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Bulbichnus giornii n. ichnogen. and n. ichnosp.: a deep-water domichnion-praedichnion made by an eunicid polychaete (Marnoso-Arenacea Formation, Miocene, Northern Apennines, central Italy)

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KEY WORDS - New ichnotaxon, deep-water, ichnotaxonomy, Miocene, foredeep, Apennines.

ABSTRACT - The ichnotaxon Bulbichnus giornii *n. ichnogen. and n. ichnosp. is herein described. The trace fossil comes from the Marnoso-Arenacea Formation (Mount San Sepolcro, Northern Apennines, central Italy). It is a vertical, three dimensional structure that preserves the bulb imprint. The diagnostic characters of this crossichnion which is about 50 cm in length and > 4 cm in diameter, are an almost flat ventral side and a convex dorsal side. A rhythmic alternation of bulbs, each about 10 mm in diameter, disposed along the edges and on the dorsal side, is the most important additional feature.* Bulbichnus giornii *n. ichnogen. and n. ichnosp. could represent a new kind of domichnion-praedichnion ethologic behaviour of an eunicid worm comparable to modern* Eunice aphroditois *Pallas, 1788 (the bobbit worm), although a simple domichnion of an unknown crustacean cannot be excluded. This new ichnotaxon enriches the knowledge of the deep-sea ichnocenoses dominated by the* Ophiomorpha *group in foredeep sediments and is a new contribution for understanding deep-sea paleoethology.*

RIASSUNTO - [*Bulbichnus giornii* n. ichnogen. e n. ichnosp. un nuovo tipo di domichnion-praedichnion di mare profondo prodotto da un verme polichete eunicide (Formazione Marnoso-Arenacea, Miocene, Appenino settentrionale, Italia centrale)] - *L'ichnotaxon* Bulbichnus giornii *n. ichnogen. e n. ichnosp. viene qui descritto. La traccia fossile proviene dal Miocene medio della Formazione Marnoso-Arenacea di Montagna, San Sepolcro (Appennino centrale). E' una struttura verticale, preservata in tre dimensioni dove si notano le impronte dei bulbi sulla roccia. I caratteri diagnostici di questo crossichnion, di circa 50 cm in lunghezza e > 4 cm in diametro, sono un lato ventrale piatto e un lato dorsale convesso. Un'alternanza ritmica di bulbi, ognuno di circa 10 mm di diametro, indica che essi sono disposti lungo i margini e nel lato dorsale.* Bulbichnus giornii *n. ichnogen. e n. ichnosp. può rappresentare un nuovo tipo di domichnion-praedichnion prodotto da un verme polichete eunicide, comparabile all'attuale* Eunice aphroditois *Pallas, 1788 (il cosiddetto "bobbit worm"), sebbene non si possa escludere che sia stato un semplice domichnion di un crostaceo sconosciuto. Questo nuovo ichnotaxon arricchisce la conoscenza delle ichnocenosi di mare profondo, dominate dal gruppo dell'*Ophiomorpha *nei sedimenti di avanfossa, e rappresenta un nuovo contributo alla conoscenza della paleoetologia di mare profondo.*

INTRODUCTION

The ability of infaunal organisms to produce vertical burrows (some of them over three cm in diameter) is one of the most exciting aspects of the study of behaviours within marine substrates (Myers, 1972; Bromley, 1990, 1996; Thomas & Smith, 1998; Lobza & Schieber, 1999; McIlroy, 2004; Curran, 2007; Monaco et al., 2007; Olivero & Gaillard, 2007; Uchman, 2007; Buatois & Mángano, 2011; Knaust & Bromley, 2012; among others). Many studies have focused on the ichnology of crustacean domichnia (Bromley & Frey, 1974; Sheehan & Schiefelbein, 1984; Monaco, 2000; Carvalho et al., 2007; Curran, 2007; Giannetti et al., 2007; Monaco et al., 2007), while burrows of polychaete worms have aroused less attention (but see Gibert et al., 2006). Polychaete worms (phylum Annelida) include about 5500 known species (http://www.earthlife.net/inverts/polychaeta.html), many of which are active burrowers. Their burrowing behaviour has been studied mainly in littoral environments (Trueman, 1966; Fauchald, 1992; Bromley, 1996; Fauchald et al., 2009; Pan-Wen & Yan-Huei, 2014; Taylor & Cunliffe, 2015), but little or nothing is known with certainty about their activity in deep-water environments (Bromley, 1996; Thomas & Smith, 1998; Du Clos, 2012; Belaústegui & Gibert, 2013). Among domichnia-fodinichnia, the assignment of some trace fossils to terebellid polychaetes (e.g., *Cylindrichnus concentricus* Toots in Howard, 1966) is still controversial (Belaústegui & Gibert, 2013, figs 3-4). Among polychaete burrowers, the "bobbit worm" (Annelida, Polychaeta: Eunicidae, *Eunice aphroditois* Pallas, 1788, reviewed by Fauchald, 1992 and Fauchald et al., 2009) is an unusually large marine, predatory polychaete worm, dwelling in the ocean floor and producing vertical domichnia that are over three cm in diameter (an extraordinarily large specimen up to 300 cm long has been described in 2009 from Shirahama, Wakayama, central Japan; Uchida et al., 2009). The animal buries its long body (which usually reaches 1 metre or more in length) within a coarse-grained sea floor substrate (usually gravel, coarse sand, or coral fragments), where it waits for a stimulus to one of its five antennae, attacking when it senses prey. Armed with sharp jaws, it can attack fishes with such speed and force that its prey is sometimes sliced in half. Although the worm hunts for food, it is omnivorous (Fauchald, 1992; Davey, 2000; Bellan, 2001; Fauchald et al., 2009).

