



***Artichnus giberti* isp. nov., a possible holothurian burrow from the Miocene of El Camp de Tarragona Basin (NE Spain)**

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ABSTRACT

A new ichnotaxon, *Artichnus giberti* isp. nov., is described in the marine middle Miocene (Serravallian) of the El Camp de Tarragona Basin, north eastern Spain. It is a mostly horizontal and rectilinear, tubular burrow with laminated lining. *Artichnus giberti* is interpreted as the result of the burrowing activity of a deposit- or suspension-feeding, worm-like animal, most likely a holothurian. This new Iberian occurrence extends the known temporal and geographical records of the ichnogenus *Artichnus*, which was previously restricted to the Eocene of Poland.

Keywords: *Artichnus giberti*, holothurians, ichnology, bioturbation, Miocene.

RESUMEN

Se describe un nuevo icnotaxón, *Artichnus giberti* isp. nov., en el Mioceno medio (Serravalliense) marino de la cuenca de El Camp de Tarragona, al noreste de España. Se trata de una madriguera tubular, principalmente rectilínea y horizontal, y con revestimiento laminado. Se interpreta como el resultado de la actividad bioturbadora de un animal vermiforme de hábitos suspensívoros o detritívoros, que muy probablemente se correspondería con un holotúrido. Este nueva cita ibérica amplía los registros temporal y geográfico conocidos del icnogénero *Artichnus*, hasta ahora limitado al Eoceno de Polonia.

Palabras clave: *Artichnus giberti*, holotúridos, icnología, bioturbación, Mioceno.

1. INTRODUCTION

The middle Miocene (Serravallian) sedimentary rocks that constitute the fill of El Camp de Tarragona Basin (NE Spain) have been profusely studied in relation with their geological, stratigraphic and tectonic aspects (e.g., Barnoles *et al.*, 1983; Fontboté *et al.*, 1990; Cabrera *et al.*, 1991, 2004; Roca *et al.*, 1999). The fossil record of this basin is also well known, although the number of publications on body fossils is rather limited (e.g., Almera, 1896; Lambert, 1927; Bataller, 1932; Pilleri, 1990).

In contrast, abundant data on specific ichnotaxa, ichnofabrics and ichnoassemblages have been provided during last two decades. Gibert *et al.* (1995) started this thorough research with the description of the ichnospecies *Dactyloidites ottoi*, recently redescribed as *Haentzschelina ottoi* by Belaústegui (2013). A subsequent detailed ichnological and taphonomic analysis of the area was carried out by Gibert *et al.* (1996), and Domènech *et al.* (2001) studied specifically the bioerosive features of the rocky shores related with the Serravallian transgression. Belaústegui & Gibert (2009, 2013) described an ichnofabric

dominated by the ichnospecies *Cylindrichnus concentricus*, present in two outcrops within the basin. Belaústegui *et al.* (2012a, 2013) worked on *Gastrochaenolites*-like structures affecting different kinds of skeletal substrates. Finally, the comprehensive ichnological study of all the shallow-marine units that constitute the present-day shoreline of Tarragona and part of the Miocene fill of the El Camp de Tarragona Basin has been recently carried out by Belaústegui (2013).

All these studies have allowed the attribution of most of the identified traces to the burrowing activity of marine invertebrates, mainly crustaceans (ichnogenera *Thalassinoides* and *Ophiomorpha*) and annelids (*Cylindrichnus*). Nevertheless, some traces remained unidentified and the aim of this contribution is to name and describe a new ichnospecies of *Artichnus* Zhang *et al.*, 2008, offering a preliminary discussion about its construction, ethology and possible tracemaker. This new ichnotaxon is quite common in El Camp de Tarragona Basin, in particular in those sections known as L'Arrabassada and Punta de la Móra, both located on the shore (Fig. 1).

