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Bioerosion in *Ostrea lamellosa* shells from the Messinian of the Tafna basin (NW Algeria)

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Abstract: Bioerosional trace fossils (borings) are reported for the first time in Algeria. Three ichnotaxa observed in the shells of *Ostrea lamellosa* from the lower Messinian (upper Miocene) deposits of the Tafna basin (NW Algeria) are described. The ichnotaxa are *Entobia* cf. *geometrica*, *Gastrochaenolites* cf. *torpedo* and *Trypanites* isp.. *Ostrea lamellosa* shells are encrusted by balanid barnacles which are bored by *Trypanites* isp.. The ichnoassemblage is assigned to the *Trypanites* ichnofacies. Besides the bioerosion and encrustation described herein, specimens permitted the identification of the different phases of the Messinian transgression across the Souk el Khemis shoal.

Key-words:

- *Ostrea lamellosa*;
- bioerosion;
- balanid barnacles;
- Messinian;
- transgression;
- Tafna basin

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Résumé : *Bioérosion des coquilles d'*Ostrea lamellosa *du Messinien du bassin de la Tafna (NO Algérie).-* Des traces fossiles bio-érosives (perforations) sont décrites pour la première fois en Algérie. Trois ichnotaxons observés dans des coquilles d'*Ostrea lamellosa* du Messinien inférieur (Miocène terminal) du bassin de la Tafna sont décrits. Ces derniers sont attribués à *Entobia* cf. *geometrica*, *Gastrochaenolites* cf. *torpedo* et *Trypanites* isp.. Les coquilles d'*Ostrea lamellosa* sont encroûtées par des balanidés eux-mêmes perforés par *Trypanites* isp.. L'ichnoassemblage étudié est attribué à l'ichnofaciès à *Trypanites*. En outre, la bio-érosion et l'encroûtement décrits ici permettent l'identification des différentes phases de la transgression messinienne sur le haut-fond de Souk el Khemis.

Mots-clefs :

- *Ostrea lamellosa* ;
- bio-érosion ;
- balanidés ;
- Messinien ;
- transgression ;
- bassin de la Tafna

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1. Introduction

Bivalves belonging to the family Ostreidae are common in the upper Miocene deposits of northwestern Algeria (Freneix *et al.*, 1988; Satour *et al.*, 2011,; Naimi *et al.*, 2020). The type genus of this family is *Ostrea* and the most common species in the upper Miocene sediments of Orania (northwestern Algeria) is *O. lamellosa* (Brocchi, 1814) which is abundant in the Miocene series. This oyster appears in the lower Miocene of the Mediterranean and was also recorded in the middle to upper Miocene of the Maghreb as well as the Moroccan Atlantic coast, Caucasia and the Russian platform (Freneix *et al.*, 1988). *O. lamellosa* is classified as a large oyster due to its dimensions, often about 200 mm long and 80 mm in width in the case of the population from the Tortonian of the Dahra massif (northwestern Algeria) (Satour *et al.*, 2011). The oyster shells often contain several types of borings (*e.g.*, Gurav & Kulkarni, 2017).

Entobia, *Gastrochaenolites* and *Trypanites* constitute three types of borings considered as bioerosion trace fossils occurring mainly on hard substrates, especially rocks and shells (*e.g.*, Vinn, 2005; Vinn & Toom, 2015, 2016; Vinn *et al.*, 2015; Salahi *et al.*, 2018; Rashwan *et al.*, 2019), and also in wood and bones (Taylor & Wilson, 2003). *Entobia* was made by sponges and *Gastrochaenolites* by clavate bivalves, whereas worms are the trace-makers of *Trypanites* (Wisshak, 2006).

Borings are known from the Ediacaran to the Holocene (Bengtson & Zhao, 1992; Tapanila & Hutchings, 2012). Shallow-marine carbonate platforms are the most favoured environment for the development of bioerosion (Knaust *et al.*, 2012).

