpton* specimens: A) string diameter, B) distance between strings; see text for further explications.

and an horizontal offset may be observed (Pl. 1, fig. 13). This offset is also more enhanced in *D. alternum* where connecting bars form a zigzag pattern, although the axial area is straight (Uchman, 1998, fig. 97). The apexes of semi-meanders are distant in *D. dertonensis* and semi-meanders are bended downward and obliquely connected by short bars, while strings are externally divergent and rarely parallel (see Pl. 1, fig. 6). The downward orientation of the axial area where semi-meanders are preserved is the fundamental taxonomic feature of this ichnospecies (Seilacher, 2007). The offset in the axial area has been recovered also in other ichnospecies (*D. alternum*) that in the studied area are rarely found and were recorded as dubitative specimens (e.g. *D. dertonensis* may be confused with *D. alternum* and vice versa). *D. ichthyforme* is the other typical ichnospecies that occurs abundantly in the studied area (Pl. 2, fig. 6) and it is characterized by angular and narrow semi-meanders that are usually bended upward (and poorly visible), in opposite direction in respect to *D. dertonensis* (bended downward, see Seilacher, 1977, fig. 7d, 2007; Uchman, 1995, text-fig. 18). Therefore the axial zone of *D. ichthyforme*, when preserved, suggests an isometric shape and appears as parallel ridges joined by short perpendicular bars that are preserved as plugs (Pl. 2, figs. 6, 8). In the holotype of *D. ichthyforme* (Macsotay, 1967, pl. 6, fig. 20) and in some specimens figured in Uchman (1995, text-fig. 18) and in Seilacher (1977, fig. 7d) the axial zone may show transverse short bars or phantoms of these structures that are perpendicular to the parallel strings. The length and regularity of strings is controversial for determination of this ichnospecies when the axial zone is not or poorly preserved (see the holotype of *D. dertonensis* Sacco from Eocene flysch deposits of Italy figured in Uchman, 1995, text-fig. 19).

TAPHONOMIC REMARKS

Taphonomic characteristics are summarized in Fig. 3 and illustrated in Plate 1 and Plate 2. Six main parameters of *Desmograpton* specimens are distinguished: a) system arrangement, b) meander preservation, c) axial system, d) string pattern, e) obstacle interference and f) fluting.

a) System arrangement. - The arrangement of the burrow system is fundamental for taxonomy of *Desmograpton* and its preservation depends mainly on the erosion induced by physical agents (Uchman, 1995; Seilacher, 2007). In *D. ichthyforme*, when the system is shallowly or moderately eroded, only horizontal segments are preserved as thin parallel strings (Fig. 3); a weak erosion and casting preserves also angular-upward bended parts (shafts) that usually are rows of plugs. Conversely, moderate erosion in *D. dertonensis* and *D. alternum* contributes to emphasize the opposite meanders, including the connecting bars that are typical morphologies of these ichnospecies. In a dubitative specimen of D. *alternum* (= *D. geometricum* of Seilacher 1977, fig. 7e) semi-meanders are very distant and connecting bars poorly preserved (Pl. 2, fig. 5). If deeper erosion occurs, the downward bending meanders are better preserved while other parts are not so evident. Most of the analyzed specimens (23/47) are included in this subcategory (see Fig. 3).