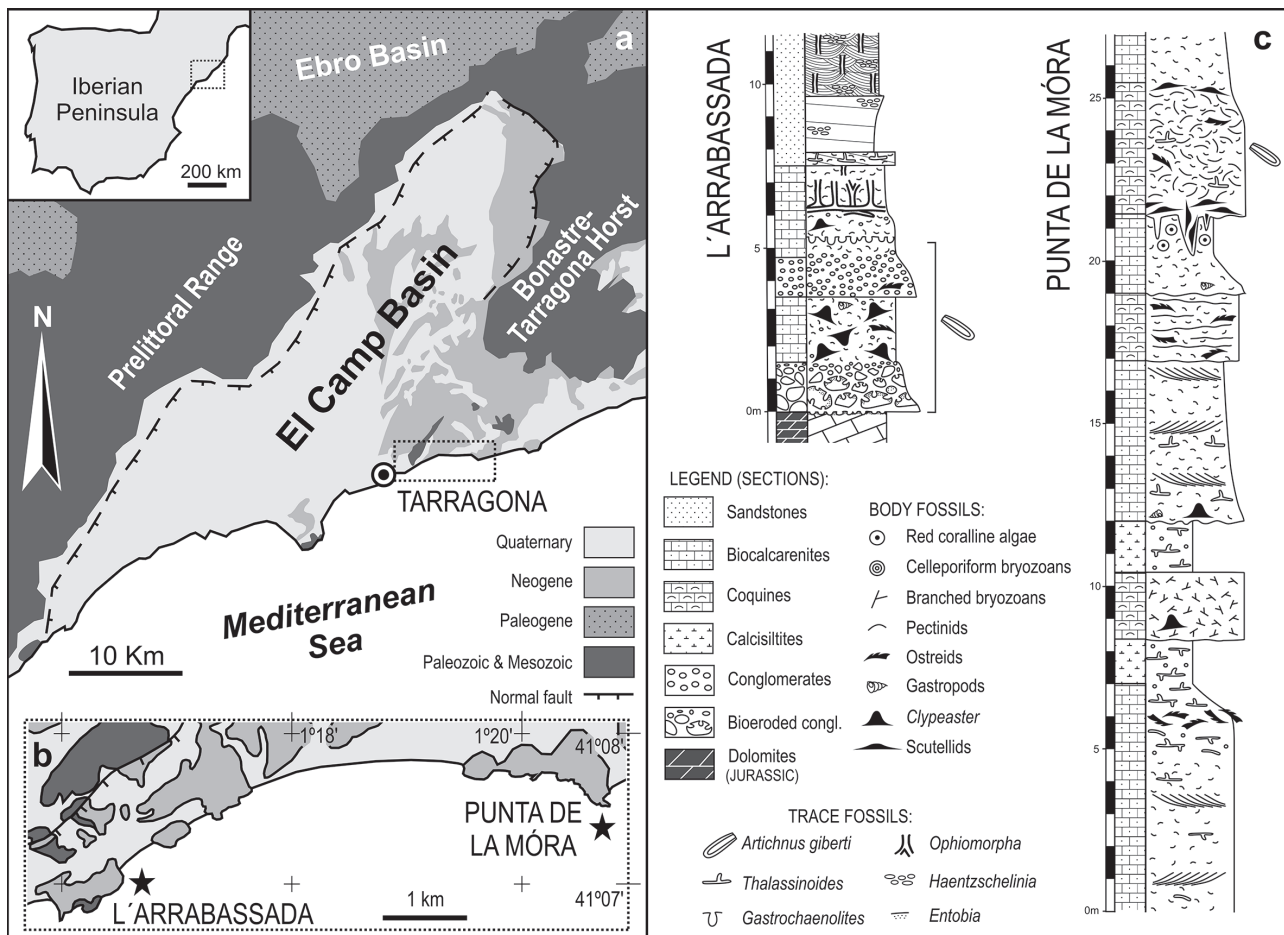


Figure 1. Geographical, geological and stratigraphical setting. **a)** Synthetic geological map of El Camp de Tarragona Basin, and its location in the Iberian Peninsula. **b)** Simplified geological map of the studied area and location of the outcrops at L'Arrabassada and Punta de la Móra (black stars). **c)** Stratigraphic sections of L'Arrabassada and Punta de la Móra.