This paper aims to describe and report borings of *Entobia*, *Gastrochaenolites* and *Trypanites* from Algeria for the first time. These abundant trace fossils were found in oyster shells from the Messinian carbonate platform at the northern edge of the Tafna basin, northwestern Algeria. Oyster specimens at hand all belong to *Ostrea lamellosa* and are also encrusted by barnacles.

2. Geological setting

The Neogene Tafna basin is located in the extreme northwestern part of Algeria, to the west of the Lower Chelif basin (Fig. 1.B). The "post-nappes" Miocene series begins with detrital sediments deposited in a shallow marine-lagoonal environment, and is correlated with the late Vallesian-early Turolian (9.1-8.7 Ma) period (Mahboubi *et al.*, 2015). These sediments are overlain by Tortonian-lower Messinian blue marls, which indicate the first upper Miocene transgressive pulses in the region. During the marine maximum flooding, carbonate platforms were established on the basin margins, represented by shoals and remarkable reefs of Sebaa Chioukh, Sidi Safi and Souk el Khemis (Saint-Martin, 1990) (Fig. 1.C).

The studied area is located in the vicinity of Souk el Khemis village (Tlemcen province), corresponding to the northwestern margin of the Tafna Neogene basin and belonging to the eastern part of the Traras Mountains (Naimi & Cherif, 2021).

The Souk el Khemis Miocene series overlie the Cretaceous metamorphic foundation. The lowermost part consists of 70 m-thick continental reddish clay-conglomeratic deposits, overlain by Messinian fossiliferous yellowish sandy marls rich in planktonic foraminifers (Guardia *et al.*, 1974). The uppermost Messinian deposits are represented by build-up limestones, consisting of a *Porites*-*Tarbellastraea* coral reef (Saint-Martin, 1990).

The studied material comes from the Messinian yellowish sandy marls (YSM). In our study area, due to the absence of the middle Miocene conglomerates, the transgressive YSM overlie the whitish Cretaceous basement (Fig. 1.D). The YSM are exclusively represented by sandstone rocks organised into two informal units: (i) the first consists of massive bioturbated and bioclastic sandstones; (ii) the second is composed of laminated sandstones (Fig. 1.E). The YSM were likely deposited in a shallow-marine setting under high-energy conditions. The top of this unit is emphasised by a hardground (Fig. 1.F).

3. Systematic ichnology

Ichnogenus *Entobia* Bronn, 1837

Type ichnospecies. *Entobia cretacea* Portlock, 1843

Entobia cf. *geometrica* Bromley & D'Alessandro, 1984

(Fig. 2.A-B)

Material: Several hundred burrows preserved on the external and internal surfaces of *Ostrea lamellosa* shells.

Locality: Souk el Khemis, northern edge of the Tafna Neogene basin (Tlemcen province, northwestern Algeria).

Stratigraphic distribution: Lower Messinian (upper Miocene).

Observations: Network-shaped irregular borings, multi-aperture, multi-chambered and interconnected, generally elliptical, elongate (with fused chambers) spherical to subspherical or subangular, aligned in rows and narrowly spaced. Our specimens are also composed of straight to slightly curved tunnels, mostly 0-5- 2.5 mm diameter, occasionally filled with detrital material.

