

# Borings formed by Late Cretaceous endobiotic foraminifers within larger benthic foraminifers

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Nielsen, J.K. 2002. Borings formed by Late Cretaceous endobiotic foraminifers within larger benthic foraminifers. *Acta Palaeontologica Polonica* 47 (4): 673–678.

Considering the fossil record, foraminifers constitute one of the most ubiquitous groups in marine deposits due to a high preservation potential of tests. Moreover, borings appear to be widely distributed in the tests. Findings of the borings have potential usefulness as palaeoecological markers and can be significant for taphonomical studies of foraminifers. Formal naming of the borings is needed to further their usefulness, and therefore a new ichnotaxon *Curvichnus semorbis* igen. et isp. nov. is erected.

Key words: Endobiotic borings, Foraminifera, ichnotaxa, Campanian, France.

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## Introduction

The foraminiferal species, *Talpinella cunicularia* (Anomalinidae), was originally established by Baumfalk et al. (1982) on specimens from the Campanian stratotype area at the village Aubeterre-sur-Dronne, Département de la Charente, France. The foraminifer was found within the larger tests of the benthic foraminifer *Orbitoides* (Orbitoidae) (Fig. 1). The latter genus is morphologically a discoidal, flat or lens-shaped larger foraminifer, which is constituted by a median, equatorial chamberlet layer. This layer is, in most species, flanked by layers of lateral chamberlets (van Hinte 1966; Neumann 1990, 1993; Caus et al. 1996). Representatives of *Orbitoides* are valuable as stratigraphical markers in Upper Cretaceous shallow-marine deposits to recognize benthic foraminifera zones (e.g., van Hinte 1976; Caus et al. 1996).

The comprehensive study by Baumfalk et al. (1982) showed that *Talpinella cunicularia* entered its host, *Orbitoides*, as a juvenile. In later ontogenetic stages *T. cunicularia* added new test chambers and earlier chamber walls were removed by resorption (Fig. 1). Its outline changed from trochospiral to increasingly irregular with development of tubular and/or linguoid chambers. The growth pattern is irregular and ends uniserial. In its final stages of development, *T. cunicularia* usually occurs in a semicircular to ring-shaped cavity within the test of *Orbitoides*. The cavity is situated in the equatorial layer around the embryonic apparatus of the latter (Baumfalk et al. 1982; Baumfalk and Nijholt 1984; Görmüş and Sagular 1998).

In this paper the cavity formed by *Talpinella cunicularia* is formally described and named ichnotaxonomically. Also, the origin of the cavity is discussed as to evaluate how it was

constructed. The construction might have involved processes such as bioerosion, bioimmuration or a combination of both.

## Material and methods

The described material (sample JR02) originates from the Campanian stratotype area at Aubeterre-sur-Dronne (France) and was collected by Jean Redeuilh from yellowish bioclastic packstones. These constitute lithological unit Campanian 5 and belong to benthic foraminifera zone C VII (Neumann and Platel 1983; Neumann and Odin 2001). Following the procedure of Baumfalk et al. (1982), tests of *Orbitoides* were split open along their equatorial planes by squeezing them with a pair of tweezers. A lancet was applied to split some of the tests. In that way, the cavities made by *Talpinella cunicularia* were exposed and could be examined in three dimensions.

The morphology of the cavities were compared with those of two hypotypes of *T. cunicularia* stored in the National Museum of Natural History, Washington D.C., and numbered USNM 324714 and 324717, originally from the samples YAB 114 and 131 (see Baumfalk et al. 1982). The sample levels correspond to the lithological units Campanian 4 (benthic foraminifera zone C VI) and Campanian 5 (C VII), respectively. The cavities also were compared with the thin-sections of Campanian–Maastrichtian specimens studied by Görmüş and Sagular (1998) and Görmüş and Meriç (2000).

Usually, the outline of bioerosion structures is applied as the main criterion to distinguish the individual ichnotaxa (e.g., Bromley 1981; Kelly and Bromley 1984; Nielsen and Nielsen 2001). This custom is followed in the present paper

to define new ichnotaxa. Another criterion applied is the texture of the boundary surface between a bioerosion structure and the surrounding substrate. This surface is termed *margin* (Goldring and Pollard 1996). The outline and margin may reflect habits of the trace-maker.