2. GEOLOGICAL AND STRATIGRAPHICAL SETTING

The studied trace fossil is found in two neighboring sites (L'Arrabassada and Punta de la Móra sections) situated on the coastline of Tarragona, north eastern Spain. Sedimentary rocks of both localities are part of the middle Miocene (Serravallian) fill of the extensional basin of El Camp de Tarragona (Fig. 1a).

This basin constitutes an extensional half-graben that includes Paleozoic to Paleogene rocks of the Catalan Coastal Ranges (Anadón *et al.*, 1979; Cabrera *et al.*, 2004). Two main depositional sequences are recognizable within the Miocene sedimentary record (Cabrera *et al.*, 1991): the Garraf and Tarragona sequences of Langhian and Serravallian age (middle Miocene), respectively. The Serravallian units are the best exposed and consist of shallow marine sediments deposited in a mixed siliciclastic-carbonate platform during to the post-rift stage (Cabrera *et al.*, 2004).

The sediments of the Serravalian platform include an abundance of calcisiltites, biocalcarenites, coquinas and sandstones, and were named as the Ardenya Unit by Barnoles *et al.* (1983). Four main groups of facies have been recently described within this unit (Belaústegui *et al.*, 2012b; Belaústegui, 2013; Belaústegui & Gibert, 2013): 1) Unsorted and bioeroded conglomerates related to paleocliffs and overlying the pre-Miocene substrate, which is also intensely bored (Domènech *et al.*, 2001); 2) inner-platform facies including a variety of bioclastic carbonate deposits dominated by bivalves, echinoids, bryozoans, and coralline algae; 3) outer-platform facies, consisting of calcisiltites with or without glaucony; and 4) siliciclastic facies made up of bioturbated, cross-bedded nearshore sandstones (Gibert *et al.*, 1995), or marly units deposited in an open marine environment.

The new ichnospecies described herein from L'Arrabassada and Punta de la Móra sites occurs in medium- to coarse-grained biocalcarenites and conglomerates included within the inner-platform facies.

3. SYSTEMATIC ICHNOLOGY

Ichnogenus *Artichnus* Zhang *et al.*, 2008

Type species. *Artichnus pholeoides* Zhang *et al.*, 2008.

Diagnosis. “Wide J-shaped, generally cylindrical structure, turbinate in the distal part towards the blind termination, and tapering in the proximal part. The proximal part comprises a steeply upward bent, narrowing shaft, tapering upwards. The burrow lumen lies within a

thickly laminated, short, vertical, mostly retrusive spreite, which is best developed in the lower part of the structure. The outer margin is longitudinally striated in some specimens” (Zhang *et al.*, 2008).

Artichnus giberti isp. nov.

Derivatio nominis. The ichnospecies is named in memory of Dr. Jordi M. de Gibert, a charismatic palaeontologist who was always interested in learning and knowing more about the trace fossil record and the modern tracemakers. His research in the Miocene Camp de Tarragona Basin is especially noteworthy.

Holotype. Specimen started on Fig. 2a (UB-IC 550, housed in the Ichnology Collection of the University of Barcelona) from Punta de la Móra section, Tarragona, NE Spain.

Paratypes. Specimens UB-IC 551, 552 and 553 (Figs 2b-2d) from the same unit (Punta de la Móra section) and hosted in the same collection as the holotype.

Material. *Artichnus giberti* is quite common in the two studied outcrops (L'Arrabassada and Punta de la Móra). The majority of the study was conducted in the field, in exposures mostly parallel to bedding, which provide a large number of oblique, longitudinal and transversal sections of this trace fossil. Only from one section, Punta de la Móra, seven specimens were recovered to analyze their morphology and internal structure in detail.