The aim of this work is to describe a new ichnotaxon, *Bulbichnus giornii* n. ichnogen. and n. ichnosp., from the Miocene Marnoso-Arenacea Formation of the Northern Apennines (Montagna, San Sepolcro, central Italy, Fig. 1). It probably represents the first known example of a domichnion-praedichnion of a polychaete eunicidid worm,

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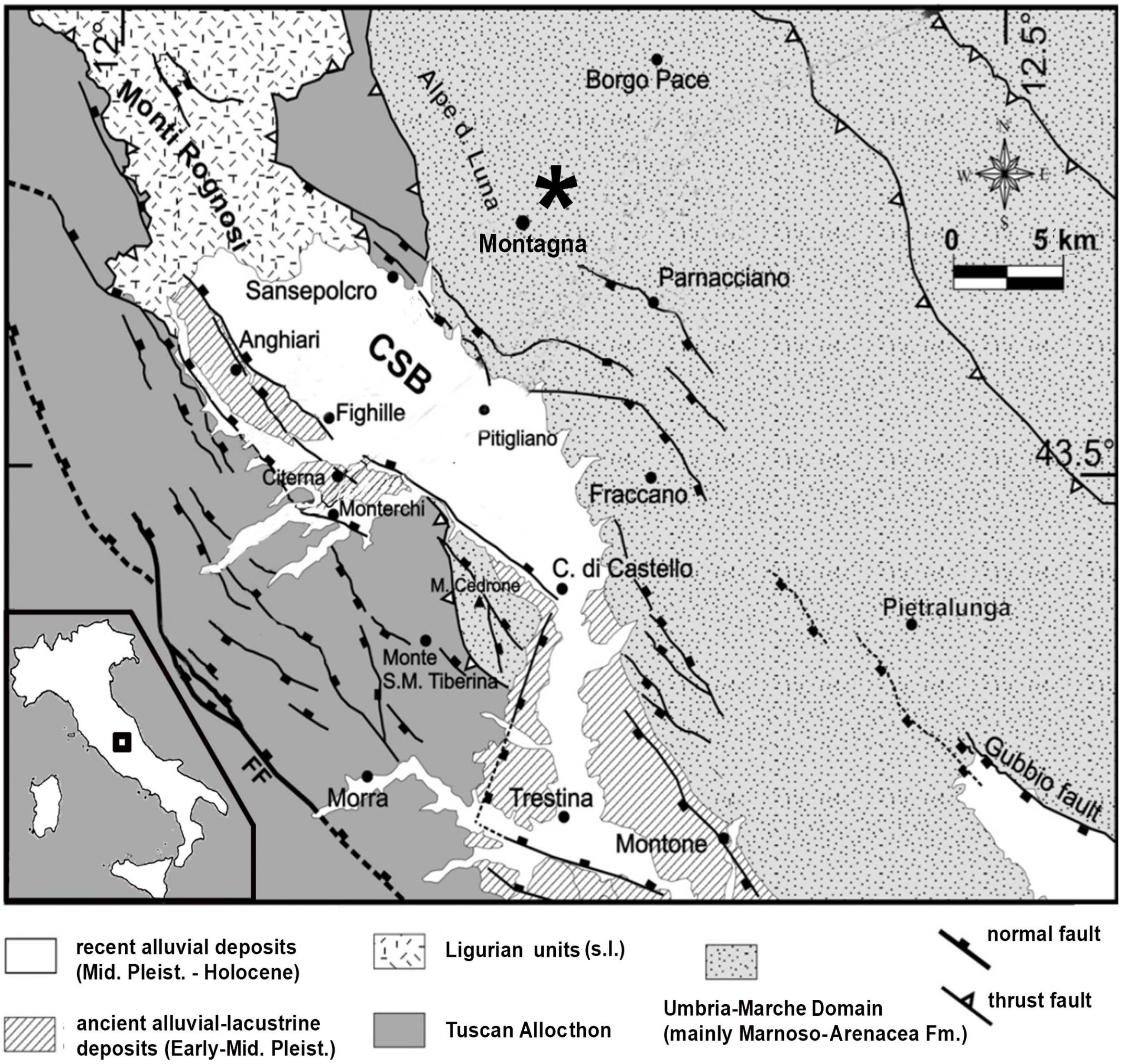


Fig.1 - Study area (modified from Brozzetti et al., 2009).

though a crustacean maker is not excluded a priori. It is a rare case of a full relief preserved sub-vertically, about 50 cm in length and > 4 cm in diameter, that crosscuts many beds and is thus a crossichnion (sensu Monaco & Caracuel, 2007). The discovery of this almost perfectly preserved crossichnion, including both the trace and its imprint in mud-sandstone sediments, could stimulate ethologic research into similar deep-sea trace fossils.

