

Lower Devonian rhynchonellid brachiopods from the Ougarta area (western Sahara, Algeria)

DENISE BRICE, KHEIRA BOUMENDJEL, PATRICK R. RACHEBOEUF & BERNARD MOTTEQUIN



The description and study of rhynchonellid brachiopods recently collected from the Lower Devonian of the Ougarta area in western Algerian Sahara permitted the revision of previously described and/or listed taxa, mainly from Morocco. Palaeobiogeographically, the nine identified taxa share many similarities with the rhynchonellid fauna of the Ibarmaghian Domain. Five of the nine identified taxa belong to three genera of the Family Nucinulidae Sartenaer, 2004. Three of these are new taxa, namely *Nucinulus orbignyanus crassicosus* subsp. nov., *Cuninulus ougartaensis* sp. nov. and *Palinulus saharaensis* sp. nov. The four remaining taxa are assigned (one of them questionably) to the genera *Lanceomyonia*, *Stenorhynchia* and *Glossinulus* of the families Hebetoechiidae, Trigonirhynchiidae, and Glossinotoechiidae, respectively. • Key words: Lower Devonian, Western Sahara, rhynchonellid brachiopods.

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The 'Homogénéisation Programme' of the SONATRACH, initiated in 2004, aimed at a detailed biostratigraphic and biogeographic revision of the Cambrian-Devonian succession in the western Algerian Sahara. This program included two field trips in the Ahnet area (2004) and the Ougarta area (2005), respectively. As a result, a first collective work concentrated on the Cambrian–Ordovician time interval, focusing in particular on the Late Ordovician glaciation and its impact on the development of the Lower Palaeozoic transgression on northern Gondwana (Ghienne *et al.* 2007). A second collective study, dealing with the Silurian–Early Devonian time interval is in progress. This paper presents the first results highlighting taxonomical and biostratigraphical aspects. The purpose of this collective work is restricted to the Silurian–Early Devonian time interval, and follows the publication by Wendt *et al.* (2006) dedicated to the Middle and Upper Devonian of the Ahnet and Mouydir (Algerian Sahara).

The present paper is dedicated to the rhynchonellid brachiopods collected in 2004 and 2005 by one of us (P.R.). The discovery of relatively abundant, well-preserved specimens, some of which new taxa, implied the

complete revision of previously described taxa from Western Sahara, including Morocco. This includes the revision of specimens described by Le Maître (1944, 1952) from the Tafilalt (Morocco) and from the Ougarta area (Algeria), and more recently by Boumendjel *et al.* (1997a, b).

The Rhynchonellida described herein belong to the families Hebetoechiidae Havlíček, 1960, Trigonirhynchiidae McLaren, 1965, Glossinotoechiidae Havlíček, 1992, and Nucinulidae Sartenaer, 2004. Following Sartenaer (2004, 2005), who described western European taxa usually assigned to the Family Uncinulidae Rzhonsnitskaia, 1956 and to the genus *Uncinulus* Bayle, 1878, a revision of the North African species formerly attributed to these taxonomic units becomes necessary in order to establish their possible assignment to the different units recently defined (family, genus, species).

Geological setting

From the two Algerian areas studied and sampled, the Ahnet and Ougarta (Fig. 1A) areas, only the second yielded

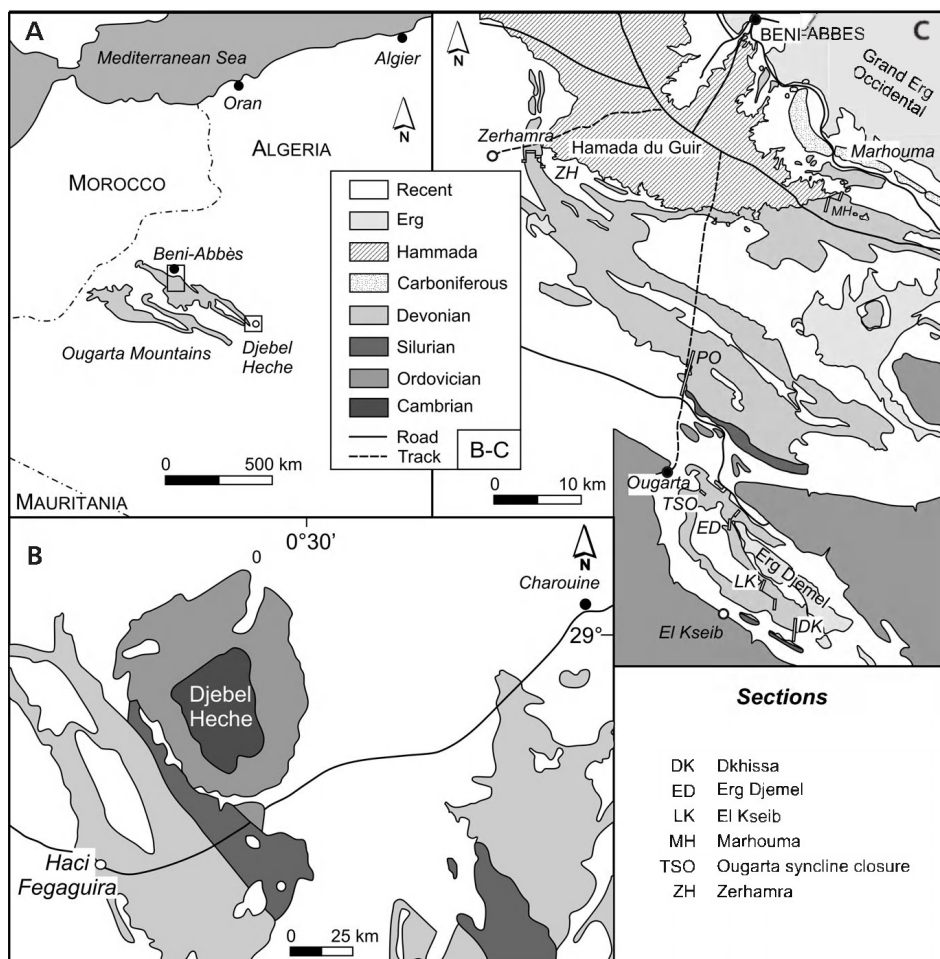


Figure 1. A – simplified map of the Ougarta mountains (modified from Ouali Mehadji *et al.* 2004). • B – simplified geological map of the Hacı Fegaguira area (modified from Service de la Carte géologique de l’Algérie 1952). • C – geological map of the Ougarta area with location of the studied sections and those cited in the text (modified from Boumendjel *et al.* 1997a).

Lower Devonian rhynchonellid brachiopods. All rhynchonellids from the Ougarta area described in this paper have been collected from the Hacı Fegaguira section (also called Jebel Heche section, or Timimoun section in the eastern part of the area), about 35 km WSW of Timimoun town, and from the Marhouma section (‘km 30’ section of the literature).

In the Hacı Fegaguira section (Figs 1B, 2), rhynchonellids were collected in the lowermost part of the Dkhissa Formation. *Lanceomyonia* aff. *occidentalis* was collected in a coquina found 11 m above the base of the formation, and 5 m above the bed with strophochonetids. *?Lanceomyonia borealiformis* was found 5 m higher in the succession, associated with other brachiopods [*Hollandina plana*, *Proschizophoria* sp., *Mclearnites* (*Mclearnites*) cf. *lecaroensis*, etc.] and trilobites (*Acastella tanzidensis*, *Digonus zemmourensis*). *Stenorhynchia briceae* was collected from the top of the ‘barre A’, which is equivalent to the ‘Muraille de Chine’. Specimens collected in 2004 and 2005 from the Marhouma section (Figs 1C, 2) are from the lower part of the Chefar el Ahmar Formation, corresponding to the MH 19–28 sampling interval of Boumendjel *et al.* (1997a). The Nucunulidae Sartenaer, 2004 include fol-

lowing recent study and revision, *Nucunulus orbignyianus crassicosus* subsp. nov., *Cuninulus ougartaensis* sp. nov., *Palinulus saharaensis* sp. nov., and *?Palinulus* sp. These are present in numerous sections (Figs 1C, 2): Marhouma, Hacı Fegaguira, Erg Djemel, El Kseib in upper Emsian (Paris *et al.* 1997) except *Palinulus saharaensis* sp. nov. which is only known with certainty in Tafilalt (Morocco), its presence in Ougarta being uncertain.