Diagnosis. Subhorizontal and mostly rectilinear ‘test tube’-shaped, cylindrical burrow, with a constant diameter throughout its length, a hemispherical and blind termination, and a smooth and thick laminated lining. In the most distal and lowermost part of the structure, this lining may consist of laminated, retrusive spreite.

Description. *Artichnus giberti* consists of simple, subhorizontal cylindrical burrows preserved in full relief (Fig. 3). Its overall architecture consists of a mostly rectilinear ‘test tube’-shaped morphology (Figs 3a-3b, 3h), although some specimens may be curved (Figs 3f-3g). While the distal part of each burrow presents a blind termination with a domed or hemispherical geometry, the proximal part (aperture) presents a subcircular cross-section with a diameter slightly narrower than that of the rest of the burrow (Figs 2, 3).

The burrows have a central tunnel surrounded by a thick, laminated lining. The fill of the tunnel is composed of the same coarse-grained material as the surrounding sediment. In contrast, the laminae that constitute the lining are composed of very fine-grained sediment identical to that of the matrix of the enclosing units (Figs 2, 3).

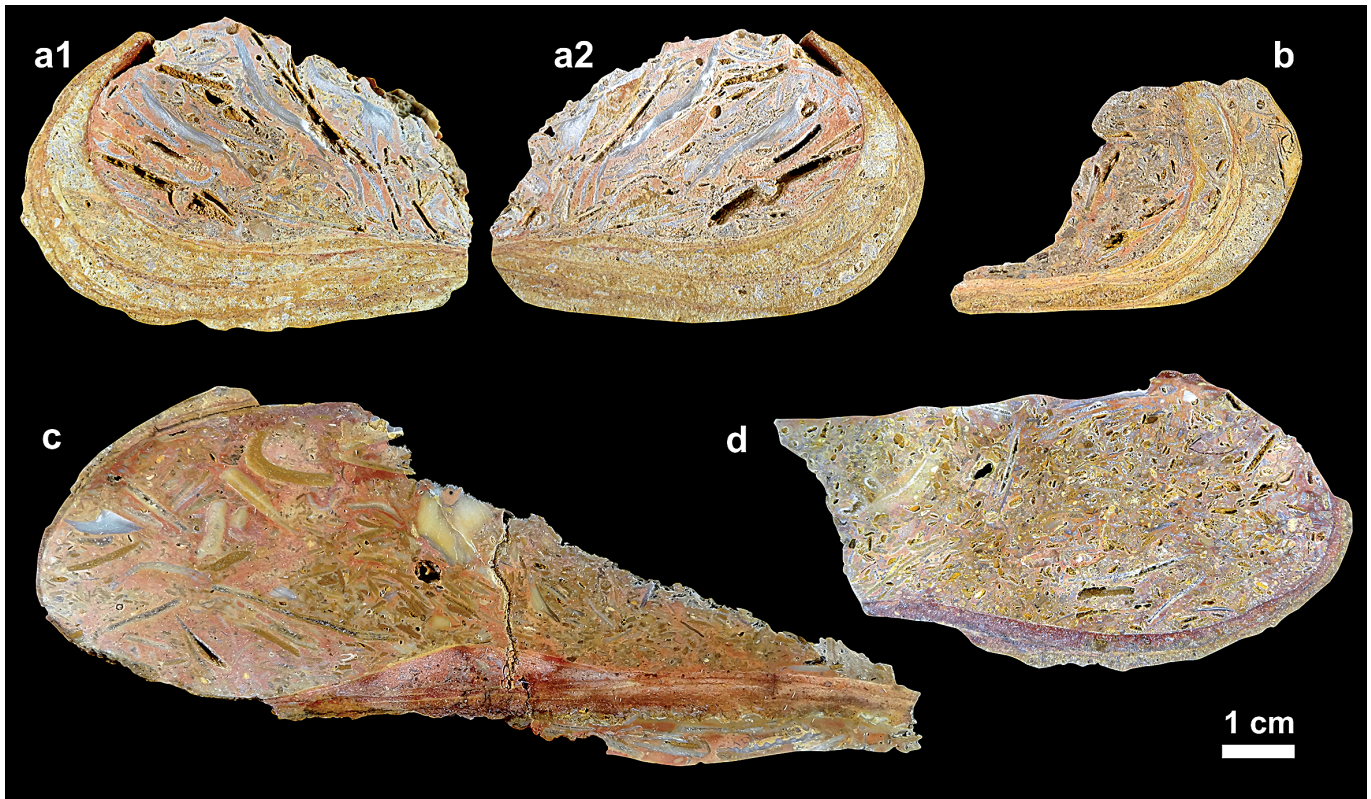


Figure 2. *Artichnus giberti* type material from Punta de la Móra section. **a1-2)** Horizontal and longitudinal sections of the holotype, specimen UB-IC 550. **b, c, d)** Horizontal and longitudinal sections of the paratypes, UB-IC 551, 552 and 553, respectively.

The burrows have circular or subcircular cross-sections with very constant diameters (from 25 to 40 mm) along its length (Figs 3a-3b, 3e-3g). Maximum lengths range from 70 to 200 mm, although often only the distal parts of the burrows, corresponding to the blind terminations, are preserved. The lining layers are not totally continuous, and occasionally are truncated or fused (Figs 2a-2b, 3d). The thickness of the lining ranges from 2 to 15 mm, and the fine-grained laminae within the lining never exceed 1 mm. While these laminae are stacked together at the upper part of the burrow, they may be widely separated in the lowest part constituting retrusive spreite (mainly vertical but occasionally also with a lateral component) (Figs 2a-2b). In this latter case it is possible to observe coarse-grained sediment between the different laminae (Figs 2a-2b, 3d-3e). While the inner boundary of the lining is smooth and sharp, the outer one is more irregular.