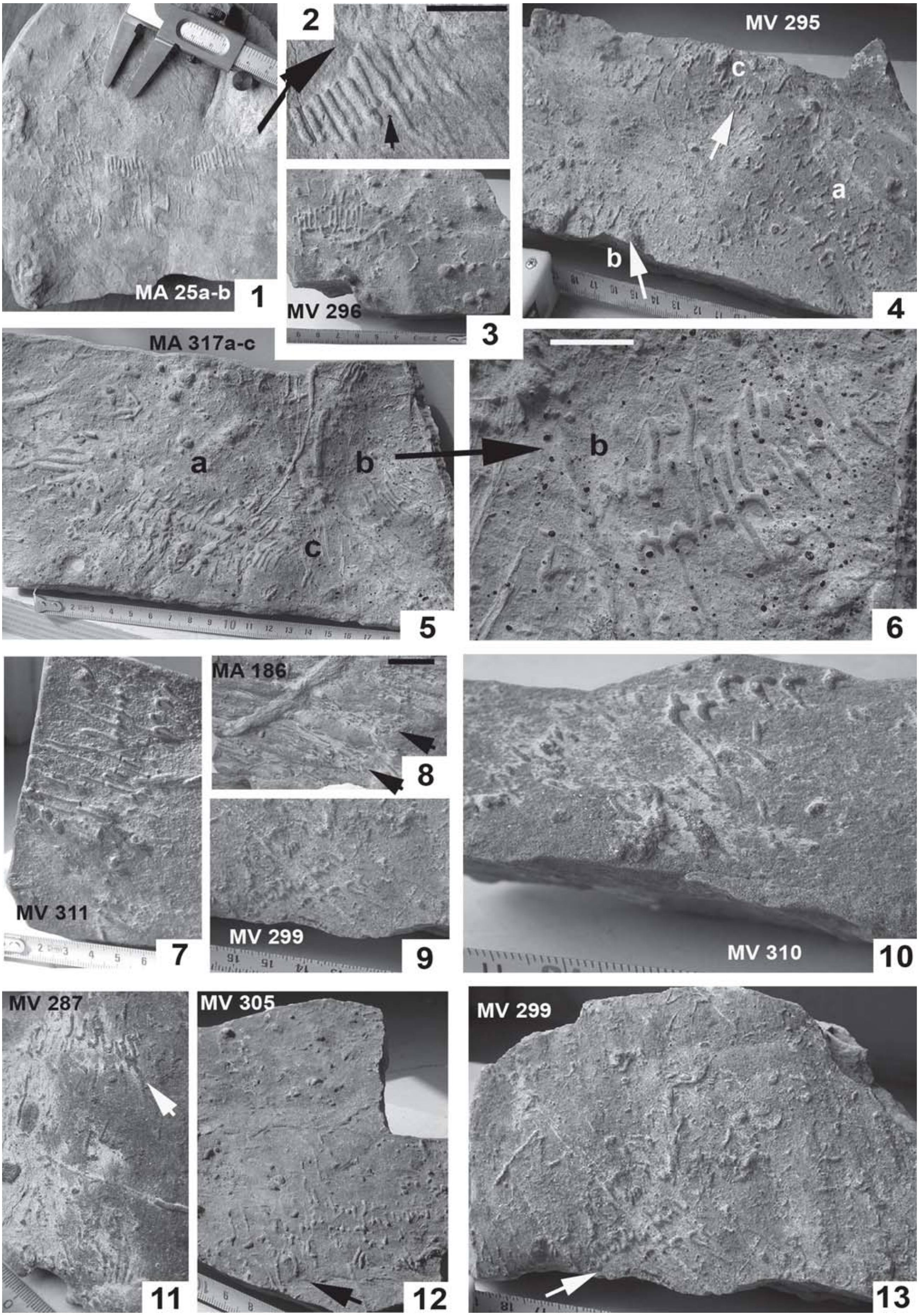
b) Meander preservation. - Meanders can be completely or incompletely preserved. Incomplete semi-meanders (J-shaped) occur in the majority of analyzed specimens (26/47) when part of the U-shaped string is lacking or asymmetrically preserved (Fig. 3). In these specimens the semi-meander exhibits a form of fish hook (Pl. 1, figs. 10, 11). This typical feature seems to correspond to the twisting tunnel where a bar departs obliquely from a meander to connect opposite one as typically occurs in the *D. geometricum* (Seilacher, 1977, p. 312, fig. 7e). The twisted arrangement induces a good preservation of the branching point while the connecting bar tends to disappear gradually (Pl. 1, fig. 10). Complete semi-meanders (U-shaped) have been found mostly in *D. dertonensis* and *D. alternum* in 11/47 specimens, mainly in shallowly eroded specimens where the connecting bars are also seldom present (Pl. 1, fig. 13). A few other specimens of *D. ichthyforme* show angular and short meanders that can be completely (2/47) or partially preserved (5/47) (Pl. 1, fig. 2). The axial bars are usually badly preserved and only short plugs can be recognized.