Material and methods

The rhynchonellids studied are part of Le Maître (1944, 1952) and Boumendjel *et al.* (1997a, b) collections and some were collected by Racheboeuf in 2005. All sampled localities are situated in Algeria (Ougarta) and Morocco (Tafilalt). Further information on the localities is provided by Le Maître (1944, 1952), Boumendjel *et al.* (1997a), Paris *et al.* (1997) and above.

Le Maître’s collections are deposited in the Faculté Libre des Sciences & Technologies (Lille, France) and catalogued with the prefix GFCL; Boumendjel *et al.* and

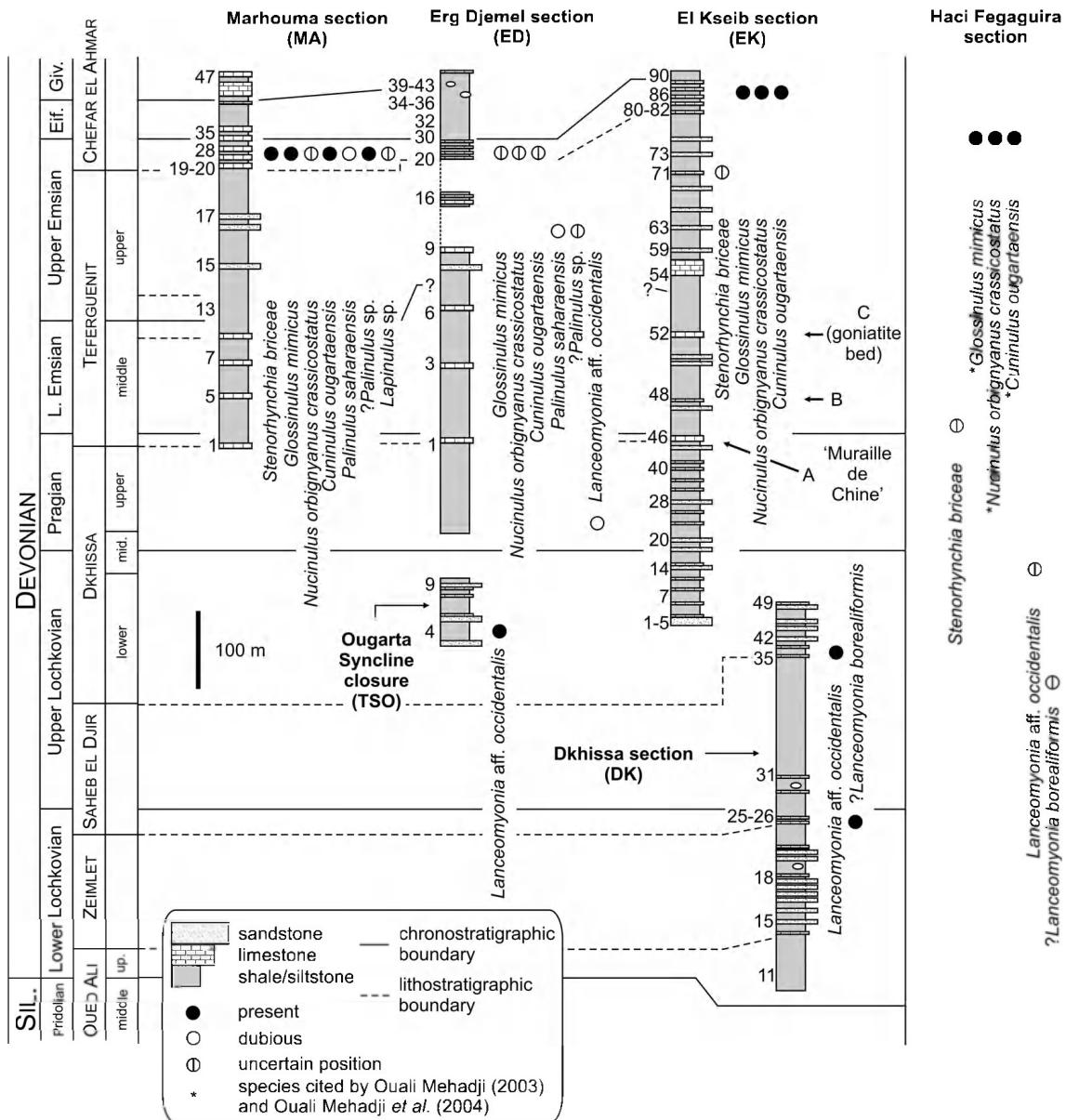


Figure 2. Lithological correlations and age assignment of the Lower Devonian formations identified in the investigated sections of the Ougarta area and distribution of the rhynchonellid brachiopods (modified from Paris et al. 1997).

Racheboeuf’s collections are curated at the Laboratoire de Paléontologie, UFR Sciences et Techniques, Université de Bretagne Occidentale (Brest, France) and indicated by the prefix LPB.

Internal features have been studied by serial transverse sections with preparation of peels and drawings with the camera lucida.

Abbreviations. – Localities: DK – Dkhissa, ED – Erg Djemel, LK – El Kseib, MH – Marhouma, PO – ‘Piste d’Ougarta’, TSO – Ougarta syncline closure, ZH – Zerhamra. Systematic palaeontology: AA – apical angle, DC – dorsal costae, L – length of the shell, LC – lateral costae,

MC – median costae, MPC – median parietal costae, PC – parietal costae, T – thickness of the shell, W – width of the shell, Ws – width of the sulcus.

Systematic palaeontology

Family Hebetoechiidae Havlíček, 1960
Subfamily Hebetoechiinae Havlíček, 1960

Genus *Lanceomyonia* Havlíček, 1960

Type species. – *Terebratula tarda* Barrande, 1847.