Type material is housed in the Geological Museum at the University of Copenhagen, with prefix MGUH.

## Systematic ichnology

### Ichnogenus *Curvichnus* igen. nov.

*Type ichnospecies: Curvichnus semorbis* igen. et isp. nov.

*Derivation of name:* “*Curv-*” (Latin *curvo*), to bend, arch, curve, refers to the curved shape of the trace fossil. “*-ichnus*” (Greek *ikhnos*), footprint, refers to trace fossil.

*Diagnosis.*—Biogenic structure having an irregular, semicircular to circular outline and situated in skeletal substrates.

### *Curvichnus semorbis* isp. nov.

Figs. 1–4.

*Holotype:* MGUH 26407 (sample JR02) (Fig. 2A), a specimen in the test of the foraminifer *Orbitoides*.

*Paratypes:* MGUH 26408 (Figs. 2B, 4C); MGUH 26409 (Fig. 3A); MGUH 26410 (Fig. 3B); MGUH 26411 (Fig. 3C); MGUH 26412 (Fig. 3D). All paratypes situated in *Orbitoides* tests from the sample JR02.

*Type locality, horizon, and age:* Aubeterre-sur-Dronne, France: lithological unit Campanian 5, benthic foraminifera zone C VII, Campanian.

*Derivation of name:* “*Sem-*” (Latin *sem*), prefix meaning half-. “*-orbis*” (Latin *orbis*), circle. Refers to the similarity to sectors of a circle.

*Diagnosis.*—Biogenic cavity characterized by an irregular, semicircular to circular outline largely positioned in the same plane of the substrate. Ends of the cavity may be bifurcated. Margin of the cavity may form lobes diverging outward. The cavity is subcircular to oval in cross-section.

*Description.*—The outline is highly variable and varies from horseshoe-like, i.e. semicircular, to a full circle (Figs. 1–3). Ends of the cavity may be bifurcated in some specimens (Figs. 1A, 2A). The ends are lobate or tubular. Apparently, there are no openings to the outer surface of the substrate. The margin is smooth where not covered by calcitic sparry cement (Fig. 4).

Largest dimension of the cavity, measured across the circle, reaches up to 4.7 mm. The diameter of the cavity in cross-section is at maximum 1.8 mm. Distance between the two ends of the cavity varies greatly between the specimens and is up to 3.2 mm. Size of the substrate is at maximum 8.1 mm.

*Remarks.*—The distinctive features of *Curvichnus semorbis* isp. nov. are its outline and the lack of passages to the outer surface of substrate. There is no known ichnotaxon similar to this structure. It bears some resemblance to curved segments of *Conchotrema canna* (see Bromley 1994: fig. 5.1). However, *C. canna* is characterized by openings connected to the