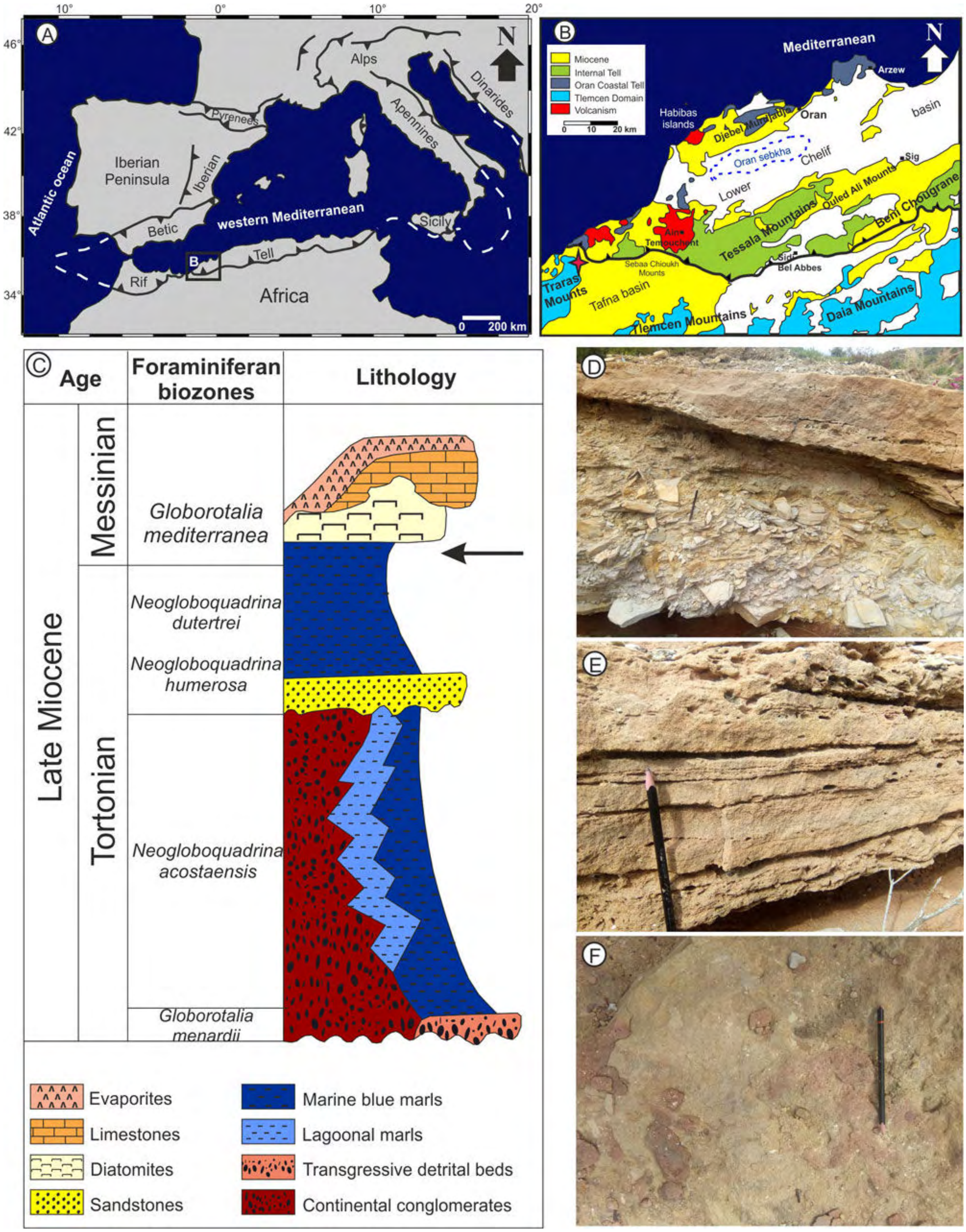

Figure 1: Location and geological overview of the study area; (A) geographical position of northwestern Algeria in the western Mediterranean area; (B) geological context of northwestern Algeria; (C) lithology and (planktonic foraminiferal) biozonation of the upper Miocene of the Tafna and Lower Chelif basins (after BELKEBIR *et al.*, 1996, modified); (D) Messinian sandstones overlying the Cretaceous basement; (E) Messinian sandstones showing a sequence subdivided into two subdivisions; (F) Hardground.

Remarks: *Entobia* includes clionid-sponge dwelling borings (domichnia), showing a branched system of chambers. Its stratigraphic distribution ranges from the Devonian to the Recent, and it occurs in shallow- to deep-marine settings. *Entobia* producers (sponges) are chemical borers, which prefer carbonate substrates such as the bivalve shells (RADWAŃSKI *et al.*, 2011). However, similar *Entobia* borings have been observed on the shells of bivalves from the upper Eocene of Egypt (RASHWAN *et al.*, 2019), the Miocene (GIANNETTI *et al.*, 2020) and Pliocene of Spain (GIBERT *et al.*, 1998), and the Holocene of Argentina (CHARÓ *et al.*, 2017).