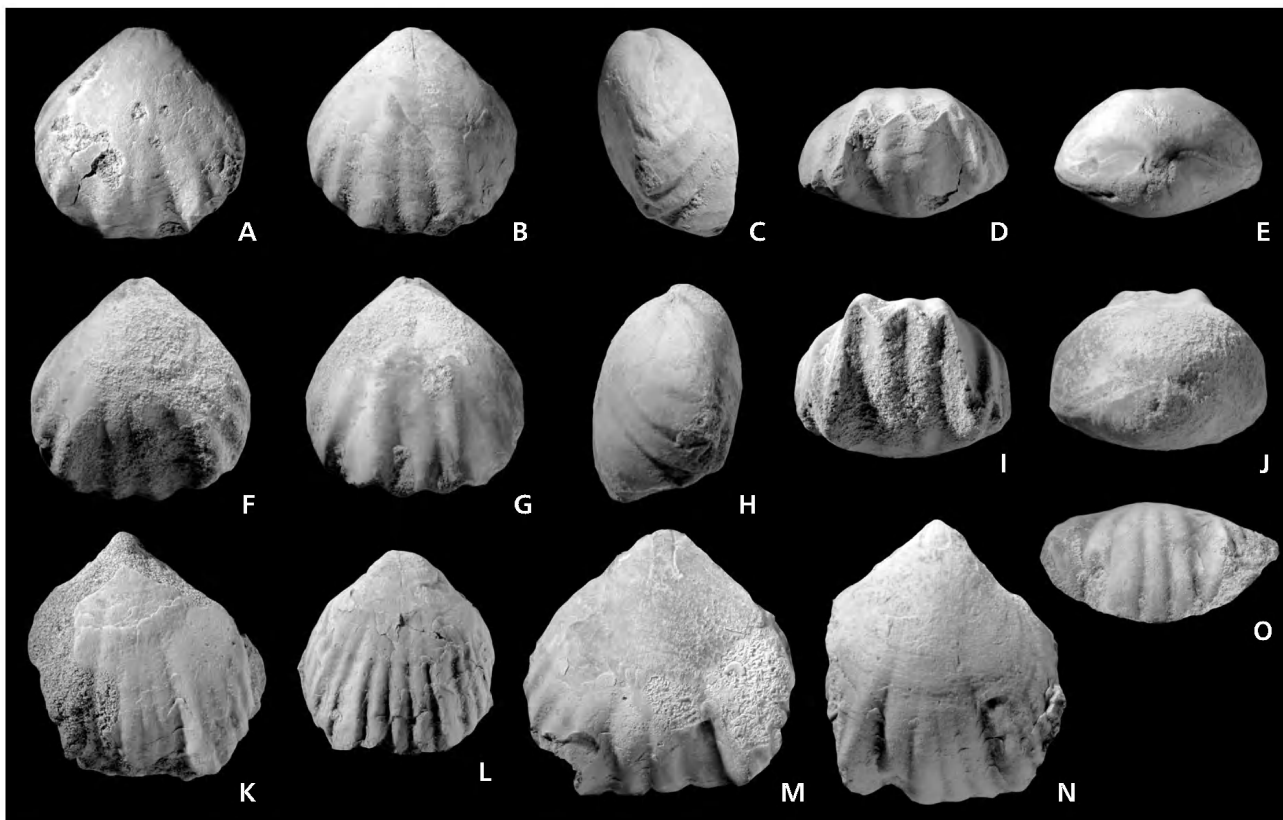


Figure 3. A–J – *Lanceomyonia occidentalis* Drot, 1964. Ougarta, Erg Djemel section, uncertain lithostratigraphic unit, ?lower Pragian. • A–E – articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, GFCL 464 (= ED 121.4). • F–J – articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, GFCL 465 (= ED 121.3). • K, L – *Lanceomyonia* aff. *occidentalis* Drot, 1964. Ougarta, Djebel Heche, Hacı Fegaguira section, base of the Dkhissa Formation, near Lochkovian/Pragian boundary. K – incomplete ventral valve, LPB 15238. L – dorsal valve, LPB 15237. M–O – ?*Lanceomyonia borealiformis* (Siemiradzki, 1906). • M – ventral valve, LPB 15240 (= DK 25), Ougarta, Dkhissa section, top of the Zeimlet Formation, upper part of lower Lochkovian. • N, O – ventral valve in ventral and anterior views, LPB 15241 a, Ougarta, Djebel Heche, Hacı Fegaguira, uncertain lithostratigraphic unit, ?upper Lochkovian. All $\times 2$.

Lanceomyonia occidentalis Drot, 1964

Figures 2, 3A–J, 4A–E

- v. 1952 cf. *Camarotoechia barrandi* Hall. – Le Maître, p. 111.
 1964 *Lanceomyonia borealiformis occidentalis* n. subsp.; Drot, pp. 119–123, pl. 17, figs 10–13, text-figs 53, 54.

Material. – Eight articulated specimens (two juveniles, six adults) from the southeastern part of the Erg Djemel section (ED 121.8) (Le Maître (1952)'s collection).

Description. – Shell small (maximum L: 16 mm; maximum W: 14.9 mm; maximum T: 11.3 mm), dorsibiconvex (L/T: 1.26–1.07), maximum width between mid-length and two-thirds of valve length from posterior margin; frontal margin straight.

Ventral valve weakly convex, with maximum convexity in its posterior part; sulcus wide (Ws/W: 0.65–0.83), shallow, developed in the anterior part of the valve; beak

acuminate, slightly incurved in contact with the dorsal umbo; apical angle varying between 94° and 105° . Dorsal valve with low and well-defined fold originating in its anterior part.

Costae low, rounded, simple (except one case of division observed in a lateral costa), originating about mid-length of the shell, separated by narrower rounded grooves; median costae (MC: 3–4/2–3) wider than lateral ones (LC: 2–3/3–4). Spines and grooves near commissures not observed.

Ventral interior with short and subparallel dental plates; large apical and small open lateral apical cavities. Dorsal interior (Fig. 4A–E) with septum supporting a small open septalium. Ventral and dorsal muscle fields not seen.

Remarks. – These specimens only differ from Drot's (1964) material by a lower number of lateral costae and the absence of parietal costae; they are thus included in *Lanceomyonia occidentalis*, which is variable in outline and ornamentation.

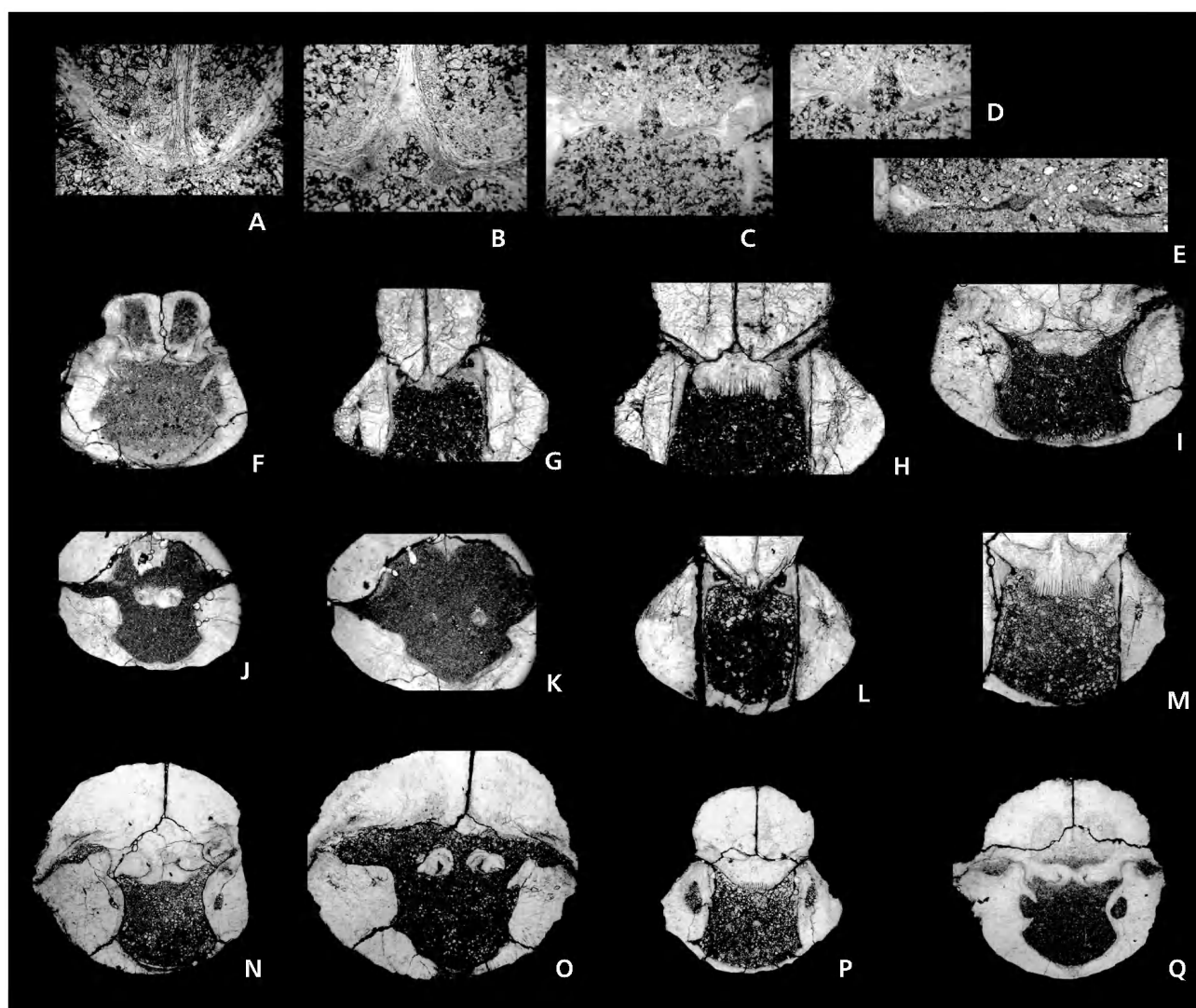


Figure 4. A–E – peels of transverse serial sections of *Lanceomyonia occidentalis* Drot, 1964 (GFCL 466 = ED 121.8) from Erg Djemel section (Ougarta), uncertain lithostratigraphic unit, ?lower Pragian; distances in mm from the top of the ventral umbo are 0.4 (A, $\times 20$), 0.6 (B, 20), 0.7 (C, $\times 15$), 1.0 (D, $\times 15$), and 1.5 (E, $\times 20$). • F–K – peels of transverse serial sections of *Nucinulus orbignyianus crassicosatus* subsp. nov. from El Kseib section (Ougarta), lowest part of Chefar el Ahmar Formation, upper Emsian. F – paratype LPB 15253 (= LK 87–88.10), distance in mm from the top of the ventral umbo is 0.9 ($\times 7.5$). G–K – paratype LPB 15254 (= LK 87.7), distances in mm from the top of the ventral umbo are 0.1 (G, $\times 10$), 0.45 (H, $\times 12$), 1.25 (I, $\times 7.5$), 2.0 (J, $\times 4.4$), and 2.55 (K, $\times 3.5$). • L–Q – peels of transverse serial sections of *Palinulus saharaensis* sp. nov. from section in front of the Hacı Remlia cliff (Morocco, Tafilalt), term 5, upper lower Emsian or lower upper Emsian. L–O – GFCL 468, distances in mm from the top of the ventral umbo are 0.85 (L, $\times 10$), 1.85 (M, $\times 10$), 2.25 (N, $\times 7.5$), and 2.7 (O, $\times 5$). P–Q – GFCL 37, distances in mm from the top of the ventral umbo are 1.4 (P, $\times 5.5$) and 2.2 (Q, $\times 4.9$).