Artichnus giberti is quite common in the two studied outcrops, mainly in horizontal surfaces parallel to the bedding. In fact, the resulting ichnofabrics (ichnofabric index, ii, 2/3 *sensu* Droser & Bottjer, 1986) are almost completely dominated by *Artichnus giberti* (Fig. 3h), and only other rare isolated and cylindrical burrows are recognizable (cf. *Thalassinoides*, 20 mm in diameter) (Fig. 3i). However, despite the moderate bioturbation, traces rarely intersect each other.

Geographical and stratigraphical distribution. Both outcrops, L'Arrabassada and Punta de la Móra, are located in the coastline of Tarragona (NE Spain). L'Arrabassada section is a well-known section located within the city of Tarragona, limited by the south western parking lot of the *Passeig Marítim* (i.e., seafront) *de Rafael Casanova* and the western boundary of the L'Arrabassada beach (Fig. 1b). This section consists of 11.5 m of Miocene sediments that overlie an intensely bioeroded substrate of Jurassic dolomites (Gibert *et al.*, 1995, 1996; Domènech *et al.*, 2001; Belaústegui *et al.*, 2012b, 2013). *Artichnus giberti* occurs in the lower 5 meters of the Miocene section, mainly in the microconglomerate and coarse-grained biocalcarenite units (Fig. 1c).

The Punta de la Móra section (Rabadà, 1994; Belaústegui *et al.*, 2012b) is located in the locality of La Móra, 8.5 km north east of Tarragona, limited by the oriental boundary of Cala de Bescs Beach and the western boundary of La Móra Beach (Fig. 1b). This is a 27-m-thick section dominated by cross-bedded, pectinid-rich biocalcarenites and mollusc coquinas, except for a calcisiltite unit occurring in the lower part of the section (Belaústegui *et al.*, 2012b). *Artichnus giberti* occurs in the top of this section, in particular in the uppermost biocalcarenite unit, which consists of a coquina rich in barnacles, pectinids and oysters (Fig. 1c).