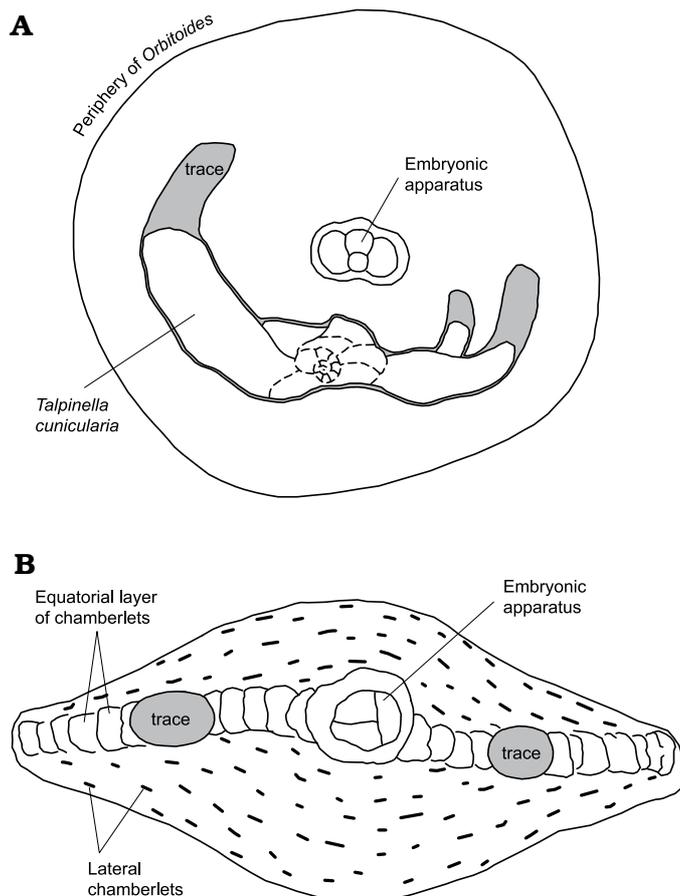


Fig. 1. Outline of the foraminifer *Talpinella cunicularia* and its trace within the equatorial layer of *Orbitoides*. **A.** Cross-section parallel to the equatorial layer. The trace, which may have bifurcated ends, forms around the embryonic apparatus of *Orbitoides*. Resorption may have removed early chamber walls of *T. cunicularia* (stippled lines). After Baumfalk et al. (1982). **B.** Cross-section perpendicular to the equatorial layer of which the trace is confined to. The equatorial layer of chamberlets is flanked by layers of lateral chamberlets. Adapted from Görmüş and Sagular (1998). Not to scale.

substrate surface, in addition to Y-branching. The latter results in a network of interconnected curved segments.

Another similar ichnospecies is *Pseudopolydorites radwanskii* that was established by Głazek et al. (1971) for U-shaped borings without spreite and closely spaced straight limbs. Near the two openings the limbs are somewhat curved. *Pseudopolydorites radwanskii* differs from *Curvichnus semorbis* isp. nov. by having openings and showing a less curved shape.

*Curvichnus semorbis* isp. nov. have only been found in tests of *Orbitoides*. The ichnospecies is common in Campanian tests of *Orbitoides* species from the localities Aubeterre-sur-Dronne, Belvès and Mirambeau in France and Maastrichtian tests from Maastricht in the Netherlands. At Mirambeau nearly 100 percent of the tests of *Orbitoides media* have been affected by *Talpinella cunicularia* (Baumfalk and Nijholt 1984) and therefore may contain *C. semorbis* isp.