GEOLOGICAL SETTING

The study area from which the sample was taken is north of San Sepolcro near the village of Montagna (Fig. 1). The geological setting has been described by Brozzetti et al. (2009). Following these authors, the central depression of the Città di Castello-Sansepolcro basin (CSB, Fig. 1) is an extensional basin filled by Pliocene-Pleistocene syntectonic deposits, below which the North-South trending Tuscan edge is buried. The eastern ridge where the trace fossil was found by Giovanni Giorni in 2002 (see asterisk in Fig. 1) consists of an "in sequence" series ("eastward-verging imbricate system" sensu Brozzetti et al., 2009) that deforms the early to middle Miocene foredeep turbidites of the inner and outer Umbria domains (Marnoso-Arenacea Formation; Brozzetti et al., 2009). The Marnoso-Arenacea Formation is well known, consisting of turbidites and sandy debris flow deposits, mostly from 20 to 150 cm thick, and thick-bedded marls (Monaco & Checconi, 2008; Milighetti et al., 2009; Tinterri & Muzzi Magalhaes, 2011). At Montagna (Fig. 1) the succession includes thin- to thick-bedded turbidites (mostly mud to sand turbidites and sandy debris flow deposits) from 20 to 70 cm thick as well as thick beds of

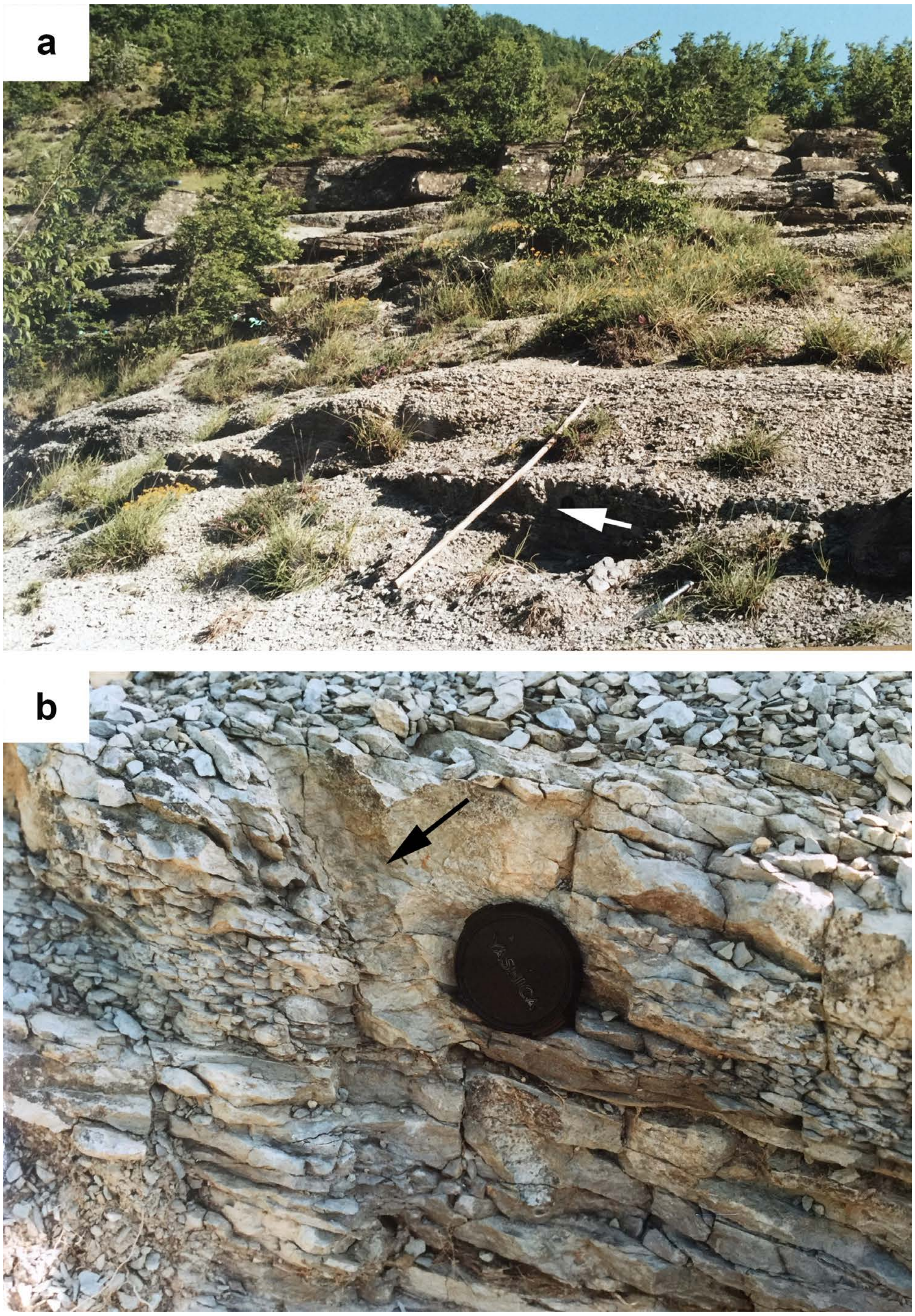


Fig. 2 - Site of *Bulbichnus giornii* n. ichnogen. and n. ichnosp. a) with indication of place with imprint in the rock (arrow); rod is two m long. b) Detail of outer imprint of bulbs (arrow), Marnoso-Arenacea Formation, middle Miocene, Montagna (San Sepolcro). Lens cap is 7.5 cm wide.

grey marls (Fig. 2). The studied specimen subvertically crosses almost five marls and fine-grained turbidite beds so it represents an interesting > 3 cm crossichnial trace fossil in turbidite environment (Monaco & Caracuel, 2007) (Fig. 2b).