Occurrence. – The material from Ougarta (Fig. 2) has been collected by Le Maître (1952) in the southeastern part of the Erg Djemel, which was assigned by her to upper Siegenian.

The type material of *Lanceomyonia borealiformis occidentalis* (here emended in *L. occidentalis*) comes from the western part of southern Morocco (Dra region) and was collected above the *Howellella mercurii* Zone, attributed to the ‘Gedinnian’ or ?lower ‘Siegenian’ by Drot (1964, p. 119). Jansen *et al.* (2007, fig. 2, p. 13) recorded the species in

southern Anti-Atlas (Dra Valley), in the Lochkovian of the Tadoucht section, level 7, between *Latericriodus woschmidti* and *L. postwoschmidti* conodont zones. Nevertheless, the Lochkovian standard conodont zonation was recently discarded as the *L. postwoschmidti* Zone is older than the *L. woschmidti* Zone (Murphy *et al.* 2004).

Drot (1964, p. 123) also recognized *L. occidentalis* in the Tafilalt, where it is only represented by a single specimen and in numerous Mauritanian localities (‘Zemmour noir’), but pointed out that their age was uncertain.

***Lanceomyonia* aff. *occidentalis* Drot, 1964**

Figures 2, 3K–L

v. 1997b *Lanceomyonia occidentalis* Drot. 1964. – Brice (in Boumendjel *et al.*), p. 106.

Material. – One small articulated specimen (LPB 15239), 12 dorsal valves, one dorsal internal mould, and five ventral valves from Ougarta, Haci Fegaguira section (Djebel Heche), Racheboeuf's 2005 collection. One ventral valve from the Dkhissa section (DK 35) and one specimen from the Ougarta Syncline closure (TSO 4) in Boumendjel *et al.* (1997a, b).

Description. – Ventral valve slightly longer than wide to wider than long, maximum width at mid-valve, slightly convex, maximum height between umbo and mid-length. Sulcus and costae originating at about mid-valve (3 or 4 broad, low, rounded median costae and 4–5 narrower lateral ones).

Dorsal valve rounded subpentagonal in outline, slightly longer than wide to almost as long as wide, maximum width at mid-valve length, regularly convex, with maximum height at about mid-length, more convex than ventral valve, with fold originating at about mid-length or slightly anteriorly. Costae rounded, irregular and sometimes divided, originating at mid-valve or slightly anteriorly, separated by narrower furrows. Trace of median septum reaching about mid-length, 4–6, often 4 median costae, 4–7 lateral costae of which one shows a short median groove.

Measurements in mm. – Articulated specimen (LPB 15239): L: 14.6+; W: 11.6; T: 9.5; dorsal valves: L: 11.9–18?; W: 10.5–18; ventral valves: L: 15.1?–15.7?; W: 13.3–17?

Remarks. – These poorly preserved specimens are tentatively assigned to *Lanceomyonia occidentalis* mainly on the basis of their external similarities. They differ from Drot (1964)'s type material in their costae, which are frequently irregular, sometimes divided and which originate more posteriorly. Moreover, their number is more variable. They probably belong to a new subspecies but, until larger collections are obtained, it is advisable to leave these specimens questionably identified as *L. aff. occidentalis*.

Occurrence. – *Lanceomyonia* aff. *occidentalis* was collected in Ougarta (Fig. 2), from the Haci Fegaguira section (Djebel Heche), in a coquina within the first calcareous sandy bed above the base of the Dkhissa Formation, 5 m above the bed with strophochonetids (coordinates N 28° 52' 01.04"; W 00° 34' 27.86") and the top of the Zeimlet Formation (DK 25) in the Dkhissa section (Boumendjel *et al.* 1997a, fig. 10a–b).

The strophochonetid bed is known in the lower member

of the Dkhissa Formation (Racheboeuf in Boumendjel *et al.* 1997b, p. 104) in the El Kseib section (LK 1, LK 7), Zerhamra section (ZH 1, ZH 2), and in the middle member of the formation in the 'Piste d'Ougarta' section (PO 31, figs 4, 5b, 9a, in Boumendjel *et al.* 1997a) dated respectively upper Lochkovian and Lochkovian/Pragian boundary (Paris *et al.* 1997, fig. 1).

The specimens (DK 35 and TSO 4) from the lower Dkhissa Formation are of upper Lochkovian age (Paris *et al.* 1997).

?*Lanceomyonia borealiformis* (Siemiradzki, 1906)

Figures 2, 3M–O

? 1889 *Rhynchonella borealiformis* n. sp.: Szajnocha, p. 194 (*nomen nudum*).

? 1906 *Rhynchonella borealiformis* Szajnocha. – Siemiradzki, pp. 258, 259, pl. 21, figs 3a–d, 4, 5.

v. 1997b ?*Lanceomyonia borealiformis*. – Brice (in Boumendjel *et al.*), p. 105.

Material. – Two incomplete ventral valves, one ventral internal mould and one incomplete dorsal valve from the Haci Fegaguira section (Ougarta, Djebel Heche, Racheboeuf's 2005 collection); one ventral valve from the Dkhissa section (DK 25), Boumendjel *et al.* (1997b, p. 105) collection.

Description. – Ventral valve slightly wider than long, rounded, subpentagonal in outline, regularly moderately convex; sulcus developed anteriorly. Umbones smooth, costae originating at about the mid-length of the valve. Ornamentation consists of four broad, low, rounded median costae and seven lateral costae. Ventral internal mould with scars of short dental plates ventrally convergent and muscle field strongly impressed in the valve, which is bounded by marked ridges.

Remarks. – These badly preserved specimens are questionably assigned to *Lanceomyonia borealiformis* (Siemiradzki, 1906) as they are similar in size, outline, sulcus and ornamentation, and partly in internal morphology. The absence of articulated specimens did not permit to observe longitudinal grooves on *paries geniculatus*, marginal spines, dorsal septum and septalium. The incomplete ventral valve from the Dkhissa section (LPB 15240 = DK 25), attributed by one of us (D.B.) (Fig. 3M), differs by its ephibic form, and by its number of costae (three broad, low, rounded median costae and four lateral costae).

Occurrence. – In Ougarta (Fig. 2), ?*Lanceomyonia borealiformis* has been collected in two sections: the Haci Fegaguira section, in the first thick calcareous sandstone bed

which yields the *Hollardina* fauna (N 28° 52' 00.69"; W 00° 34' 27.86") (Racheboeuf, field notes), and in the Dkhissa section (Boumendjel *et al.* 1997a, p. 85, figs 10a, b), at the base of Saheb et Djir Formation, near the lower/upper Lochkovian boundary (Paris *et al.* 1997, fig. 1). Drot (1964, p. 119) pointed out that some forms of the *Wilsonia tarda* group were described in the upper Ludlow in Saoura by Poueyto (*in* Alimen *et al.* 1952), but stressed that this identification needs to be confirmed after revision.

In Morocco, *L. borealiformis* has been described by Drot (1964, p. 116) from the western part of southern Morocco (Dra region) in beds of 'Gedinnian' to ?lower 'Siegenian age' (beds with *Acastella* cf. *rouaulti*). Furthermore, Drot (1964, p. 119) indicated that some forms of the *W. tarda* group were collected in the Meseta (Gigout 1951, p. 304) in localities assigned to the Ludlow and Wenlock but probably younger in age.

Moreover, according to Drot (1964, p. 119), *L. borealiformis* is present in Mauritania ('Zemmour noir') but very rare in beds of early 'Gedinnian' age bearing *Acastella tiro* (Sougy, 1961).

Family Trigonirhynchiidae McLaren

in Schmidt & McLaren, 1965

Subfamily Trigonirhynchiinae McLaren

in Schmidt & McLaren, 1965

Remarks. – In the first edition of the *Treatise on Invertebrate Paleontology, part H (Brachiopoda)*, McLaren (1965, p. H559) is identified as the author of the Family Trigonirhynchiidae. The same year, Schmidt (1965, p. 2) established Trigonirhynchiidae fam. nov.; Savage (1996, p. 252, 2002, p. 1052) considers Schmidt (1965) as author of the Family Trigonirhynchiidae and Subfamily Trigonirhynchiinae.