Ichnogenus *Gastrochaenolites* LEYMERIE, 1842

Type ichnospecies. *Gastrochaenolites torpedo* KELLY & BROMLEY, 1984

Gastrochaenolites cf. *torpedo* KELLY & BROMLEY, 1984

(Fig. 2.B)

Material: Several burrows preserved on *Ostrea lamellosa* shells.

Locality: Souk el Khemis, northern edge of the Tafna Neogene basin (Tlemcen province, northwestern Algeria).

Stratigraphic distribution: Lower Messinian (upper Miocene).

Observations: *Gastrochaenolites* specimens are club-shaped borings, subcylindrical and smooth, characterised by shallow depressions; apertural region circular or oval;–chambers 0.6-1 mm long and 0.5-0.9 mm wide.

Remarks: *Gastrochaenolites* consists of bivalve-produced cavities, is classified as an unbranched bioerosional trace fossil, and belongs to the ethological category domichnia. It occurs in hard- and firm-grounds of shallow-water settings. These borings are known from the Ordovician to the Recent (EKDALE & BROMLEY, 2001) and are common in the Jurassic. Their trace-makers include suspension-feeding gastrochaenid and pholadid bivalves (TAPANILA & HUTCHINGS, 2012). *Gastrochaenolites* may be associated with *Entobia*, but rarely (GIBERT *et al.*, 2012).

Ichnogenus *Trypanites* MÄGDEFRAU, 1932

Type ichnospecies. *Trypanites weisei* MÄGDEFRAU, 1932

Trypanites isp.

(Fig. 3.A, .C)

Material: Several borings preserved in *Ostrea lamellosa* shells.

Locality: Souk el Khemis, northern edge of the Tafna Neogene basin (Tlemcen province, northwestern Algeria).

Stratigraphic distribution: Lower Messinian (upper Miocene).

Observations: *Trypanites* isp. specimens consist of simple cylindrical, subcylindrical or elongate, smooth, unbranched, straight to slightly curved shafts, 0.5 to 5 mm in diameter and 3 mm long. All borings are preserved in external surfaces of shells of *Ostrea lamellosa* and encrusting balanid barnacles.

Remarks: *Trypanites* is a cylindrical, unbranched, bioerosional trace fossil, produced by sipunculans and polychaetes and belonging to the ethological category domichnia (GIBERT *et al.*, 2012; CHARÓ *et al.*, 2017). It is recorded from the Cambrian (JAMES *et al.*, 1977) to the Holocene. *Trypanites* borings occur in biogenic substrates such as brachiopods (VINN, 2005) and bivalve shells (CHARÓ *et al.*, 2017; RASHWAN *et al.*, 2019), but also in hardgrounds. It gives its name to the *Trypanites* ichnofacies. *Trypanites* is constructed by chemical means in carbonate substrates (KNAUST *et al.*, 2012).

Undetermined boring

(Fig. 3.B)

Seven borings are multi-tunnelled (Fig. 3.B). Their branching boring system has a flower-like morphology. It is not clear whether the trace is unroofed or preserved in its original state. In the case of unroofed boring, there is currently no applicable ichnotaxon (Max WISSHAK, pers. comm., 2020). Although it slightly resembles a multi-lobed *Maeandropolydora*, its dimensions are too large for the latter. If the trace is a depression rather than a tunnel-shaped boring, it probably belongs to an ichnospecies of *Planavolites*.