THE TRACE FOSSIL SUITE

The typical ichnocoenosis of the Marnoso-Arenacea Formation at Montagna comprises many ichnotaxa, as described in similar deposits (Uchman, 1995; Monaco & Caracuel, 2007; Monaco, 2008; Milighetti et al., 2009; Monaco et al., 2010): the crossichnial *Thalassinoides, Ophiomorpha rudis* (Książkiewicz, 1977), the endichnial *Planolites, Chondrites intricatus* (Brongniart, 1823), *C. targionii* (Brongniart, 1828), *Trichichnus* isp. and *Halopoa* (Monaco, 2014). Several hypichnial forms are common, such as *O. annulata* (Książkiewicz, 1977) and graphoglyptids on the soles of turbidites (e.g., *Paleodictyon minimum* [Sacco, 1888], *P. strozzii* Meneghini, 1850, *P. hexagonum* van der Marck, 1863, *Urohelminthoida dertonensis* Sacco, 1888, *Desmograpton dertonensis* Fuchs, 1895, *D. ichthyforme* [Macsotay, 1967]), and other burrows, mainly epichnial *Scolicia prisca* de Quatrefages, 1849, *S. vertebralis* Książkiewicz, 1977 and hypichnial *S. strozzii* (Savi and Meneghini, 1850).

This ichnocoenosis is typical of the deep-sea inner fan environment (probably on the lower continental slope) with alternating thin- to very thick-bedded turbidites and thick marls such as these which characterize the Oligocene-Miocene foredeep basins of the Apennines (Monaco et al., 2010; Amendola et al., 2015).

SYSTEMATIC PALEOICHNOLOGY

Bulbichnus n. ichnogen.
(Pl. 1)

Type ichnospecies *Bulbichnus giornii* n. ichnosp., Miocene of Montagna, Northern Apennines, central Italy.

Etymology - *Bulbichnus*, from the Latin term *bulbus* ("βολβός" in Greek, "bulbo" in Italian) that corresponds to a bulb and *ichnus* (ίχνος in Greek) = trace (Rindsberg, 2015). Although the term "bulb" is usually applied to a whole object rather than to single parts, it has been here preferred to "nodose" or "nodular" mainly because bulbs are larger than nodules and to avoid confusion with other ichnotaxa (e.g., *Ophiomorpha nodosa*).

Diagnosis - Sub-vertical, arcuate cylinder, up to 50 cm long and > 4 cm wide, ventrally flat and dorsally convex, without pelletoidal lining in cross section, with rhythmically spaced, extruded bulbs each 10 mm wide, disposed along marginal ridges and in dorsal view.

Bulbichnus giornii n. ichnosp.
(Pl. 1)

Etymology - From the surname of the discoverer of the trace fossil, Giovanni Giorni, who found it in 2002 close to Montagna, San Sepolcro, in the Marnoso-Arenacea Formation.

Diagnosis - Sub-vertical trace fossil, ventrally flat and dorsally convex, with rhythmically spaced, extruded bulbs each 10 mm wide, disposed along marginal ridges and in dorsal side.

Description - The burrow is a simple, single cylinder that is oriented not perpendicular to the sea floor but inclined in respect to the bedding (about 30°, Fig. 2). It is generally over four cm in diameter (usually from 3.7 to 4.8 cm, Pl. 1), about 50 cm long, almost flat ventrally (Pl. 1, ve = ventral) and decisely convex dorsally (Pl. 1, do = dorsal). Bulges are rhythmically disposed on the sides of trace, and are rhythmically and symmetrically disposed along the entire trace (Pl. 1, fig. 5: black arrows; Pl. 1, fig. 3: white arrows). Each bulge, up to ten mm wide (see Pl. 1, fig. 5: black arrows), is rounded and protrudes outward. Wider bulbs are disposed along the two margins of the trace and well preserved also on the convex dorsal side. Together, the bulges form two "dorsal ridges" (Pl. 1, figs 3, 5: black arrows; see also Pl. 2, fig. 1). The ventral side, on the contrary, is somewhat flat and lacks bulbs (Pl. 1, fig. 4: flat). The dorsal bulbs are rhythmically arranged within the two ridges, and locally also along the median zone (Pl. 1, figs 3, 5: white arrows). A concretion of dubious origin is present, making it difficult to determine whether it corresponds to a branch junction (Pl. 1, fig. 1: white arrow). In thin section, no lining is observed and the fill of the trace fossil is a homogeneous structureless, massive sand composed of quartz, feldspars, muscovite and lithic fragments, typical minerals of sandy beds of the Marnoso-Arenacea Formation (Pl. 1, figs 7-8).

Material - The trace fossil is represented by a single specimen (OPHIOSTR-MA-01, Pl. 1, fig. 1), which shows also its outer imprint in the rock (Fig. 2b). The type locality is on the hill about one km from the village of Montagna, within marly sediments of the Marnoso-Arenacea Formation, middle Miocene (Fig. 1). The upper part of the trace is badly preserved due to the weathering of the marls (Fig. 2a-b). The holotype is stored at the BIOSED-LAB (Ichnology and Taphonomy Laboratory) of the Department of Physics and Geology, University of Perugia (Italy).