c) Axial system pattern. - The arrangement of the axial system is another interesting element that could probably depends on environmental conditions and indicates differences in the preservation processes. Axial system pattern was never mentioned or considered in the literature but it could represent an important feature for palaeoenvironmental and taphonomical interpretations. This part of the burrow system comprises two rows of opposite semi-meanders that are horizontally disposed and preserved in about 85% of the studied specimens. Three types of disposition have been recorded: straight (1), divergent (2) and curved (3) (see Fig. 3). In (1) the two rows of meanders are parallel and the meanders are often regularly opposed in *D. dertonensis* and *D. alternum* in moderately or deeply eroded specimens (Pl. 1, figs. 7, 13). In (2) and (3), respectively, the apex of opposite meanders tends to diverge horizontally or can be curved showing also meandering or zigzag trends (Pl. 1, fig. 4, Pl. 2, fig. 1). Typical samples that show these features are MV 295, MV 299, MV 304, MV 310, MA 205, MV 287, and MV 298 (Fig. 3). In the samples MA 233a-b, MV 287 an intrusion by another burrower produces a divergence in the axial system. Here some straight pre- or post-*Desmograpton* trace fossils (*Protovirgularia*, *Halopoa*; Pl. 2, fig. 4) are observed in correspondence of the axial system, both producing a slight divergence in the alignment of meanders deforming

EXPLANATION OF PLATE 1

Desmograpton preserved as hypichnia in thin-bedded turbidites, Northern Apennines.

fig. 1 - regular pattern of parallel strings, *D. ichthyforme* Macsotay, sample MA 25, Verghereto Balze, Marnoso-arenacea Fm.
fig. 2 - detail, note short and angular meander (arrow), bar = 1 cm.
fig. 3 - irregular pattern of parallel strings with plugs, *D. ichthyforme*, sample MV 296, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 4 - randomly-oriented, irregular pattern of incomplete strings, *D. dertonensis* Sacco (see a); string arrangement shows zigzag trend (arrows b, c), sample MV 295, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 5 - three *Desmograpton* systems (a, b, c) regular or irregular, *D. dertonensis* (a, c), placed above fluted structure, Verghereto South (SE of Bagno di Romagna).
fig. 6 - detail of b, note symmetric meanders and curved strings; bar = 1 cm.
fig. 7 - well developed axial system with opposite meanders, sample MV 311, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 8 - irregular pattern with aligned strings adapted between two adjacent ridges (arrows), sample MA 186, Mandrioli Pass, Marnoso-arenacea Fm., bar = 1 cm.
fig. 9 - curved axial system with opposite meanders partially twisted, *D. dertonensis*, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 10 - deeply eroded axial system (curved) with twisted meanders, *D. dertonensis*, sample MV 310, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 11 - irregular pattern with scattered strings, note fish hook-shaped, aligned meanders (arrow), sample MV 287, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 12 - irregular string pattern curved around an obstacle (arrow), sample MV 305, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.
fig. 13 - slightly curved and divergent axial system with opposite meanders (arrow), *D. dertonensis*, sample MV 299, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.


MA 25a-b
1
2
MV 296
3
MV 295
c
a
b
4
MA 317a-c
a
b
c
5
b
6
MV 311
7
MA 186
8
MV 299
9
MV 310
10
MV 287
11
MV 305
12
MV 299
13

the axial area (see Pl. 2, fig. 4 on the right); but in the case of pre-*Desmograpton* trace fossil (*Protovirgularia*) the divergent axial disposition (2) is probably a direct consequence of the ethology of the burrower(s) that adapted the axial area of burrow system in presence of an obstacle (the tunnel); in the other case (post-*Desmograpton*) the trace fossil *Halopoa (H.* cf. *imbricata*) produced itself a cause of deformation of the axial area (2) due to the intrusion of a string-shaped burrower and the consequent weak deformation of *Desmograpton* mesh (Pl. 2, fig. 4 arrow).