Genus *Stenorhynchia* Brice, 1981

Type species. – *Terebratula nymphe* Barrande, 1847.

Stenorhynchia briceae García-Alcalde (*in* Truyols-Massoni & García-Alcalde, 1994)

Figures 2, 5, Tables 1–2

- v. 1944 *Camarotoechia nymphe* (Barrande). – Le Maître, pp. 47, 48, pl. 6, figs 25, 26.
- v. 1952 *Camarotoechia nymphe* (Barrande). – Le Maître, p. 112, pl. 21, figs 40, 41.
- 1994 *Stenorhynchia briceae* nov. sp.; García-Alcalde (*in* Truyols-Massoni & García-Alcalde), pp. 232, 233, pl. 3, figs 11–16.

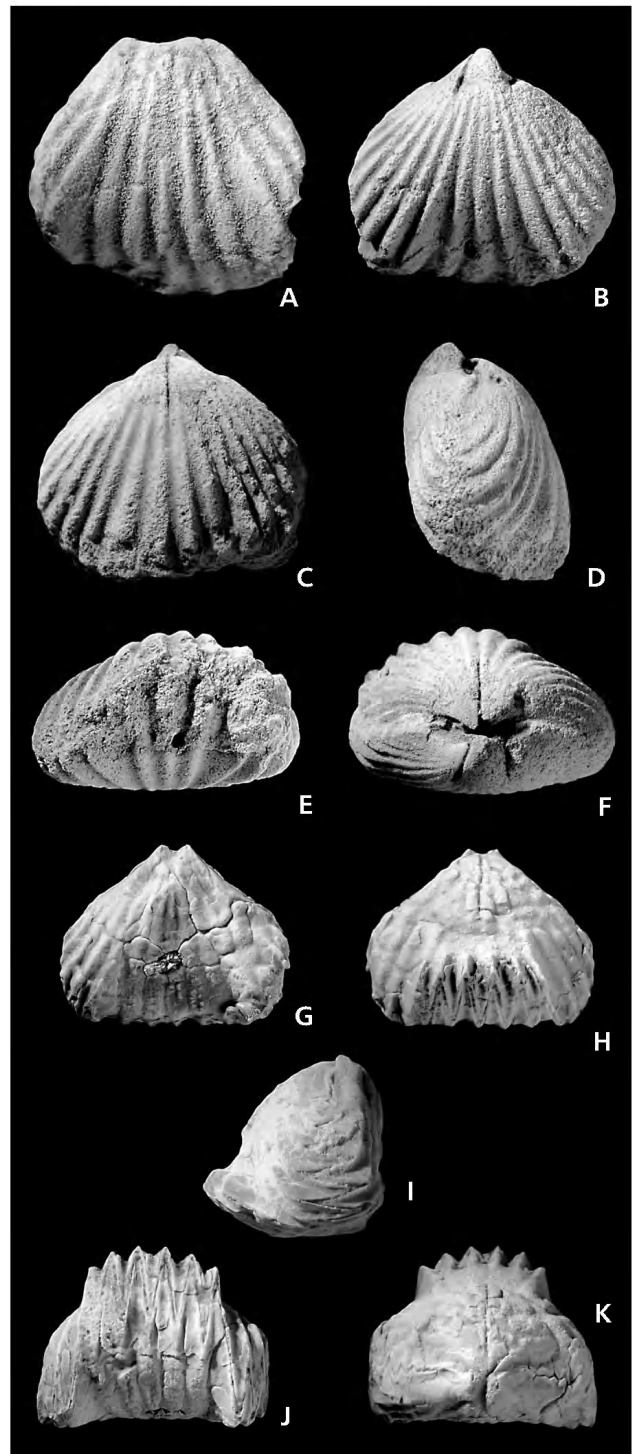


Figure 5. A–K – *Stenorhynchia briceae* García-Alcalde (*in* Truyols-Massoni & García-Alcalde, 1994). • A – ventral valve, GFCL 467 (= EK 30), from El Kseib. • B–F – articulated internal mould in ventral, dorsal, lateral, anterior, and posterior views, LPB 15242, from Ougarta, Djebel Heche, Hacı Fegaguira section, 12 m below bank B, Grès de Benyassin Formation, ?base of Emsian. • G – articulated specimen in ventral view, LPB 15243, Ougarta, Marhouma section, Chefar el Ahmar Formation (MH 19–28), upper Emsian (MH 19–28). All × 2.

Table 1. Measurements in mm of *Stenorhynchia briceae* García-Alcalde (in Truyols-Massoni & García-Alcalde 1994).

	LPB 15243	LPB 15242	GFCL 30	GFCL 31	GFCL 796	GFCL 427 (ventral valve)
L	12.1	15.5	11.1	14.3	12.9	?
W	14.8	18.3	15.7	16.9	15.5	17.4
T	11.5	12.1	9.9	10.1	7.4	–
AA	101°	105°	106°	105°	111°	100°?
MC	5/4	?/3	5/5	6/5	6/5	3
PC	0–1/0–1	?/1–1	1–0/0–0	0	0	1–1
LC	5/5	7–?/7–7	7–6/7–6	5–6/5–5	7–7/6–7	?
L/W	0.82	0.85	0.71	0.85	0.83	–
T/W	0.78	0.66	0.63	0.60	0.48	–
Ws/W	0.69	0.69	0.68	0.71	0.65	0.70

Table 2. Comparison between external characters of *Stenorhynchia briceae* García-Alcalde (in Truyols-Massoni & García-Alcalde, 1994) and *Xahetomus hexadaleidensis* Sartenaer, 2009 (* = data from type material, J = juvenile specimens).

	<i>S. briceae</i> Asturias (Cabo La Vela)	<i>S. briceae</i> Armorican Massif (La Lézaïs)	<i>X. hexadaleidensis</i> Eifel (Wiltz beds)
L* (mm)	8.7–15.8 (J: 4.6–6.7)	–	5.9–10.8
W* (mm)	9.4–17.8 (J: 4.6)	–	15.6–26
T* (mm)	4.3–11.5 (J: 3.6)	–	8.6–14.8
L/W*	0.87–0.98 (J: 0.84)	–	0.70–0.95, mostly 0.84–0.89
MC	6/5 (80%), 7/6 (10%), 5/4 (10%)	5–7/4–6, mostly 6/5	6/5 (43%), 4/3 (32%), 5/4 (20%), 3/2 (5%)
PC	–	mostly absent but one median or one lateral costa could be considered as parietal one	0 (76%), 1–1/1–1 (10%), 0–1/0–1 (7%), 1–0/1–0 (7%)
LC	20–25 costae on each valve	6–10, mostly 6/7 (50%)	8/9 (43%), 7/8 (25%), 9/10 (23%), 10/11 (7%), 11/12 (2%)
Ws	60 to 65% of the width	–	55 to 73%, mostly 65 to 73% of the width

Material. – Algeria, Ougarta: two specimens (LPB 15243) from Marhouma section, MH 19–28; LPB 15242 from Haci Fegaguira section, Racheboeuf’s 2005 collection, three ventral valves of which one (GFCL 427) was illustrated by Le Maître (1952, fig. 40) and one dorsal valve (GFCL 428) figured by Le Maître (1952, fig. 41) from El Kseib section, Le Maître’s (1952) collection. Morocco, Tafilalt: Haci Remlia term 5, three specimens of which two (GFCL 30, 31) illustrated by Le Maître (1944, figs 25, 26), Le Maître’s (1944) collection.

Description. – Shell subtriangular to subpentagonal in outline, dorsibiconvex, wider than long, maximum width anteriorly; anterior commissure strongly serrate, uniplicate.

Ventral valve almost plane, maximum convexity located posteriorly; beak suberect; sulcus wide (Ws/W: 0.65–0.70), originating near the beak, flat-bottomed, moderately developed at the front; tongue curved and low (except for LPB 15243). Dorsal valve slightly convex with maximum thickness at or near the anterior commissure.

Shell covered by simple, subangular costae originating at beak; parietal costae sometimes present.

Ventral interior with short dental plates. Dorsal interior with septum. Muscle fields not observed.

Measurements. – See Table 1.