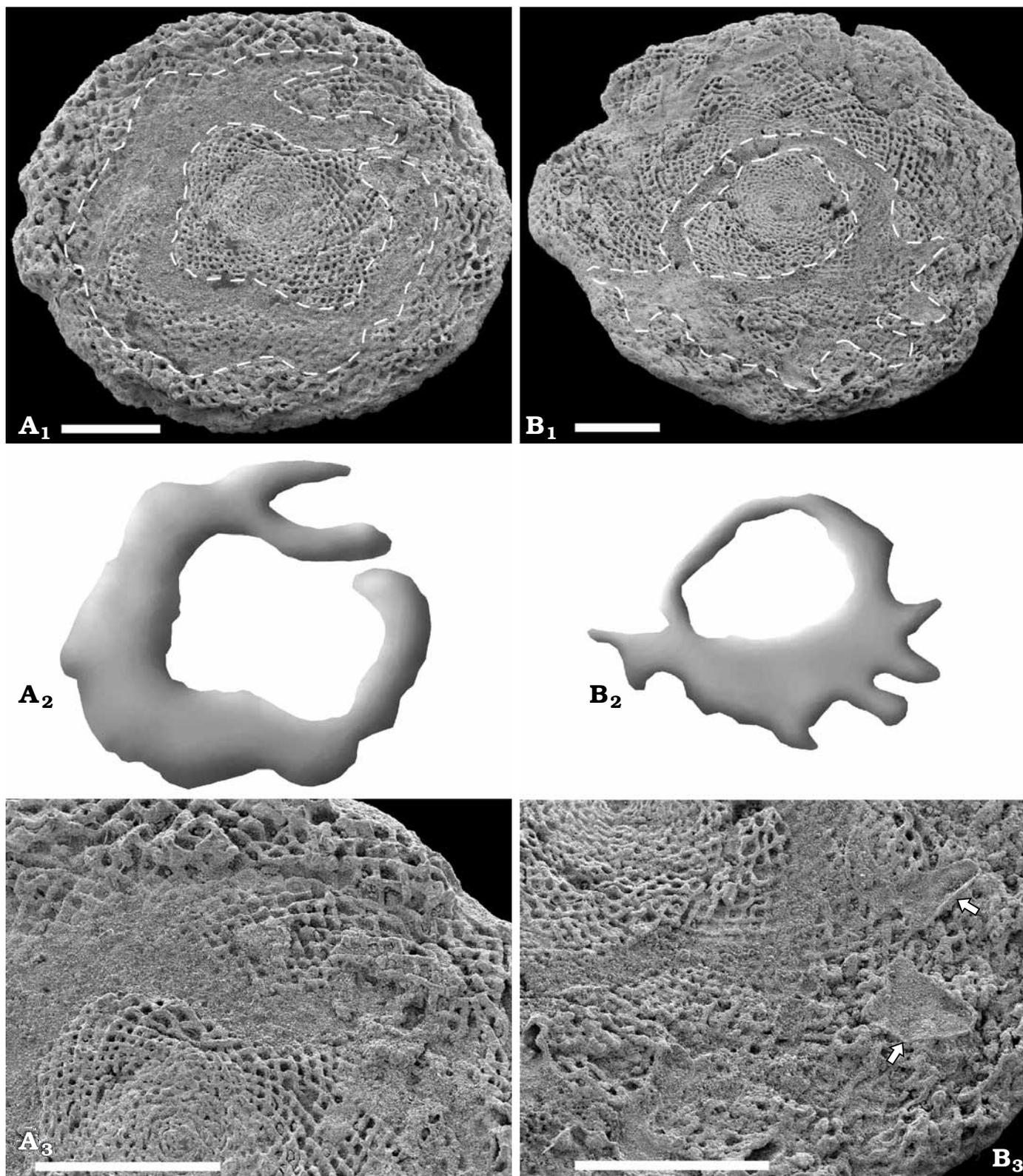
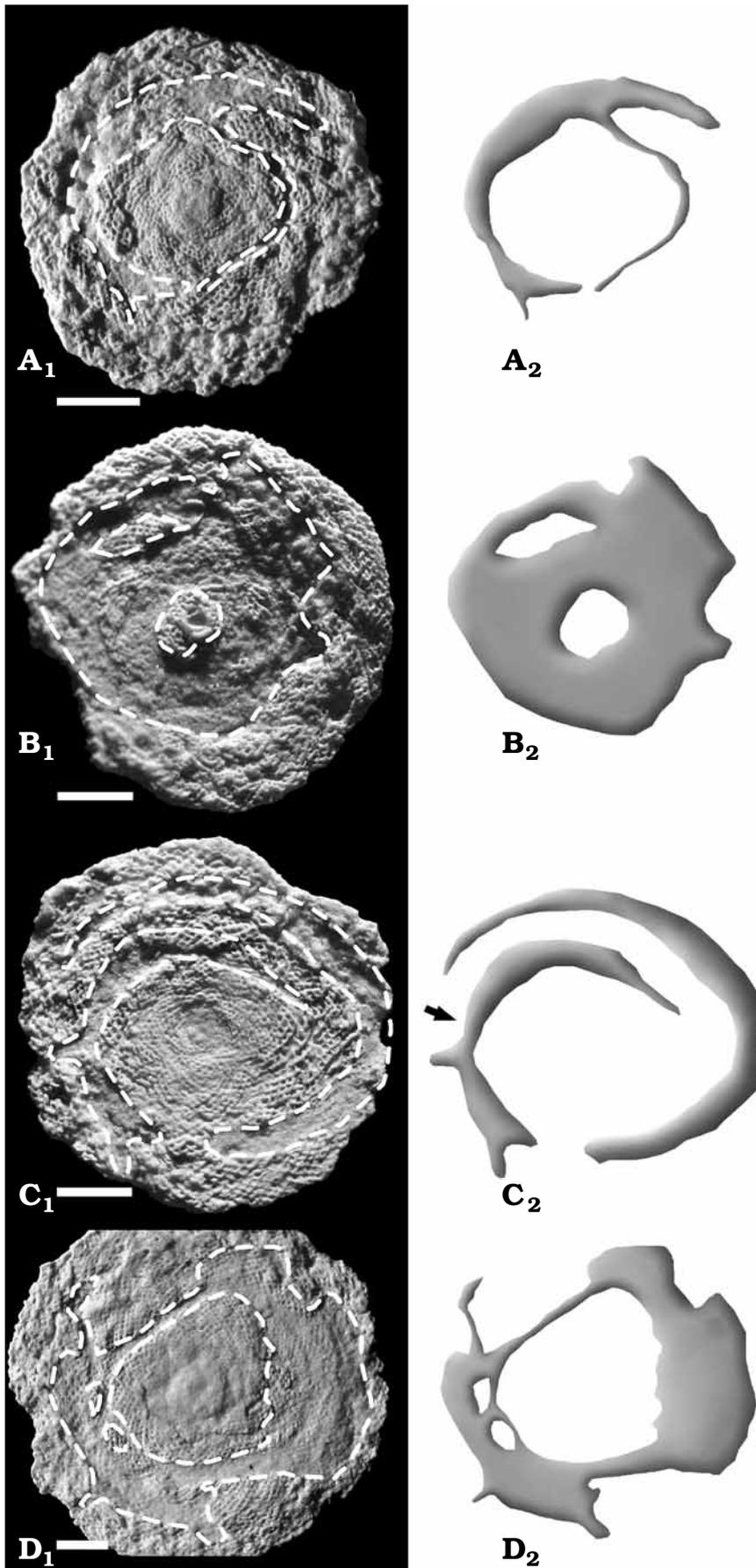