d) The string pattern. - Among biramous meander graphoglyptids the regularity of the string pattern of *Desmograpton* may contribute to detect irregularities in the deep sea-floor, because this type of burrow can evolve and differentiate following any weak variation of substrate and/or facies (Monaco et al., 2009; Monaco & Checconi, in press). In the examined 47 specimens the string pattern may change from regularly to irregularly disposed systems (see Pl. 1, figs. 1 and 4, respectively). In regular patterns, tunnels are well developed (up to 3-4 cm long) and occur as clusters of parallel strings (Pl. 1, fig. 1); in irregular patterns, deeply eroded systems usually show randomly arranged segments that differ in length (usually are short) but oriented approximately in the same direction (Pl. 1, figs. 4, 12). Some samples have two or three string systems orthogonally disposed (see a, b, c in Pl. 1, fig. 5, Pl. 2, fig. 10).

e) Obstacle interference. - Many strings of *Desmograpton* develop above obstacles or surrounding them (Pl. 1, fig. 12 arrow); this feature has been observed in 70 % of studied specimens. Usually the strings are distributed above irregularities of the substrate, without any deformations. These irregularities usually are mud lineations induced by fluting processes produced by bottom currents or smooth ridges that evolve gradually to elongated plugs (Monaco, 2008) (Pl. 2, figs. 1, 9 arrows). The obstacles are locally very abundant and they often influence the string pattern distribution of *D. dertonensis* and *D. alternum*, while only secondarily of *D. ichthyforme*. The interference with an obstacle, causing deviations in the burrowing system, has been observed in 30 % of studied specimens (see Fig. 3). In some cases the string evolves from straight to curve when burrower encounters a hole or ridge in the mud producing two strings that diverge around the obstacle (MV294, MV 300, and MV 305, Pl. 1, fig. 12). In some samples the string pattern was adapted between two adjacent ridges (MA 186, Pl. 1, fig. 8) or arranged with a radiate disposition (MV 303, MA 190). In other samples we can observe an asymmetry in the length of strings when they encounter an obstacle or other previously formed burrows (MV 287, MV 296, Pl. 1, figs. 3, 11). The changes in the string orientation has been noted in several cases where probably also different systems developed contemporaneously (MV 294, MV 295, and MA 94).

f) Fluting. - Most of the studied specimens show fluted surfaces. This taphonomic feature can occur in pre- or post *Desmograpton*-burrowing phases. Pre-burrowing fluted structures (indicated as mud lineations in Monaco, 2008) are produced by currents on the mud. These are very frequently smothered with undercurrent tails that were crossed by the string system of *Desmograpton* without deformations (Pl. 2, figs. 8-9 arrows). This typical feature has been observed in 27 samples and in some of these it is particularly well developed (MA 36, MA 184, MV 297, and MV 302). It suggests that bottom currents were active on the sea-floor before the graphoglyptid development as observed in the ichnologic-

EXPLANATION OF PLATE 2

Desmograpton preserved as hypichnia in thin-bedded turbidites, Northern Apennines.

fig. 1 - irregular string patterns placed above previous fluted structures (lower arrow), while fluted strings can occur (upper arrow), *D. dertonensis*?, sample MV 297, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.

fig. 2 - irregular pattern of strings that are also curved following irregularities (see arrow), sample MV 294, Poggio Alto, Ville di Montecoronaro, Verghereto Marls.

fig. 3 - regular pattern with axial system (gently curved) and twisted opposite meanders with bars, sample CEV 240, Alpe di Poti (Ar), Cervarola Fm.

fig. 4 - post-*Desmograpton* trace fossil (*Halopoa* cf. *imbricata*) produces deformation of the axial area (center) with intrusion (right), sample MA 233, Mandrioli Pass, Marnoso-arenacea Fm.

fig. 5 - moderately eroded specimen showing regular pattern with axial area and opposite meanders, *D.* cf. *alternum* Ksiazkiewicz, sample MA 211n, Alpe di Poti (Ar), Cervarola Fm.