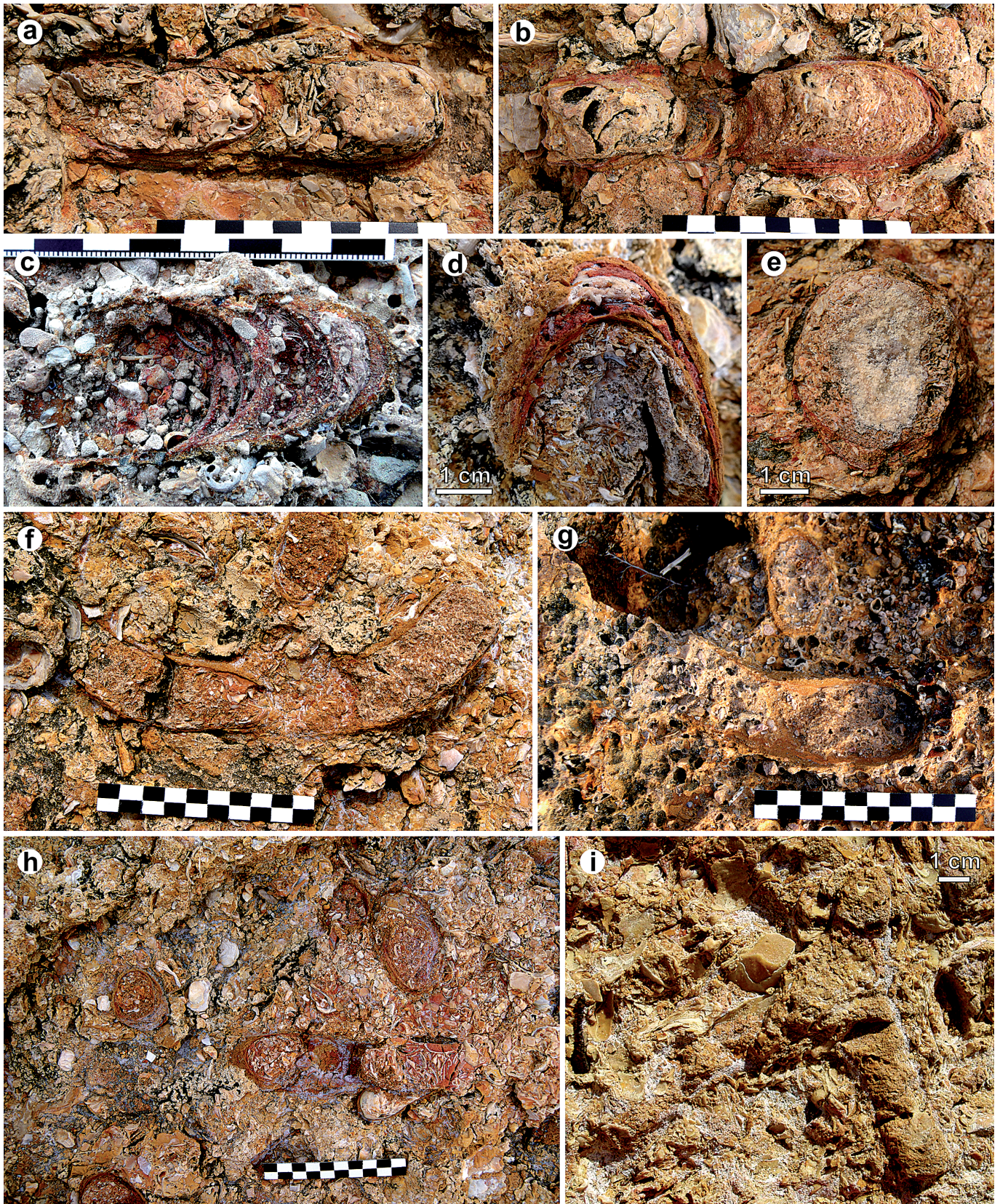


Figure 3. *Artichnus giberti*, *in situ* specimens. **a, b**) Rectilinear and longitudinal sections from Punta de la Móra section. **c, d**) Longitudinal sections (from L'Arrabassada and Punta de la Móra sections, respectively) with detail of the laminated lining in the blind terminations. **e**) Subcircular cross-section from Punta de la Móra section. **f, g**) Curvilinear and longitudinal sections from Punta de la Móra and L'Arrabassada sections, respectively. **h**) *A. giberti* ichnofabric from Punta de la Móra section. **i**) *Thalassinoides*-like structure in Punta de la Móra section. Note: All the pictures correspond to horizontal surfaces parallel to bedding, except Fig. 3e that correspond to a vertical surface perpendicular to bedding; scales in centimetres.

3.1. Identity of the tracemaker

Zhang *et al.* (2008) pointed out the similarity of the ichnogenus *Artichnus* to burrows produced today by holothurians. Currently, holothurians or sea cucumbers are common in both shallow- and deep-marine environments (Bakus, 1973; Meglitsch, 1986). Most of them live in mud or in fine sand, although it is also possible to find sea cucumbers in coarse sands and shell accumulations (Schäfer, 1972). These echinoderms present different lifestyles as free swimmers or epibenthic creepers; as inhabitants of crevices, undersurfaces or surfaces of large rocks and even of marine plants; and as burrowers (Ruppert *et al.*, 2004).

Burrowing sea cucumbers are mainly classified in the orders Dendrochirotida, Molpadiida and Apodida (Nichols, 1969). Some of them may construct U-shaped burrows projecting the anus and the tentacles (oral part) to the surface (e.g., Frey & Howard, 1972; Bromley, 1990), or simpler burrows projecting only the tentacles or the anus (e.g., Ruppert *et al.*, 2004). This is because some holothurians must have the anus in contact with seawater for respiratory functions (Fretter & Graham, 1976; Ruppert *et al.*, 2004; Zhang *et al.