4. Encrusting barnacle balanids

The oysters studied were colonised by clusters of encrusting acorn barnacles (Fig. 3.A-C), well-preserved and frequent on both the external shell surfaces of *O. lamellosa*, and in cross-sections of fragmented shells, which indicate post-mortem encrustation. Barnacle shells have a truncated conical form, made of six cemented articulating plates, with diameter ranging from 15 to 30 mm and height about 10 to 15 mm; some shells are open, whereas others are closed. In addition, the preservation of orifice orientation may indicate *in situ* preservation of the cluster, in an intertidal environment (DOYLE *et al.*, 1997). Commonly, these balanomorph barnacle shells display circular to elongate *Trypanites* borings (Fig. 3.C), with average diameter of 0.5 mm diameter, indicating that some worm boring activity took place after the barnacle encrustation of *O. lamellosa* shells.

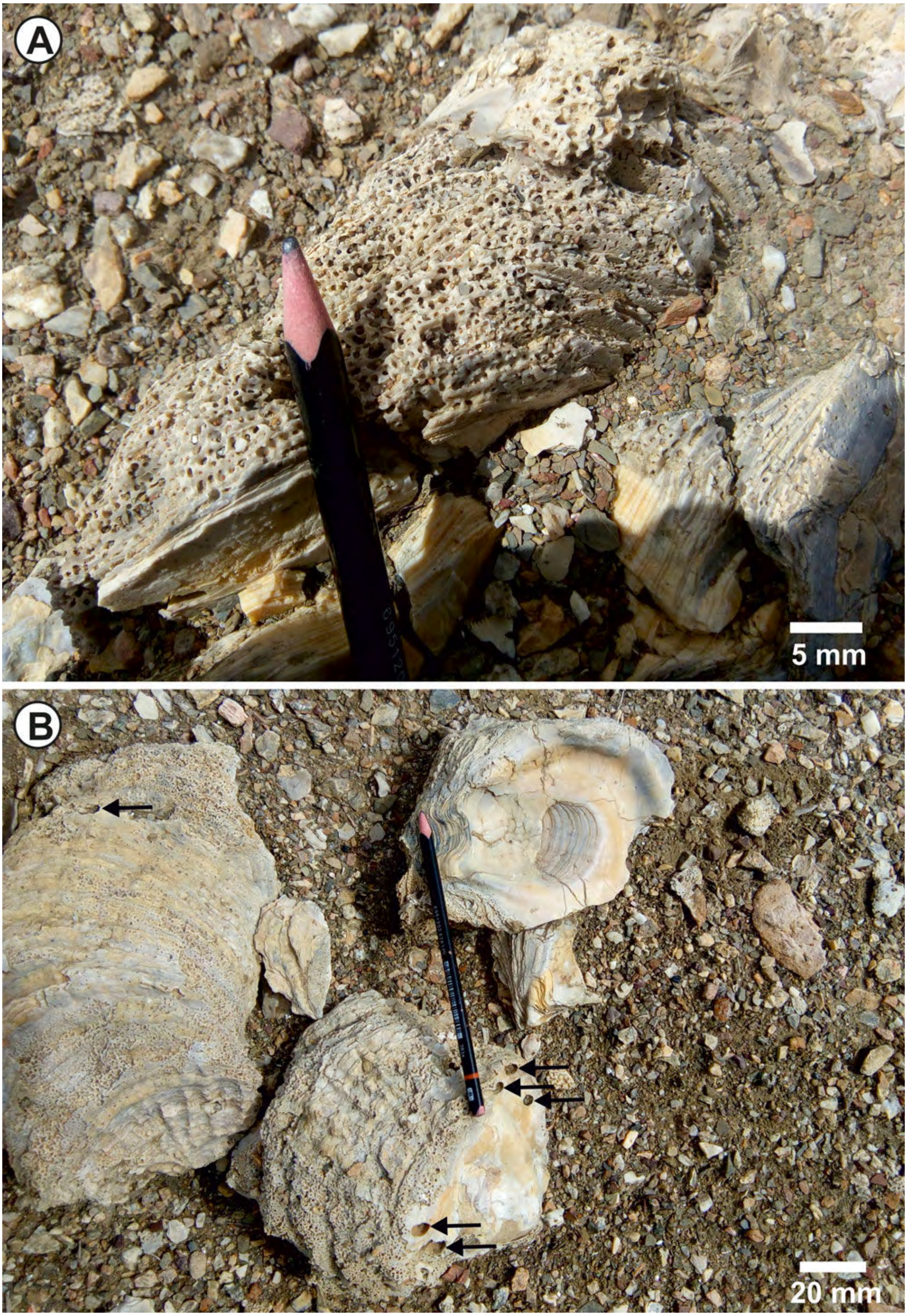

Figure 2: (A) abundant *Entobia* cf. *geometrica* borings in an *O. lamellosa* shell; (B) *O. lamellosa* shells bored by both *Entobia* and *Gastrochaenolites* (arrows indicate *Gastrochaenolites* burrows).

5. Discussion and conclusions

The phenomenon of bioerosion observed in the Messinian deposits of Souk el Khemis (Tafna basin, northwestern Algeria) results from the boring activity of clionid sponges (*Entobia*), sipunculid and polychaete annelids (*Trypanites*) and bivalves (*Gastrochaenolites*). These three domichnial ichnogenera are the most common components of the substrate-controlled *Trypanites* ichnofacies. They are usually associated with other bioerosional ichnotaxa such as *Caulostrepis*, *Maeandropolydora*, *Cochotrema*, and *Ubiglobites* (Glaub & Vogel, 2004; Pemberton *et al.*, 2004). This ichnofacies characterises lithified substrates (hardgrounds) and, more rarely, bone beds and coquinas (Pemberton *et al.*, 2004). In the case of isolated shells and clasts, Bromley and Asgaard (1993) erected the *Gnathichnus* subichnofacies as part of the *Trypanites* ichnofacies, whereas the *Entobia* subichnofacies characterises rocky hardgrounds. Later, MacEachern *et al*. (2007) suggested the use of *Trypanites* ichnofacies, and of both *Gnathichnus* and *Entobia* as expressions of the ichnocoenosis.