Remarks - Although only one specimen is avalaible, its very good preservation warrants its use as the basis of a new ichnotaxon (Knaust, 2012; Rindsberg, 2015). McIlroy et al. (2009) suggested that at least one specimen in perfectly full relief is absolutely necessary to the sure taxonomic attribution of a newly discovered trace fossil. This is the case with *Bulbichnus giornii* n. ichnogen. and n. ichnosp. herein described, which can be seen in three dimensions along with its imprint in the rock (Fig. 2b). This is fundamental for the explanation of its morphological features and to discuss the ethology of the tracemaker (Uchman, 1998; Rindsberg, 2015). It represents a vertical crossichnion sensu Monaco & Caracuel (2007), but it

EXPLANATION OF PLATE 1

Bulbichnus giornii n. ichnogen. and n. ichnosp.

Fig. 1 - Side view, part of the complete specimen 50 cm long; bar = 5 cm. Note bulbs (black arrows) and a concretion (white arrow).

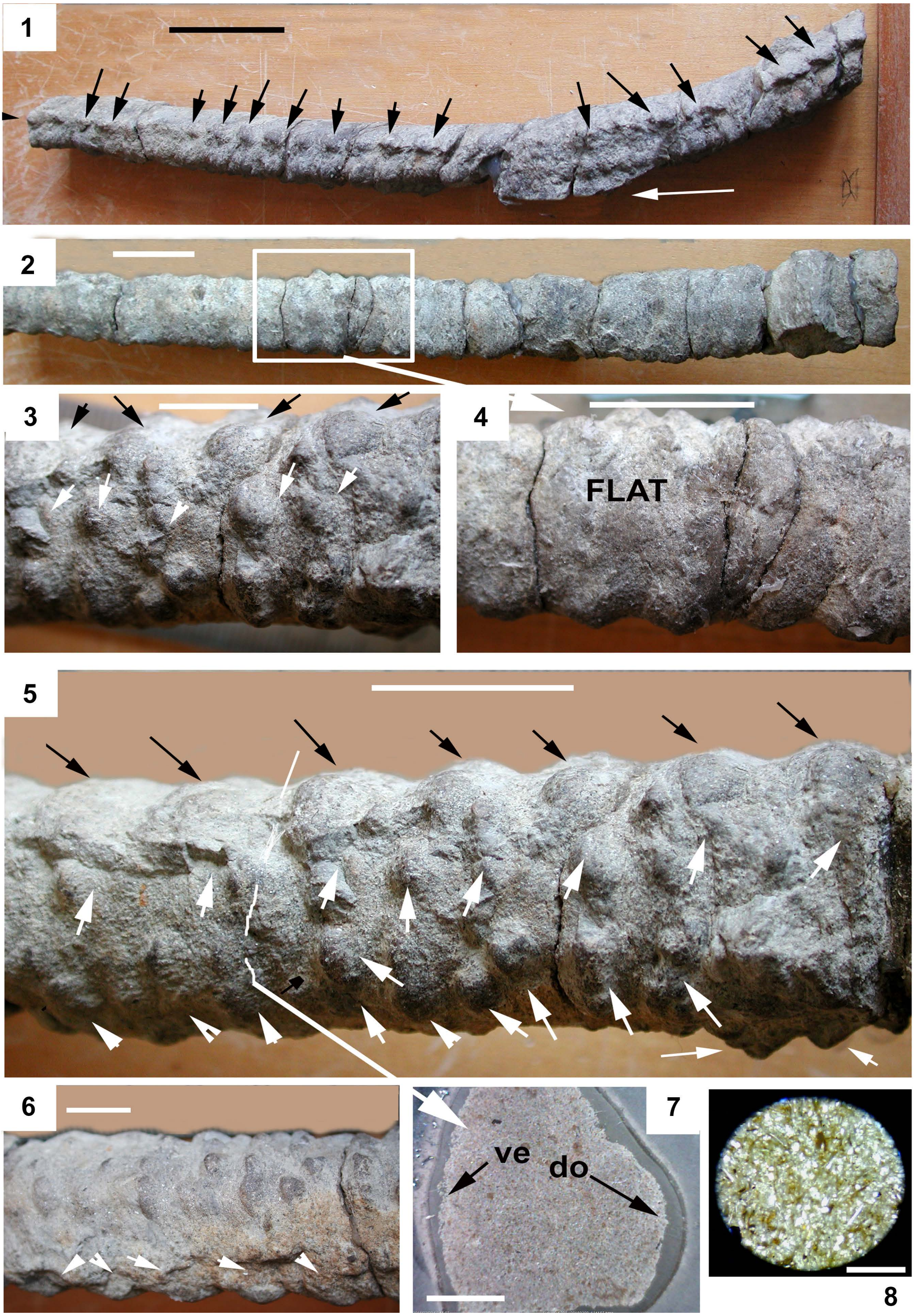
Figs 2, 4 - Ventral view with marginal bulbs rhythmically disposed at sides (see the enlarged rectangle in fig. 4). Scale bar = 3 cm.

Figs 3, 5 - Dorsal view with rhythmically arranged marginal bulbs (black arrows), and dorsal bulbs (white arrows). Scale bar = 2 cm.

Fig. 6 - Detail of marginal bulbs (arrows). Scale bar = 2 cm.

Fig. 7 - Cross section (see dashed line in 5) with ventral side nearly flat (ve) and dorsal one convex (do). Scale bar = 1.5 cm.