Fig. 2. Two specimens of *Curvichnus semorbis* igen. et isp. nov. in tests of *Orbitoides*. **A.** MGUH 26407, holotype. **B.** MGUH 26408, paratype. Split tests of *Orbitoides* penetrated by *Curvichnus*, marked by dashed lines (A<sub>1</sub>, B<sub>1</sub>). Reconstruction of the shape of *Curvichnus* (A<sub>2</sub>, B<sub>2</sub>). Close-up of bifurcation (A<sub>3</sub>). **B<sub>3</sub>**. Close-up of boring section of *Orbitoides* with remains of *Talpinella cunicularia* (arrows). Scale bars 1 mm.

nov. About 80 percent of the tests of *O. media* at Aubeterre-sur-Dronne have been infested by *T. cunicularia* (Baumfalk

et al. 1982). The studied hypotypes of *T. cunicularia* are associated with *C. semorbis* isp. nov. More recently, Görmüş



and Sagular (1998) recorded a similar trace fossil in Maastrichtian *Orbitoides* tests from Bolu and Darende, Turkey. It is also occurring in Maastrichtian tests from Turkey (Görmüş and Meriç 2000).

*Stratigraphical range.*—Campanian to Maastrichtian, Cretaceous.

## Discussion

Previous studies have shown that bioerosion structures are common phenomena in foraminiferal tests (e.g., Sliter 1971; Shroba 1993; Nielsen 1999). Some foraminifers are also known to bioerode (Palmer et al. 1991; Plewes et al. 1993; Hallock and Talge 1994; Vénec-Peyré 1996). These studies included borings situated in the outer surface of the tests and therefore visible from the outside. However, *Curvichnus semorbis* isp. nov. described herein is situated inside the test and does not penetrate its outer surface. Thus, it is important to discuss the constructional origin of this trace fossil. Additionally, the International Code of Zoological Nomenclature (1999) defines ichnotaxa as the fossilized work of organisms (ICZN: article 1.2.1). Ichnotaxa do not apply to structures such as internal moulds, external impressions and replacements (ICZN: 122). This invites the following question: Did *Curvichnus semorbis* isp. nov. form by bioerosion or bioimmuration?

Bioimmuration is overgrowth of one encrusting organism by another (Taylor 1990; Bromley 1994). Bioclaustration, which is a type of bioimmuration, occurs in those cases where the embedding organism formed both the substrate and the overgrowing organism, i.e., confined the epibiont (Taylor 1990: fig. 1c). Apparently, *Talpinella cunicularia* did not create the cavity by deforming the growth of the host *Orbitoides*. The cavity passes right through the test structure like a boring and seems to post-date the formation of the *Orbitoides* test (Figs. 2A<sub>3</sub>, 4C). The cavity, i.e., *Curvichnus semorbis* isp. nov., cannot be referred to as bioclaustration and

Fig. 3. Four paratypes of *Curvichnus semorbis* igen. et isp. nov. in *Orbitoides* tests showing variability of the shape. A. MGUH 26409. B. MGUH 26410. C. MGUH 26411 (arrow). D. MGUH 26412. Split tests of *Orbitoides* with outlines of *Curvichnus* marked by dashed lines (A<sub>1</sub>, B<sub>1</sub>, C<sub>1</sub>, D<sub>1</sub>). Reconstructions of the shape of *Curvichnus* (A<sub>2</sub>, B<sub>2</sub>, C<sub>2</sub>, D<sub>2</sub>). Scale bars 1 mm.