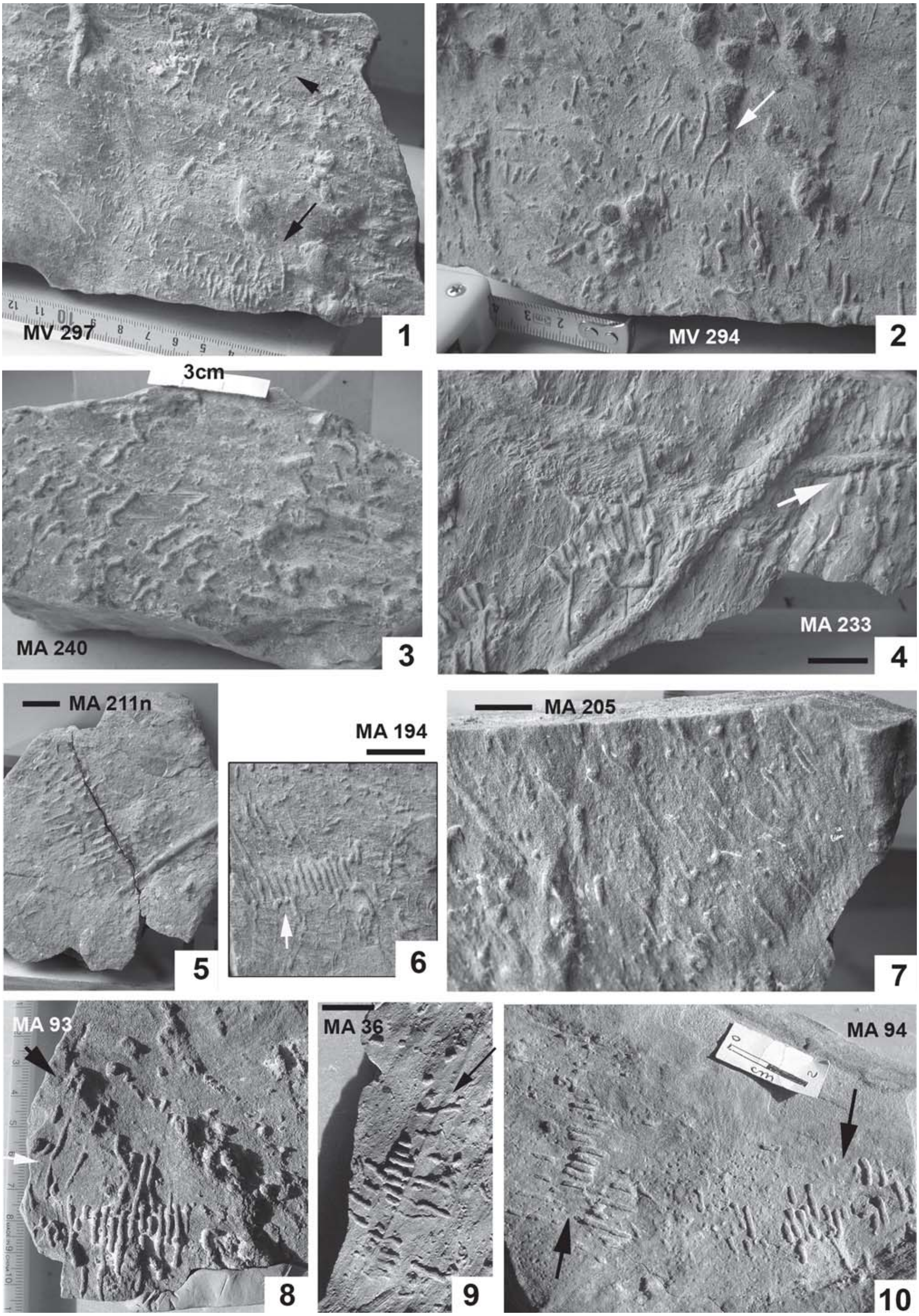
fig. 6 - regular and parallel strings with short meanders and plugs, *D. ichthyforme*, sample MA 194, Mandrioli Pass, Marnoso-arenacea Fm., bar = 1 cm.