Remarks. – The species *briceae* is maintained in the genus *Stenorhynchia* Brice, 1981 and not assigned to the genus *Xahetomus* Sartenaer 2009 as Sartenaer (2009, p. 34) suggested. According to one of us (D.B.), *X. hexadaleidensis* Sartenaer, 2009, the type species of *Xahetomus*, could be a synonym of *S. briceae* García-Alcalde (in Truyols-Massoni & García-Alcalde, 1994) as it has a similar strongly dorsibiconvex profile, a strongly serrate commissure and other external characters (Table 2). However, internally, it appears that the characters of *X. hexadaleidensis* as illustrated by the drawings of Sartenaer (2009, fig. 1c) need to be documented.

In spite of several differences, the specimens from Ougarta are assigned to *S. briceae*. The three specimens from Haci Remlia (Morocco) are similar to specimen LPB15242 from the Haci Fegaguira section in Ougarta, which is characterized by a weakly dorsibiconvex shell

and a tongue lower than that of specimen LPL15243 from the Marhouma section. The type specimens of *S. briceae* from the La Ladrona Formation in Spain (Arnao, Asturias) present comparable variations in the L/W and T/W ratios. For the Spanish material, these ratios vary between 0.84–1 (Ws: 0.71–0.85 for the described material) and between 0.45–0.76 (Ws: 0.48–0.78), respectively.

Occurrence. – *S. briceae* García-Alcalde (in Truyols-Massoni & García-Alcalde, 1994) is known in the Ibarmaghian Domain (*sensu* Plusquellec 1987), in the lower/upper Emsian boundary at Cabo la Vela in Spain (Asturias) according to García-Alcalde (in Truyols-Massoni & García-Alcalde, 1994), and in the upper Emsian Les Marettes Formation at La Lézais in the Armorican Massif (Brice 1981). The species is recognized for the first time in Algeria (Ougarta) in three sections (Fig. 2): Marhouma section (MH 19–28) in the lowest part of Chefar el Ahmar Formation, upper Emsian in age (Paris *et al.* 1997, fig. 1, p. 118) associated with *Glossinulus mimicus* (Barrande, 1879), in the Hacı Fegaguira section, and in the El Kseib section where its precise position is uncertain. The species is also present in Morocco (Tafilalt), in the Hacı Remlia section, term 5, where it is associated with *Palinulus saharaensis* sp. nov.

Family Glossinotoechiidae Havlíček, 1992

Genus *Glossinulus* Schmidt, 1942 em. Havlíček, 1961

Type species. – *Rhynchonella adolphi mimica* Barrande, 1879.

Glossinulus mimicus (Barrande, 1879)

Figures 2, 6–7, Table 3

- 1879 *Rhynchonella Adolphi* Barrande var. *mimica*; Barrande, p. 178.
- 1942 *Uncinulus (Glossinulus) adolphi mimicus* (Barr.) – Schmidt, p. 394, figs 16, 17.
- v. 1952 *Uncinulus kayseri* (Barrois) (= *U. adolphi mimicus* Barr.) – Le Maître (in Alimen *et al.*), p. 58, figs 12, 13.
- v. 1952 *Uncinulus kayseri* (Barrois) (= *U. adolphi mimicus* Barr.) – Le Maître, p. 116, pl. 21, figs 35–39.
- 1964 *Glossinulus mimicus* (Barrande, 1879). – Drot, p. 143, pl. 16, figs 1, 2, 14–17, text-figs 62, 63.
- v. 1997b *Glossinulus mimicus* (Barrande, 1879). – Brice (in Boumendjel *et al.*), p. 106.
- 2003 *Glossinulus mimicus* (Barrande, 1879) (= *Uncinulus kayseri* [Barrois, 1882]). – Ouali Mehadji, p. 138, pl. 3, fig. 6.

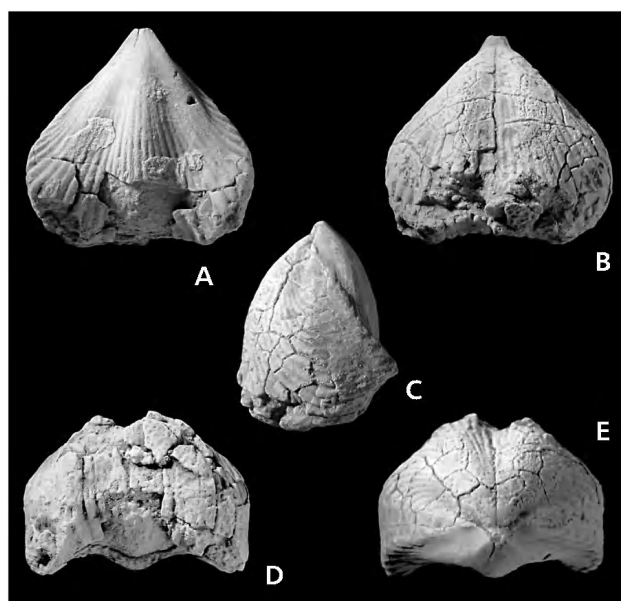


Figure 6. A–E – *Glossinulus mimicus* (Barrande, 1879). Ougarta, Marhouma section, lowest part of Chefar el Ahmar Formation (MH 19–28), upper Emsian. Articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, LPB 15241. All $\times 2$.

Material. – Nineteen specimens from Ougarta: five specimens from Marhouma section, Racheboeuf's 2005 collection; eight specimens from Erg Djemel (ED 12: six specimens, ED 35: one specimen, ED 101: one specimen); five specimens from El Kseib section (EK 24), Le Maître's (1952) collection and LK 82 (one incomplete specimen); LK 86 (two specimens); LK 87 (one specimen); LK 88 (one specimen), in Boumendjel *et al.* (1997b) collections.

Description. – Shell triangular in outline, small-sized (up to 17.2 mm in length), dorsibiconvex, posteriorly acuminate; anterior and lateral margins truncated, *paries geniculatus*, *squamae*, *glottae* with spine-like projections present.

Ventral valve slightly convex in umbonal region then flattened to concave anteriorly; beak suberect, limited laterally by rounded crests; sulcus weak, not clearly defined; tongue higher than wide, almost flat and rectangular, with median crest or fold attenuated on the tongue. Dorsal valve convex without distinct fold with a weak median sulcus; maximum height anteriorly.

Costae numerous, fine, rounded, originating near the umbones.

Ventral interior (Fig. 7) lacking dental plates, small lateral apical and large apical cavities. Dorsal interior (Fig. 7) with high rectangular cardinal process with short ridges.

Measurements. – See Table 3.

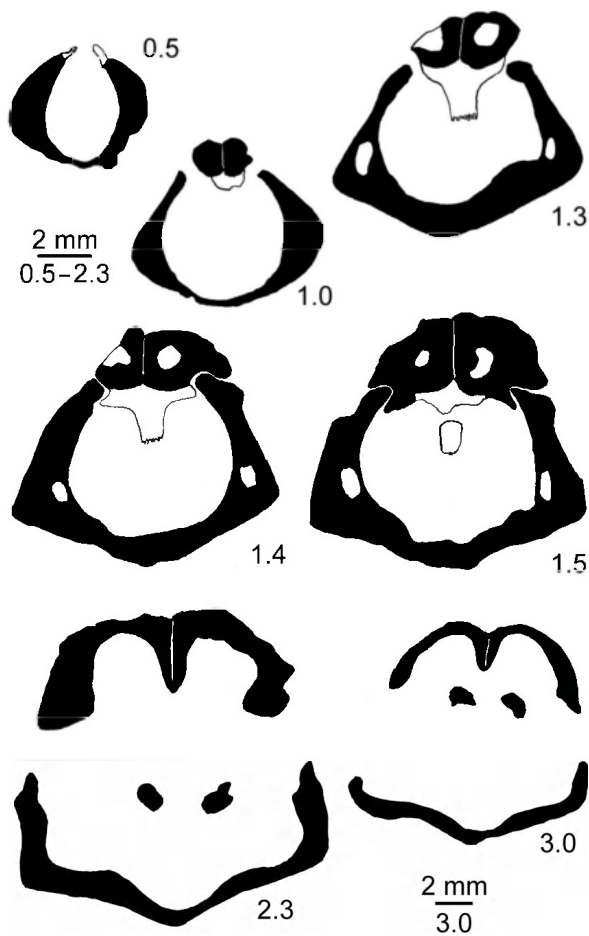


Figure 7. Transverse serial sections of *Glossinulus mimicus* (Barrande, 1879). Numbers refer to distances in mm from the top of the ventral umbo; LPB 15244 from the Marhouma section (Ougarta, Algeria), lowest part of Chefar el Ahmar Formation (MH 19–28), upper Emsian.