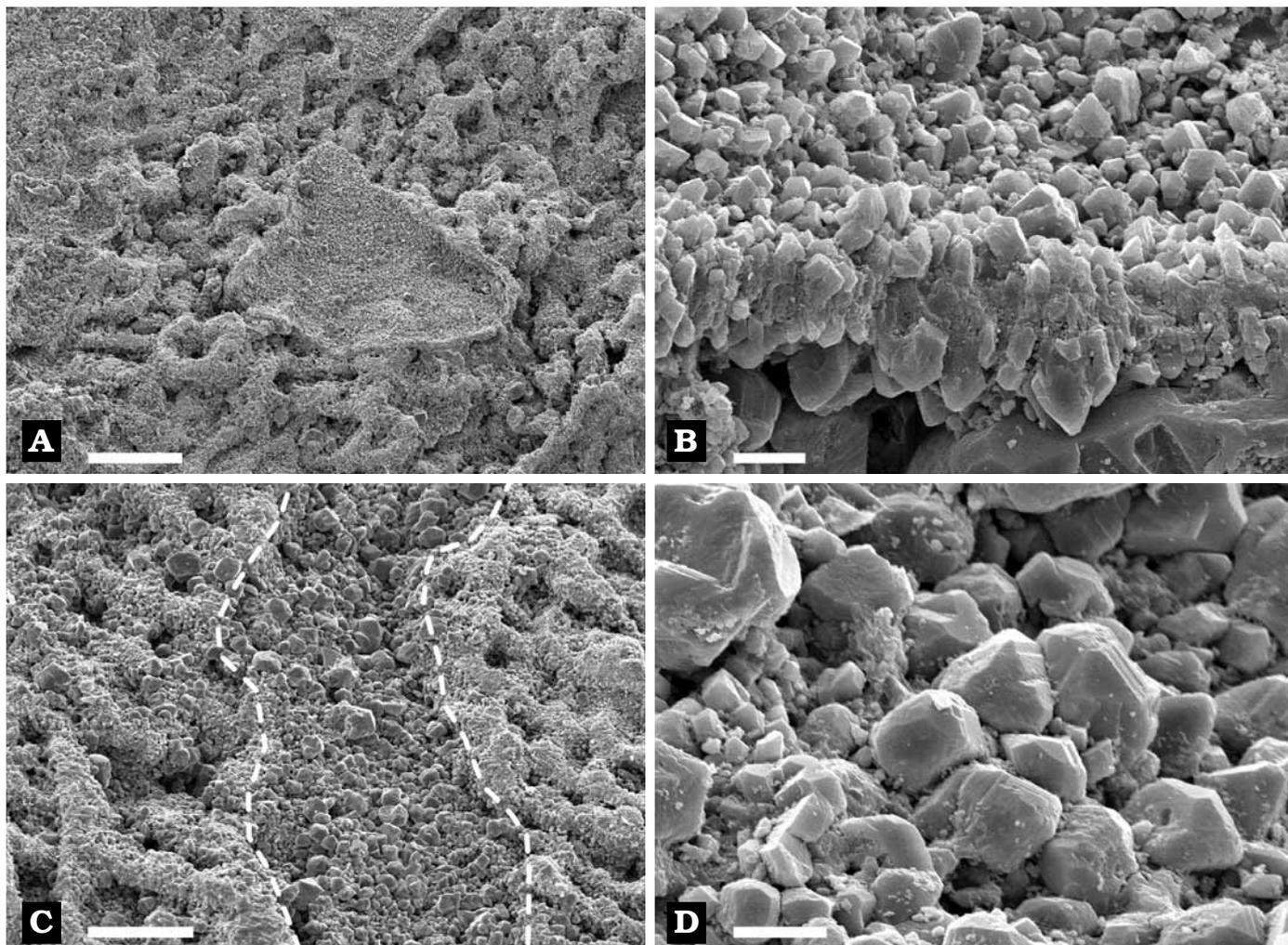


Fig. 4. *Talpinella cunicularia* and *Curvichnus semorbis* isp. nov. in relation to diagenesis. MGUH 26408. **A.** Test remains of *Talpinella cunicularia*. Scale 200  $\mu\text{m}$ . **B.** Close-up of the test surrounded by a fringe of spar cement. Scale 10  $\mu\text{m}$ . **C.** Spar cement inside *Curvichnus semorbis* isp. nov. The latter delineated by stippled lines. Scale 100  $\mu\text{m}$ . **D.** Close-up of the cement. Scale 10  $\mu\text{m}$ .

may thus be interpreted as a true boring. The boring was probably formed by dissolution. This is likely, because *T. cunicularia* had the ability to resorb early chamber walls (Fig. 1A).

As *Curvichnus semorbis* isp. nov. only exists in *Orbitoides* and not in any other Foraminifera, the trace-maker *T. cunicularia* was most likely symbiotic or parasitic (Baumfalk et al. 1982; Görmüş and Sagular 1998). Other foraminiferal tests of comparable shape were available, but do not bear this marking. This indicates that *T. cunicularia* did not grow in empty tests, but lived as a true endobiont, probably using the *Orbitoides* endoplasm as a feeding source (Baumfalk and Nijholt 1984). This may explain the reason for *T. cunicularia* to explore the equatorial layer rather than the test margin (Görmüş and Sagular 1998). As *T. cunicularia* did not destroy the embryonic apparatus of its host, a symbiotic life mode cannot be ruled out. Infestation with *T. cunicularia* would probably have been lethal to the host (Baumfalk et al. 1982; Görmüş and Sagular 1998). In etho-

logical terms *Curvichnus semorbis* isp. nov. reflects a simple behavioural pattern and could be classified as a dwelling, i.e. domicionion (see Bromley 1994: tables 5.1–5.2). However, the enclosed setting of the trace fossil within *Orbitoides* suggests a combined feeding and stationary dwelling behaviour of the trace-maker. The size of the trace-maker tends to be significantly smaller than its trace fossil, indicating that the trace-maker enlarged its domicile for feeding purpose. Thus, the trace fossil is classified here as a fodinichnion.