fig. 7 - irregular pattern of strings (fluted?), *D. dertonensis*?, sample MA 205, Mandrioli Pass, Marnoso-arenacea Fm., bar = 1 cm.

fig. 8 - partially regular pattern of parallel strings that change their orientation for an obstacle (white arrow), *D. ichthyforme*, sample MA 93, close Poggio Alto, Ville di Montecoronaro, Verghereto Marls.

fig. 9 - regular pattern of strings arranged orthogonally above a mud lineation (arrow), *D. ichthyforme*, sample MA 36, Verghereto SE (road to Bagno di Romagna), Marnoso-arenacea Fm., bar = 1 cm.

fig. 10 - two systems of parallel strings (arrows) with axial area, *D. ichthyforme*, sample MA 94, close Poggio Alto, Ville di Montecoronaro, Verghereto Marls.


MV 297
1
MV 294
2
3cm
MA 240
3
MA 233
4
MA 211n
5
MA 194
6
MA 205
7
MA 93
8
MA 36
9
MA 94
cm
10

lagerstätte of overbank deposits of the Verghereto High (Monaco & Checconi, in press). Usually in these samples the string system developed orthogonally to the fluted structures (Pl. 2, fig. 9).

Concerning the post-*Desmograpton* burrowing phase, this ichnogenus was fluted itself by subsequent events on the sea floor, but this feature is rare. The presence of fluting structures that were produced after the burrowing phase is demonstrated by smoothed *Desmograpton* strings and meanders deformed by physical currents; usually a part of a string shows an elongation in the down-current side with thinning of the structure that becomes a phantom (Pl. 2, fig. 7). The post-*Desmograpton* fluting has been observed in 17 specimens and in a case the fluting involves a string that surrounds an obstacle (MV 297). Seilacher (1977, 2007) proposed a model for graphoglyptid preservation that follows the turbidite erosion in distal environments. It concerns a depositional phase that is immediately preceded by an erosional one that produces subtle signs of erosion, such as delicate fluting on the down-current side of tunnel casts. It can be promoted by the turbid water body that acted as a shock wave in front of turbidite event that would suck the unconsolidated mud surface reaching the mesh level. During the casting, the open mucus-lined mud-burrows can be easily filled by the fine suspended sand, including fluted structures just produced. But to preserve all features, is fundamental that the casting takes place only if the turbid cloud was in its depositional phase. Post-turbiditic compaction of the sediments can create deformations in particular in correspondence of the mud/sand interface, where a bound lithologic difference is present. For this reason further analyses will de developed in order to define these aspects and to demonstrate that *Desmograpton* is for sure a pre-turbiditic trace fossil. Recorded data seem to confirm the taphonomical model by Seilacher (2007), although some questions are still open: foremost why the erosion by turbidity current exhumes only the middle part of the mesh system and not other parts? How can this small sized delicate burrow system be cut by currents and then filled by sandy deposits that perfectly preserve every detail of the trace? We hope that future analyses will produce new data to better understand this scenario.

CONCLUSIONS

A very rich hypichnial assemblage of *Desmograpton* specimens in turbiditic deposits of the Northern Apennines allows obtaining interesting taphonomic features.

1) System and meander preservation depends mainly on the erosion (few millimeters) of mud induced by physical agents; however the same erosional level seems to affect in different ways each ichnospecies. Weak erosion can preserve and highlights angular-upward bended parts of some specimens (e.g. *D. ichthyforme*) while it enhances only parts of semi-meanders in other specimens (e.g. *D. dertonensis, D. alternum*).

2) The pattern of the axial system can be straight, divergent and curved and it seems to be related to environmental conditions and to preservation processes. Consequently it cannot be easily considered as a taxonomical parameter for the characterization of the different species but it can represent an important tool for taphonomic and palaeoenvironmental interpretations.

3) Obstacles or irregularities in the substrate can strongly influence the string pattern producing localized deviations in the burrowing system. These deviations can induce problems in the taxonomic assessment of ichnospecies, due to slight modifications of the original regular pattern (e.g. the axial area or length of some strings). A more extended irregular system can be due to a three dimensional development of the burrowing mesh that is only locally eroded and brought to light.