Table 3. Measurements in mm of *Glossinulus mimicus* (Barrande, 1879). Abbreviations: MH – Marhouma; ED – Erg Djemel; EK, LK – El Kseib.

	MH (5)	ED (7)	EK, LK (8)
L	11.7–15.9	10.5–17.2	9.8–15.5
W	13.1–15.7	11.2–17.5	9.2–16.4
T	12.2–14.5	8.2–14.05	7.5–12.9
AA	83°–90°	80°–91°	79°–91°
MC	11–16/10–15	12?/13–16	13?/14
LC	16–18?	17?	20?
L/W	0.89–1.03	0.96–1.02	0.95–1.18
L/T	0.98–1.28	1.17–1.27	1.16–1.4
Ws/W	0.64–0.76	0.61–0.7	0.66–0.72

Remarks. – Specimens from the Marhouma section share characters with the type material of *Glossinulus mimicus* from Bohemia, while some specimens from Erg Djemel and El Kseib are characterized by a very variable shell size, often smaller than that observed in the type material.

Occurrence. – In Algeria (Ougarta) (Fig. 2), some forms from Erg Djemel and El Kseib, which were identified as *Uncinulus kayseri* by Le Maître (1952) and collected from the *Paraspirifer cultrijugatus* Zone, were assigned to *Glossinulus mimicus* by Brice (in Boumendjel *et al.* 1997b). Barrande’s (1879) species has also been recorded within the Marhouma (‘km 30’), Erg El Djemel and Hacı Fegagura sections, in the upper to uppermost Emsian by Ouali Mehadji (2003, figs 15–17).

Furthermore, *G. mimicus* has been recognized in the upper Emsian of southern Morocco and in Maïder-Tafilalt by Drot (1964, p. 146) and in the southern border of the Tindouf syncline. According to this author, it also occurs in the Emsian of northern Mauritania (Zemmour).

Family Nucinulidae Sartenaer, 2004

Genus *Nucinulus* Sartenaer, 2004

Type species. – *Terebratula Orbignyana* de Verneuil, 1850.

Nucinulus orbignyanus crassicosus subsp. nov.

Figures 2, 4F–K, 8–10; Tables 4–5

- ?1971 *Uncinulus orbignyanus* (de Verneuil, 1850). – Drot, p. 70, pl. 1, fig. 2a–c.
- v. 1997b *Uncinulus orbignyanus* (de Verneuil, 1850). – Brice (in Boumendjel *et al.*), p. 106.
- 2003 *Uncinulus orbignyanus* (de Verneuil, 1850). – Ouali Mehadji, p. 129, pl. 3, fig. 3.

Types. – Holotype: LPB 15245 (= LK 87.6) (Fig. 8A–E) from El Kseib section. Paratypes: LPB 15246 (= LK 87.8) (Fig. 8J), LPB 15247 (= LK 87–88.4) (Fig. 8F–I), LPB 15248 (= LK 87–88.5) (Fig. 8K–O), LPB 15249–15253 (Figs 4F, 9) (= LK 87–88.6, 7, 8, 9, 10), same locality and level as holotype.

Type horizon and locality. – Lowest part of the Chefar el Ahmar Formation (uppermost Emsian), between LK 86–LK 88 (Boumendjel *et al.* 1997b, fig. 1, p. 74, fig. 9c, p. 84), El Kseib section (Ougarta).

Material. – Twenty-two specimens from the El Kseib section (LK 85–86, 86, 87, 87–88, 91) = *Uncinulus orbignyanus* (Brice in Boumendjel *et al.* 1997b, p. 106); nineteen specimens from El Kseib (EK 21, 24) and three from Erg Djemel (ED 12), Le Maître’s (1952) collection; four specimens and one fragment from Marhouma section (MH 19–28), Racheboeuf’s 2005 collection; six specimens from the Marhouma section (MA 98, MA 110), Le Maître’s (1952) collection.

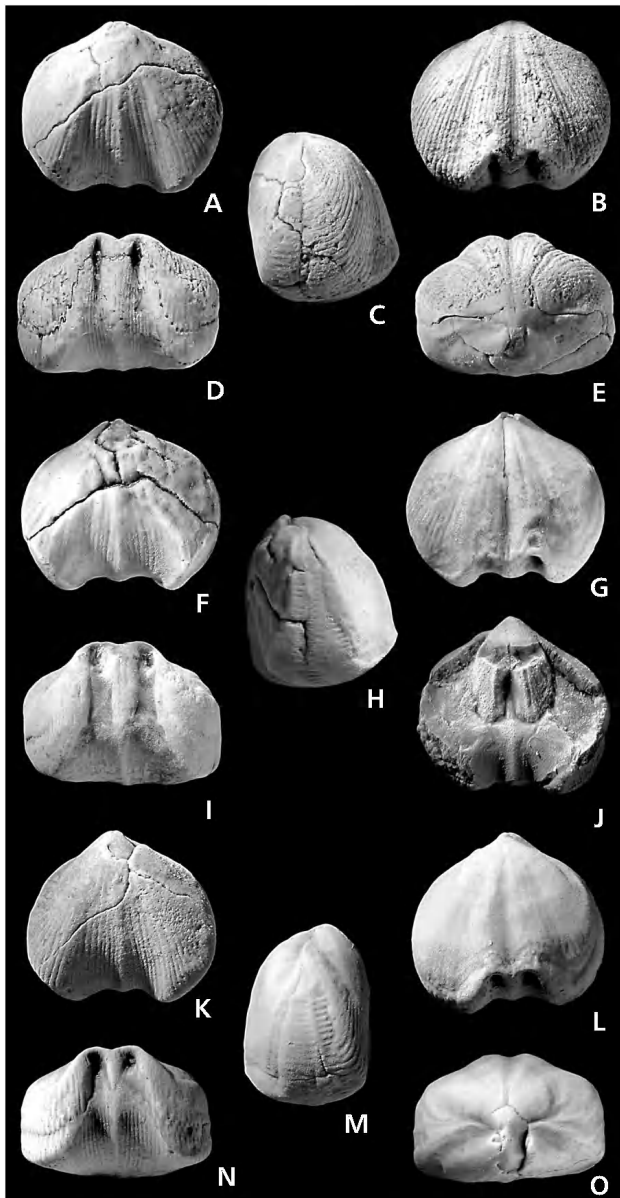


Figure 8. A–O – *Nucinulus orbignyianus crassicosus* subsp. nov. Ougarta, El Kseib section, lowest part of Chefar el Ahmar Formation, upper Emsian. • A–E – articulated specimen in ventral, dorsal, lateral anterior, and posterior views, holotype LPB 15245 (= LK 87.6). • F–I – articulated specimen in ventral, dorsal, lateral, and anterior views, paratype LPB 15247 (= LK 87–88.4). • J – articulated internal mould in ventral view, paratype LPB 15246 (= LK 87.8). • K–O – articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, paratype LPB 15248 (= LK 87–88.5). All $\times 2$.

Etymology. – The name refers to the ornamentation, characterized by fewer and wider costae than the type species of the genus *Nucinulus*.

Diagnosis. – Subspecies of *Nucinulus orbignyianus* with fewer, wider costae than type species, and ventral apical cavities less developed.

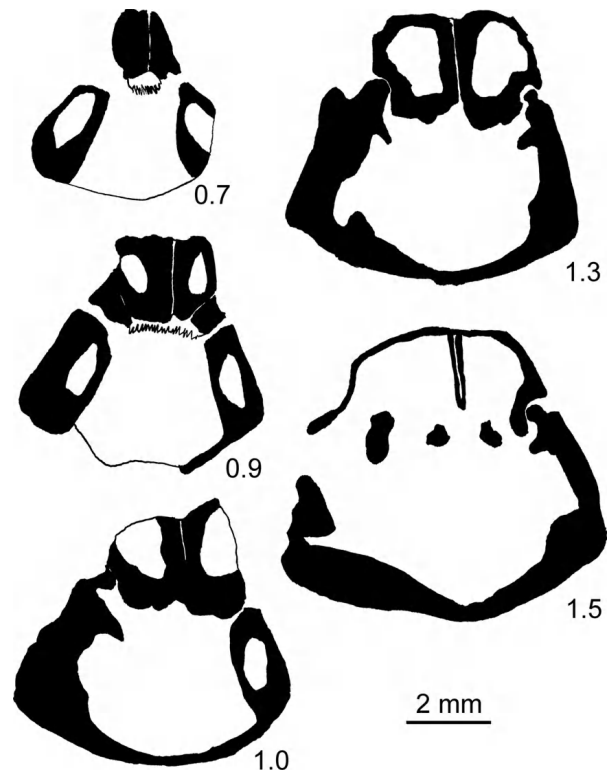


Figure 9. Transverse serial sections of *Nucinulus orbignyianus crassicosus* subsp. nov. Numbers refer to distances in mm from the top of the ventral umbo; LPB 15253 from El Kseib section (Ougarta, Algeria), lowest part of Chefar el Ahmar Formation, upper Emsian (LK 87–88.10).