Fig. 8 - Thin section showing grains of quartz, feldspars, muscovite and lithic fragments, Marnoso-Arenacea Formation. Scale bar = 2 mm.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cannot be a shaft of the *Ophiomorpha* Lundgren, 1891 group, because it does not display any peloidal lining (Bromley & Frey, 1974; Frey et al., 1978; Anderson & Droser, 1998; Monaco, 2000; Tchoumatchenco & Uchman, 2001; Monaco et al., 2007; Uchman, 2009; Giannetti et al., 2011; Knaust, 2012; Soria et al., 2014). *Bulbichnus giornii* n. ichnogen. and n. ichnosp. differs considerably from the classical features of *Ophiomorpha* and similar forms described in literature; for this reason a new ichnogenus is herein proposed. Such unique large bulbs have never been found before. Moreover, they are not extrusions as pelletoidal lining (knobs, pellets, granules) as occurs usually in *Ophiomorpha* (e.g., *O. nodosa* Lundgren, 1891, *O. borneensis* Keij, 1965, *O. puerilis* de Gibert, Netto, Tognoli and Grangeiro, 2006, *O. annulata* [Książkiewicz, 1977], *O. irregulaire* Frey, Howard, & Pryor, 1978, *O. rectus* [Fischer-Ooster, 1858] and *O. rudis* [Książkiewicz, 1977]) (see Lundgren, 1891; Frey, 1975; Frey et al., 1978; Gibert et al., 2006; McIlroy et al., 2009; Uchman, 2009; Leaman et al., 2015), or in other pelletoidal forms such as *Rutichnus rutis* D'Alessandro, Bromley & Stemmerik, 1987 (see discussion in Monaco, 2011) and *Ereipichnus geladensis* Monaco, Giannetti, Caracuel & Yébenes, 2005. The Montagna specimen differs from the specimen figured by McIlroy et al. (2009, fig. 2D) by lacking a lining, by its greater dimensions and by the regular dorsal distribution of pellets (different in shape and dimensions by those described in *Ophiomorpha* by Frey et al., 1978). Moreover, the Montagna specimen was formed in deep-water conditions (flysch deposits), and differs completely from typical shallow-water ichnotaxa (e.g., *Ereipichnus geladensis* and vertical *O. nodosa*, *O. borneensis* and also some specimens of *O. irregulaire*), found in storm-affected paleoenvironments (Frey et al., 1978; Curran, 1994; Monaco & Garassino, 2001; Monaco et al., 2005; Curran, 2007; Monaco & Caracuel, 2007; Soria et al., 2014; Leaman et al., 2015). Other deep-water forms such as *O. annulata, O. irregulaire* and *O. rudis* show the same vertical trend but are different in disposition, shape and dimensions of bulges (Uchman, 1995, 1998, 2009; Gibert et al., 2006; McIlroy et al., 2009; Leaman et al., 2015). In particular, *O. rudis,* though very common in deep-water environments, exhibits smooth or irregular walls insofar as lacking the flat ventral side and convex bulbous dorsal side, which are not present in its figured types (see Uchman, 2009, fig. 1f-g). Finally, we can exclude a similarity with some diagenetic structures, for example the enigmatic vertical structures called "paramoudra" (e.g., *Bathichnus paramoudrae* Bromley, Schulz and Peake, 1975; Mortimer & Pomerol, 1987), which are still indeterminate whether biogenic or diagenetic (e.g., methane seep field, Nelson et al., 2004; http://craies.crihan.fr/?page_id=2620).

ETHOLOGIC CONSIDERATIONS

Tracemaker

Some ethologic considerations are here presented to reconstruct the probable tracemaker. The recovery of the nearly complete Montagna specimen provides new insights for the study of paleoethology in deep-sea sediments. *Bulbichnus giornii* n. ichnogen. and n. ichnosp. could be considered as a domichnion/praedichnion, but it is difficult to establish what type of organism produced this trace. Ethology is often debated among ichnologists to identify the probable tracemaker of burrows in marine environment (McIlroy, 2004; Gibert et al., 2006; Seilacher, 2007; Uchman, 2007; Buatois & Mángano, 2011; Knaust, 2012; Knaust & Bromley, 2012). Some authors have described vertical biogenic structures, but smooth, usually with lining and without bulbs. In southwestern France, Gaillard et al. (2013) interpreted thick vertical structures as lungfish aestivation burrows or marine fish burrows. Difficulties are great in deep-sea sediments (Uchman, 2007; Uchman & Wetzel, 2012) where vertical structured domichnia rarely occur completely preserved (e.g., *Thalassinoides* in slope areas; see Hubbard et al., 2012, fig. 9B). Among them, *Ophiomorpha rudis* and *O. irregulaire* are the most common and are attributed to crustaceans; they are found partially preserved in outer shelf to slope and deep-sea fan deposits in Cenozoic flysch (Uchman, 2009; Monaco et al., 2010; Leaman et al., 2015).

Crustaceans or giant worms?

Ruling out other organisms (as discussed by Gaillard, 1991; Gibert et al., 2006; Gaillard et al., 2013), the choice is narrowed here to two groups that created domichnia: crustaceans and polychaete worms. Some aspects favor the first group and others the second group.