4) The development of D*esmograpton* probably precedes the turbiditic event. The majority of studied specimens was formed above existed fluted structures in the mud, while others, but not a majority, are fluted itself. Therefore, very few specimens show a clear deformation of strings and meanders (phantoms) due to bottom currents. Our observations confirm that this ichnogenus can be considered as typical pre-turbidite graphoglyptid trace fossil; but must be considered that in distal basin plain (and overbank deposits), the casting produced by turbidity currents reveal that a complex suite of events (biogenic and physical) occurred in the background mud, mainly connected with bottom currents that must be carefully considered in the future depositional analyses. It is also possible that *Desmograpton* deformation could be the result of post-turbiditic events occurring at the mud/sand interface, probably due to compaction or, more in general, to diagenesis.

ACKNOWLEDGEMENTS

The field analysis was carried out with the fundamental help of M. Milighetti. We are very grateful to reviewer (A. Uchman) for suggestions for improving the manuscript. This research was supported by research project RB 2008-2010 of the Earth Science Dept. of the University of Perugia (P. Monaco).

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Fig. 3 - Morphologic characteristics of studied *Desmograpton* specimens; see text for explanation. Legend: the second column "Loc. Fig. 1" indicates the location of each sample with reference to the location of outcrops in Fig. 1.

Desmograpton		SYSTEM PRESERVATION			MEANDER PRESERVATION				AXIAL SYSTEM			STRING PATTERN		OBSTACLE		FLUTING	
SAMPLE	Loc. Fig.1	shallowly eroded	moderately eroded	deeply eroded	asymmetrical		symmetrical		parallel	divergent	curved	regular	irregular	crossed	surrounded	pre	post
MA25	3	X				•		•			□	*		*	*	*	*
MA36a	3			X									*	*		*	
MA36b	3			X	•					□		*		*		*	
MA81	5	X			•								*	*			
MA93	6		X	X		•			□			*					
MA94a	6			X	•								*			*	*
MA94b	6			X	•								*			*	*
MA168	6			X	•								*		*	*	
MA175	2		X		•						□		*	*	*		
MA184	4			X			•						*		*		*
MA186	4			X			•				□		*	*	*		*
MA190	4			X	•								*	*	*	*	*
MA194	4			X				•			□	*		*		*	*
MA205	4			X	•				□				*			*	*
MA211N	1		X				•				□	*		*		*	
MA213	6			X	•						□		*	*		*	*
MA233a	4		X		•					□		*		*			
MA233b	4	X					•		□	□			*	*			
CEV240	6		X		•		•		□			*		*		*	
MV287	6		X	X	•					□	□	*		*		*	*
MV294a	6			X	•						□		*		*	*	
MV294b	6			X	•						□		*			*	
MV295	6			X	•						□		*	*		*	
MV296	6			X		•			□			*		*	*	*	
MV297a	6		X		•				□			*		*		*	
MV297b	6			X	•				□			*		*		*	*
MV298	6		X			•		•	□			*		*		*	
MV299	6		X	X	•					□			*	*	*	*	*
MV300	6		X		•						□		*	*	*	*	
MV302a	6		X		•					□			*	*		*	
MV302b	6		X		•					□			*	*		*	
MV303	6		X		•				□			*		*	*	*	
MV304	6		X		•						□			*		*	
MV305	6		X	X	•						□		*		*	*	*
MV310	6			X	•						□	*		*			
MV311	6		X		•				□			*					*
MV312	6	X					•		□			*					*
MV313	6			X			•				□		*				
MV314a	6			X	•												*
MV314b	6			X			•				□	*					*
MV315	6			X	•						□	*					*
MV316	6		X		•						□	*				*	
MV317a	3	X					•		□			*					
MV317b	3		X				•				□	*					
MV317c	3			X	•							*					
MV318	7			X	•					□		*			*	*	
MV319	6		X				•		□				*				

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Manuscript received 19 April 2010
Revised manuscript accepted 16 July 2010