*, 2008). Fretter & Graham (1976) pointed out that the most efficient holothurian burrowers are the vermiform, apodous forms belonging to the family Synaptidae (order Apodida), which burrow by means of the tentacles and the muscular action of the body; they do not need to project the anus above the substratum for respiration (Fretter & Graham, 1976). For this reason, Zhang *et al.* (2008) proposed apodids as possible producers of *Artichnus*.

Ginsburg *et al.* (1966), describing a method to impregnate cores of modern unconsolidated sediments with resin, illustrated the cross-section of an eccentric, thickly laminated, lined structure identified as produced by a burrowing holothurian, which is very similar to those described by Zhang *et al.* (2008) for the ichnogenus *Artichnus*. In addition, Ayranci & Dashtgard (2012) attributed *Artichnus*-like traces to the burrowing activity

of modern holothurians in the Fraser River Delta (British Columbia, Canada), and Dashtgard & Gingras (2012) figured *Asterosoma*- and *Teichichnus*-like structures produced by the modern sea cucumber *Molpadia intermedia*, which could also compare with the ichnogenus *Artichnus*. Thus, burrowing holothurians seem to be very likely producers for this ichnogenus, and hence also for *Artichnus giberti* (Fig. 4). Additionally, and supporting this interpretation, possible Holothuroidea ossicles are observable in thin-sections of the studied units.

3.2. Discussion

The new described Miocene trace fossil has been attributed to the ichnogenus *Artichnus* Zhang *et al.*, 2008 because of their morphological and constructional similarities. Therefore, its functional and ethological interpretation should be also very similar to those proposed by Zhang *et al.* (2008), i.e., a stationary or long-term domicile of a deposit- or suspension-feeding, worm-like animal. Following Dashtgard & Gingras (2012), it is worth pointing out that the recognition of holothurian-generated burrows still requires additional research. The recognition of paleo-infaunal communities from these traces has to be carefully considered, but recent examples (see previous section) suggest a holothurian origin for *Artichnus*.