Crustaceans - In favor of a crustacean tracemaker are the shape and steep inclination of the studied trace fossil. There are some analogies in the inclination of burrow with the subvertical shaft, e.g. those of *Psilonichnus upsilon* Frey, Curran and Pemberton, 1984 in beach backshore and dunes, washover fans, upper foreshore and supratidal zones (Curran, 2007, fig. 14.6C). *P. upsilon,* interpreted by the author as a crustacean burrow, frequently shows a Y- or U-shaped geometry, exhibiting only occasionally, small, round peloids in the outer lining (Frey & Pemberton, 1987). The similarities with the specimen of Curran (2007,

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EXPLANATION OF PLATE 2

Bobbit worms and their burrows.

Figs 1-2 - Vertical burrow of the bobbit worm *Eunice aphroditois* Pallas, 1788; note convex, bulbose dorsal side (1, arrows) and flat ventral side (2) with rhythmically arranged lateral appendages (arrow in fig. 1), image from: http://epiccreature.blogspot.it/2015/01/bobbit-worm.html. Scale bar = 3 cm.

Figs 3-4 - A bobbit worm in aquarium with convex dorsal side (3) and flat ventral side (4), note length and diameter, image from: http://www.telegraph.co.uk/news/10389023/Secret-giant-worm-behind-mystery-of-vanishing-aquarium-fish.html. Scale bar = 3 cm.

Fig. 5 - The small eunicidid worm *Eunice jihueiensis* Pan-Wen & Yan-Huei, 2014 (from Pan-Wen & Yan-Huei, 2014, fig. 5); note rhythmically distributed marginal parapodia. Arrows indicate lateral appendages. Scale bar = 5 mm.

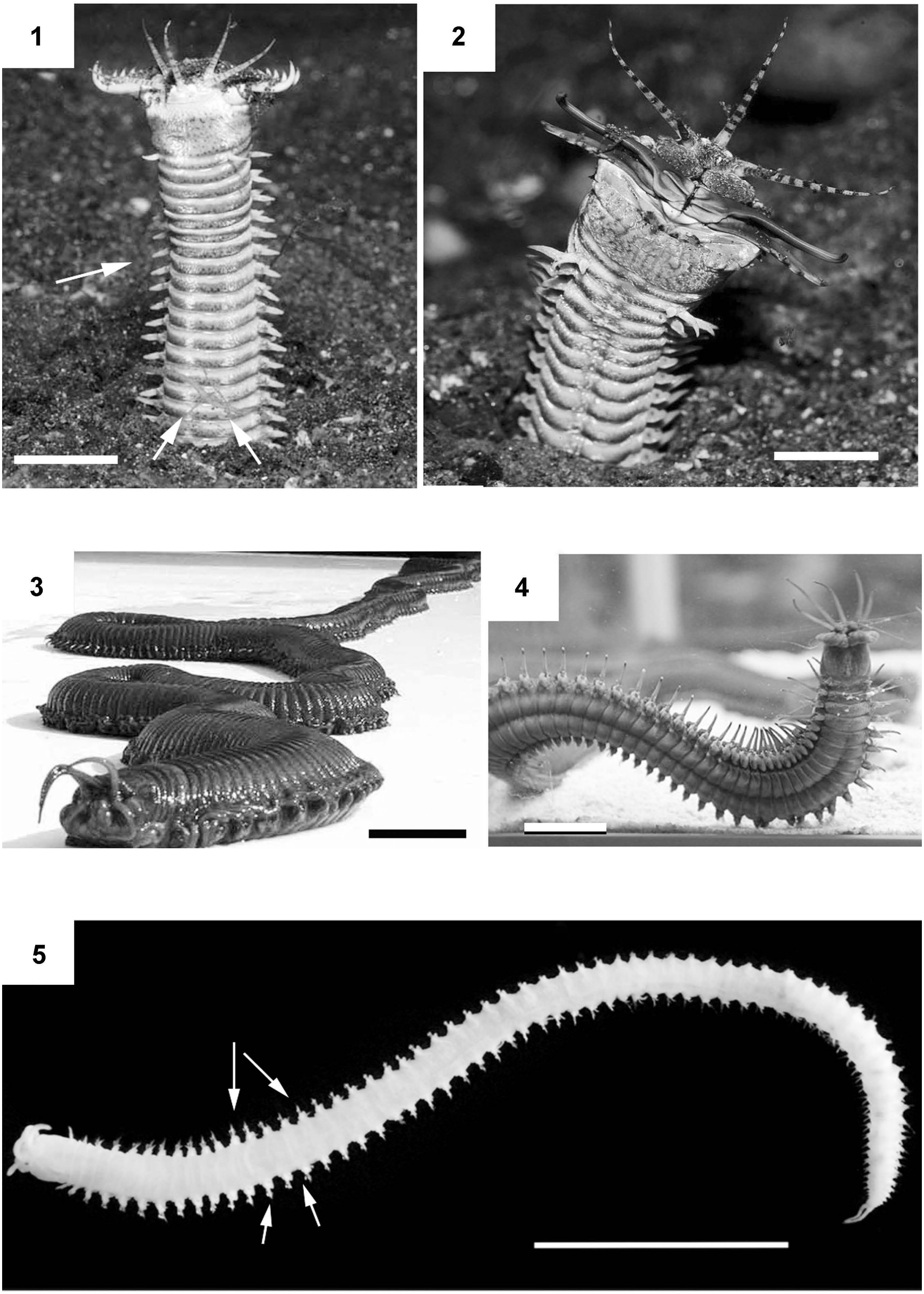
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fig. 14.6C) are few and the depositional environment and substrate characteristics are completely different. In deep-sea sediments, examples are numerous. The subvertical, pelleted *Ophiomorpha nodosa* from slope-channel deposits of the Upper Cretaceous Tres Pasos Formation at Laguna Figueroa, Chile, exhibits large pellets and its diameter is about three cm (Hubbard et al., 2012, fig. 9K). However, even though the inclination of this trace fossil corresponds to that of *Bulbichnus giornii* n. ichnogen. and n. ichnosp. the diameter is smaller and the pellets were irregularly distributed by an unknown crustacean and pointed in the shape of a rose thorn, most similar to those of *O. irregulaire* (Leaman et al., 2015). Additionally, the callianassid crustacean *Neotrypaea californiensis* Dana, 1854 was drawn upon to understand the behaviour of modern taxa that produce burrows closely resembling *O. irregulaire* (Leaman et al., 2015). High-resolution, three-dimensional morphological models were created for *Ophiomorpha* on the basis of the material from the type locality of *O. irregulaire* in Utah and from Eocene deep-marine turbidites of the Juncal Formation, California, USA (Leaman et al., 2015). Another case is *O. rudis,* produced by a crustacean multilayer colonizer in deep-sea fans (Uchman & Wetzel, 2012). In the Grès d'Annot deposits of the French Alps, a long vertical shaft, smooth and < 3 cm, crossing a few turbiditic beds is presented (Uchman, 2007, 2009). *O. rudis* is very common in the Marnoso-Arenacea Formation, but shows relevant differences in shape and disposition and does not display regular bulges as in *Bulbichnus giornii* n. ichnogen. and n. ichnosp. (Uchman, 1995; Monaco & Caracuel, 2007; Monaco et al., 2007, 2010; Milighetti et al., 2009). Rhythmic bulbs show also some differences with *Arthrophycus* figured in Seilacher (2007). Bulbs are difficult to explain; they may represent the anchor points for the ascent of the crustacean or moving through the tunnel, small sub-chambers to stock food, or simple structural reinforcements of the shaft in order to mantain the burrow (the classic hypothesis). Any striae produced by claws or legs of a crustacean have been observed; the presence of bulbs on the dorsal side and not on the ventral side are difficult to explain in the context of a crustacean behaviour.