The *Trypanites* ichnofacies is characteristic of estuaries (Gingras *et al.*, 2012) and rocky shorelines of shallow-marine siliciclastic systems (Gibert *et al.*, 2012) and carbonate platforms often in subtidal and intertidal environments (Knaust *et al.*, 2012).

In the present study, all the epi- and endobionts are characteristic of a shallow-water environment, and some may also indicate the littoral to sublittoral zone. However the *Entobia-Gastrochaenolites* ichnoassemblage could also indicate a slight deepening, characterised by the replacement of a large oyster-dominated environment by a sponge-dominated environment (Bromley & Asgaard, 1993; Gibert et *al.*, 1998). It may thus confirm the preservation of the late Miocene transgressive phase on the Souk el Khemis shoal, which continued until the development of coral reefs, built by digitate and lobed forms of *Porites lobatosepta* Chevalier, 1961, and concentric colonies of *P. calabricae* Chevalier, 1961, *Tarbellastraea* cf. *reussiana* (Milne-Edwards & Haime, 1850) and *Acanthastrea* sp. (Saint-Martin, 1990).

Moreover the bioerosion and the balanid-barnacle encrustation helps us to reconstruct steps in the late Miocene transgression in this area: (i) the initial transgressive phase: marine pulsations characterised by the occurrence of large oysters encrusted post-mortem by barnacles indicating an intertidal environment; followed by (ii) shallow-tier bioerosion represented by *Trypanites* borings recorded on both oyster shells and barnacle plates; and (iii) a final deepening, indicated by deep-tier borings (*Entobia* and *Gastrochaenolites*), which allowed the establishment of the first Messinian carbonate platform in northwestern Algeria. Alternatively, there was a two-step development of the transgression with a transition from oyster-dominated to sponge-dominated communities.