The presence of *Curvichnus semorbis* isp. nov. probably affected the preservation potential of *Orbitoides*. The relatively large-sized boring may have weakened the test and hasten its destruction by taphonomic processes such as fragmentation and dissolution (see Peebles and Lewis 1988; Martin and Liddell 1991). The boring increased the interior surface area and could have eased penetration of dissolving and precipitating fluids through the test. Sparry cement of very finely crystalline calcite is widespread on boring margins and test remains of *Talpinella cunicularia* (Fig. 4). The latter may be surrounded

by a fringe of cement, indicating that the cement initiated its growth on these remains. The borings also are likely to have eased fragmentation of *Orbitoides* tests. The majority of the tests have broken edges, exposing the cavities of *C. semorbis* isp. nov. Apparently, bored tests are less able to resist fragmentation than unbored tests. As *C. semorbis* isp. nov. with remains of *T. cunicularia* may occur abundantly in assemblages of *Orbitoides*, the taphonomical implications could be significant for palaeoecological studies.

## Conclusion

A new ichnospecies, *Curvichnus semorbis* gen. et isp. nov., is erected. The trace fossil is interpreted as a boring as no evidence of bioimmuration could be seen in the substrate, and reflects a combination of feeding and stationary dwelling behaviour. The trace-maker appears to be another foraminifer, *Talpinella cunicularia*. The bioeroding behaviour probably changed the preservation potential of both *T. cunicularia* and its host.

## Acknowledgements

I acknowledge Jean Redeuilh (Yviers) at the Section Aquitaine of Club géologique des PTT for collecting *Orbitoides* tests, and Muhittin Görmüş (Çünür-Isparta) for the loan of his collection of thin sections. Martin Buzas (Washington) kindly arranged the loan of USNM specimens. Thanks are given to Alfred Uchman (Cracow), Anne Fortuin (Amsterdam), Danuta Peryt (Warsaw) and an anonymous referee for highly constructive comments.

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