Giant worms - The hypothesis of giant polychaete worms is considered here as most probable. Recently, some studies (Davey, 2000) concern the behaviour of carnivorous bobbit worms (e.g., *Eunice aphroditois* Pallas, 1788, Pl. 2, figs 1-2), which produce vertical burrows that are > 3 cm in diameter (https://www.youtube.com/watch?v=fJNYlIRYRqg). *E. aphroditois,* among other eunicids (Pl. 2, figs 1-3)*,* is a worm with many rhythmic appendages (parapodia) laterally distributed (similar to posterior parapodia of the well-known polychaete worm *Nereis*), which could have produced the bulbs found in the studied trace fossil. This polychaete has the same shape as *Bulbichnus giornii* n. ichnogen. and n. ichnosp. (Pl. 1, figs 1-6). Its body is more convex in the dorsal part with "bulbs" in margins where rhythmically distributed parapodia are present, and flatter on the ventral side without bulbs, exactly as the studied trace fossil (Pl. 2, figs 1-4). The worm lurks in the loose sediment and comes out quickly to ambush prey such as fishes or other benthic organisms. Therefore, the laterally arranged bulbs may be the anchor points for quick escape from the sediment or for another unknown reason (perhaps to consolidate the internal side of burrow). The structure of the uppermost part of burrow at the sediment-water interface, where *E. aphroditois* catches its prey, may be rapidly destroyed or collapse, but the worm immediately recreates the original burrow before hiding with antennae on the surface waiting for new victims (Pl. 2, figs 1-2). It seems probable that the worm stabilizes the substrate with mucus. As indicated by Petrash et al. (2011), mucous secretions, composed primarily of the glycoprotein mucin, play important roles in the stabilization of the bobbit worm before shooting top to hunt prey. Thus, there are many similarities between the shape, behaviour and orientation of *Bulbichnus giornii* n. ichnogen. and n. ichnosp. and eunicid worm burrows (e.g., these produced by the genus *Eunice*).

The polychaete worm *Nereis* comprises many, mostly marine species, including the sandworm *Nereis virens* and the common clam worm *Nereis succinea*. The worm *Nereis* possesses setae and parapodia for locomotion on the sea-floor but little is known about its structures and vertical burrowing activity (e.g., Schäfer, 1972). The question about burrowing behaviour of the genus *Nereis* in the fossil record is very complex and beyond the aim of this work (see Uchman, 2007; Pazos et al., 2015, fig. 2C-F, cum biblio).

CONCLUSIONS

A new ichnotaxon, *Bulbichnus giornii,* that is almost perfectly preserved in three dimensions is herein described. It was found in a foredeep thrust basin, crossing marls and gravity flow beds of the Marnoso-Arenacea Formation (middle Miocene) at Montagna, San Sepolcro (Umbria, central Italy). This new ichnotaxon represents a subvertical burrow that is included in the ethological category of domichnia-praedichnia, produced probably by a deep-sea, deeply burrowing eunicidid worm (?genus *Eunice*). Its diagnostic features include ventral flattening, dorsal convexity with double rows of bulbs and rhythmically arranged marginal bulbs. These features are comparable with living shallow water eunicidid worms (Pan-Wen & Yan-Huei, 2014), although a simple crustacean domichnion cannot be excluded a priori.

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