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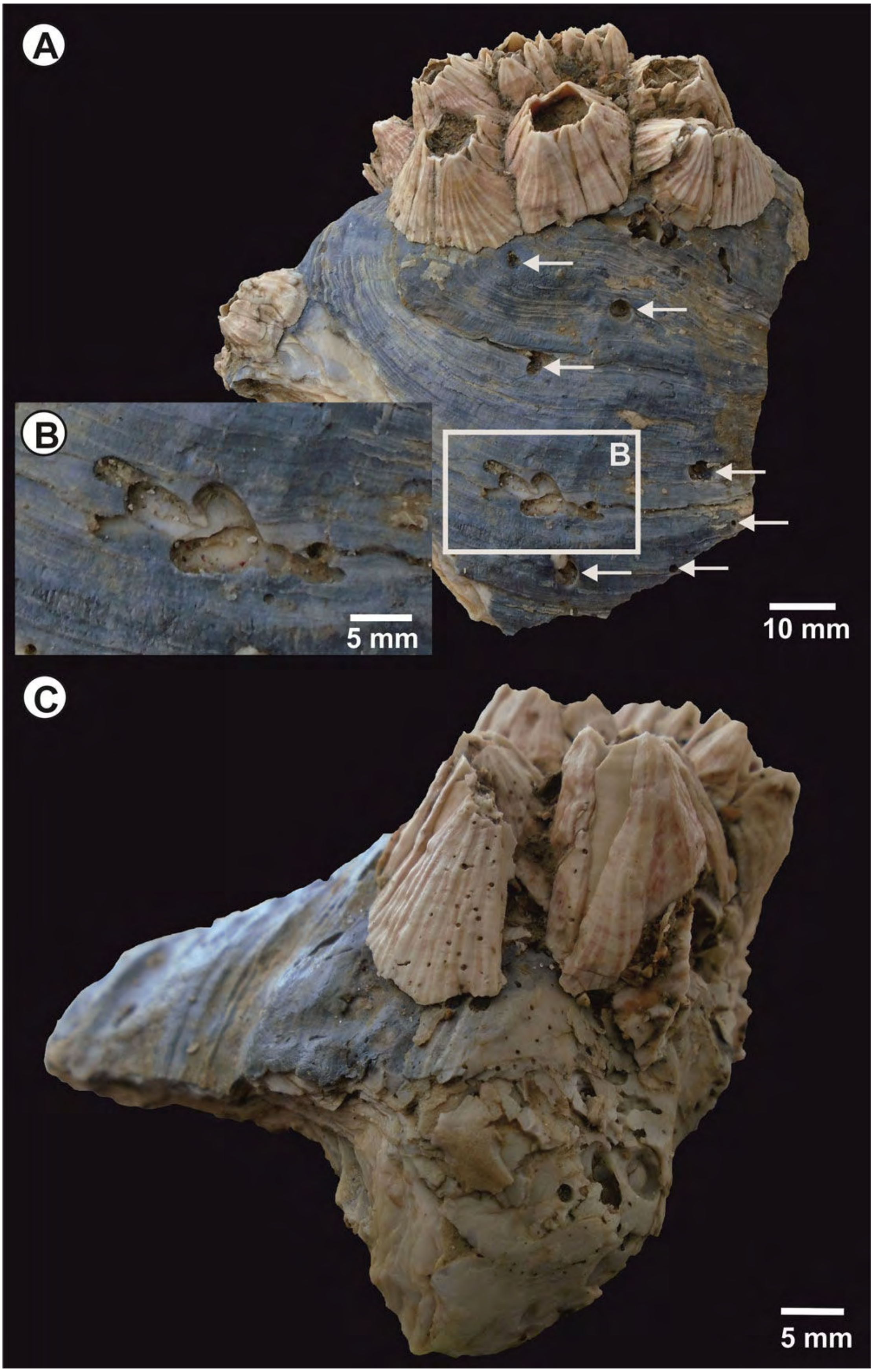

Figure 3: (A) *O. lamellosa* shell encrusted by a cluster of balanid barnacles and bored by *Trypanites* (arrows); (B) undetermined branching boring system on the external shell of *O. lamellosa*; (C) thin *Trypanites* borings on both *O. lamellosa* and barnacles shells.

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