Zhang *et al.* (2008) described only one ichnospecies, *A. pholeoides*, for this ichnogenus. *Artichnus giberti* isp. nov. is distinguished from *A. pholeoides* by its much more variable morphology. While *A. pholeoides* presents a characteristic J-shaped architecture with a vertical and short shaft in the proximal part (or aperture), *A. giberti* has a simpler tubular morphology. Also, *A. pholeoides* consistently bears thickly laminated, vertical, retrusive spreite surrounding the burrow lumen, while *A. giberti* may lack this complex lining. Finally, no signal of outer longitudinal striation has been observed in *A. giberti*, a feature that would indicate *A. pholeoides*.

Making use of various points of similarity, Zhang *et al.* (2008) compared *A. pholeoides* with other ichnospecies belonging to the ichnogenera *Teichichnus*, *Pholeus*, *Diplocraterion* and *Macanopsis*. Additionally, some of the cross-sections illustrated by these authors (see Fig. 5C, D and H of Zhang *et al.*, 2008) could be also confused with the ichnogenus *Asterosoma*. Of course, *A. giberti* also shares some of the features present in these ichnogenera (e.g., spreite, circular or subcircular cross-section, laminated lining or blind termination). However, most of the ichnotaxa mentioned above, including *A. pholeoides*, have an overall morphology (mainly J-shaped) that is more complex than the simple tubular architecture of *A. giberti*.

In recent substrates, it has been observed that sea cucumbers may produce bow-shaped *Arenicolites* and *Diplocraterion* in intertidal settings, and *Arenicolites*,

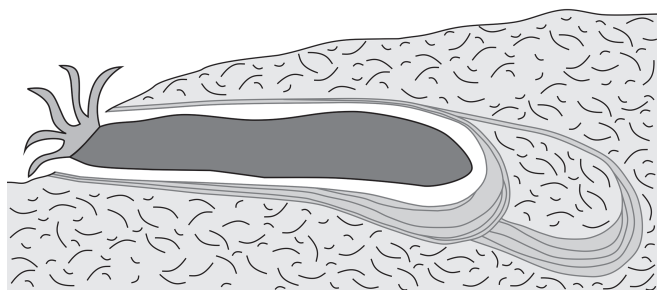


Figure 4. Reconstruction of *Artichnus giberti* produced by a possible holothurian tracemaker.

Skolithos, *Asterosoma* and *Teichichnus* burrows in deeper-water settings. Hence, those traces produced in shallower environments (*Arenicolites* and *Diplocraterion*) could correspond to the activity of suspension-feeding holothurians, while the deeper ones (*Skolithos*, *Asterosoma* and *Teichichnus*) would be made by deposit-feeding holothurians (Dashtgard & Gingras, 2012).

In the two Miocene outcrops (L'Arrabassada and Punta de la Móra sections) of the El Camp de Tarragona Basin, *Artichnus giberti* occurs in shallow marine sediments interpreted as deposited in sublittoral settings, under medium to high sedimentation rates, moderate-energy conditions, wave-influence and reworking through storms. (Gibert *et al.*, 1996; Belaústegui, 2013). Since so far the modern and fossil record of *Artichnus* is quite limited, more studies will be needed to understand the burrowing activity of holothurians in relation with the bathymetry.

4. CONCLUSIONS

'Test tube'-shaped, laminated burrows from the middle Miocene (Serravallian) of El Camp de Tarragona Basin are described as the ichnospecies *Artichnus giberti* isp. nov.

The trace was probably produced by burrowing holothurians under shallow marine conditions, although *Artichnus* has been previously related with burrows excavated by modern holothurians in deeper environments.

This new Iberian occurrence of the ichnogenus *Artichnus* extends its known temporal and geographical record to the middle Miocene; previously it was restricted to the Eocene of Poland.

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