Description. – Shell small (up to 12 mm in length), strongly dorsibiconvex, rounded or subpentagonal in outline, wider than long, maximum width slightly anterior to mid-length.

Ventral valve weakly convex, almost flat; beak short, curved on dorsal umbo; sulcus shallow to moderately deep, not clearly defined, always divided by a median ridge and originating close to the beak; tongue clearly delimited laterally; frontal part depressed by two cavities similar to nostrils of Drot (1964, p. 150) or named ‘M’-shaped front by Sartenaer (2004, p. 82). Dorsal valve with maximum height situated slightly posteriorly to the front; fold low, divided by a median groove from beak to the anterior margin.

Costae low and rounded, showing divisions and rare intercalations and originating near the umbones. Separate counts of parietal and median costae are difficult. Number and width of median costae are variable, while lateral ones are regular and flattened with median grooves corresponding to spine projections on *paries geniculatus*; bundles always absent.

Ventral interior (Figs 4F–K, 9, 10) with large deltidial plates observed in serial sections; dental plates short, weakly divergent then usually converging towards the valve floor; teeth stout; central apical cavity large contrary to lateral apical ones; muscle field prominent on internal

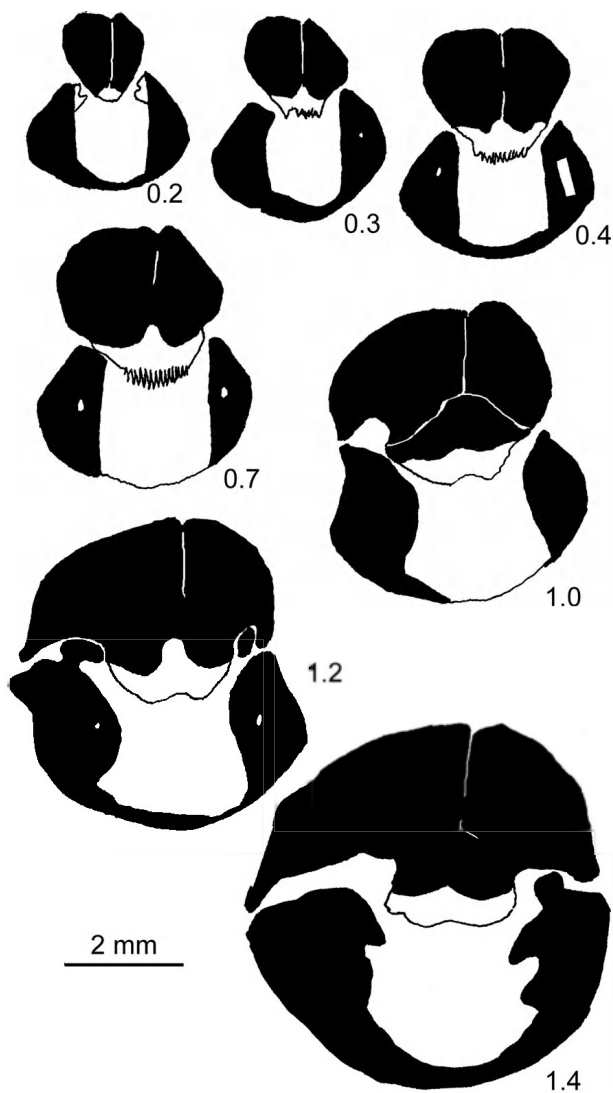


Figure 10. Transverse serial sections of *Nucinulus orbignyanus crassicostatus* subsp. nov. Numbers refer to distances in mm from the top of the ventral umbo; LPB 15254 from El Kseib section (Ougarta, Algeria), lowest part of Chefar el Ahmar Formation, upper Emsian (LK 87.7).

mould, oval, divided by a groove (Fig. 8J), deeply impressed in the shell floor and divided by a thin ridge. Dorsal interior (Figs 4F–K, 9, 10) with thick hinge plate and small septalium filled by a callus; short cardinal process composed of numerous ridges (about 22) and covering the whole hinge plate; septum stout supporting septalium up to the articulation; apical cavity partly filled by callus; muscle field not observed.

Measurements. – See Table 4.

Remarks. – The specimens from Ougarta are similar to *Nucinulus orbignyanus* (de Verneuil, 1850) by their external and some internal characters, but they differ from the type material by wider and fewer median and lateral costae, and by ventral apical cavities variably developed. These differences (see Table 5) justify the new subspecies *N. orbignyanus crassicostatus*. Some specimens from Erg Djemel (El Kseib, LK 87) are questionably attributed to the species because their apical angle as well as the T/W and T/L ratios are smaller than those observed in the types.

Occurrence. – In Ougarta (Fig. 2), *Nucinulus orbignyanus crassicostatus* occurs in the lowest part of the Chefar el Ahmar Formation of uppermost Emsian in age (Paris *et al.* 1997, fig. 1, p. 118), where it is known from numerous sections usually associated with *Glossinulus mimicus* in El Kseib, Erg Djemel, and Marhouma sections. Ouali Mehadji (2003, p. 129) describes *Nucinulus orbignyanus* (= *N. orbignyanus crassicostatus*) from Marhouma ('km 30'), Erg Djemel and Hacı Fegaguira sections in the same upper Emsian level (Ouali Mehadji 2003, figs 15–17).

Genus *Cuninulus* Sartenaer, 2005

Type species. – *Cuninulus melanopotamicus* Sartenaer, 2005.

Table 4. Measurements in mm of type specimens of *Nucinulus orbignyanus crassicostatus* sp. nov.

LPB	15245	15247	15248	15250	15251	15252	15253	15254	15255
L	9.9	10.7	10.7	9.65	10	?	9	10.2	12
W	12.2	12.1	11.7	12	13.1	10.8	11.4	12.2	15
T	10	8.95	?	8.95	9.3	9	8.4	9.5	12.2
AA	100°	107°	?	116°	109°	112°?	110°	102°	114°
MC	12?	12?	17	?	?	12?	?	12?	12?
PC	3–4	4?	5?	?	4?	?	?	3–4	4–5
LC	14	18+	?	14+	16+	?	?	14	13?
L/W	0.81	0.88	0.91	0.80	0.76	?	0.79	0.84	0.8
T/L	0.82	0.74	?	0.75	0.71	0.83	0.74	0.79	0.81
T/W	1.01	0.84	?	0.93	0.93	?	0.93	0.93	1.02

Table 5. Comparisons between measurements of type specimens of *Nucinulus orbignyianus* (de Verneuil, 1850) and *N. orbignyianus crassicosus* subsp. nov. from Ougarta: Racheboeuf's 2005 (R) collection, Le Maître's (1952) collection (MA, ED, EK), and Boumendjel et al. (1997b) collection.

	<i>Nucinulus orbignyianus crassicosus</i>					<i>Nucinulus orbignyianus</i>
	R (4)	MA 98, 110 (6)	ED (3)	EK 21, 24	LK 85–88, 91	
L/W	0.85–0.91	0.8–0.88	0.79–0.86	0.82–1 (16)	0.76–0.95 (13)	0.82–1
T/W	0.79 (1)	0.76–0.88	0.74–0.78	0.72–0.88 (17)	0.71–0.83 (13)	0.79–0.88
T/L	0.91–0.93 (2)	0.86–1.06	0.83–0.99	0.79–0.97 (17)	0.76–1.01 (12)	0.79–1

***Cuninulus ougartaensis* sp. nov.**

Figures 2, 11–12, Tables 6–7

v. 1952 *Uncinulus lodanensis* (Burhenne, 1899). – Le Maître, p. 115, figs 25–28.

2003 *Uncinulus lodanensis* (Burhenne, 1899). – Ouali Mehadji, p. 135, pl. 3, fig. 5a–c.

Types. – Holotype: LPB 15256 (= R2) (Fig. 11A–E). Paratypes: LPB 15257 (= R1) (Fig. 11K–O), LPB 15258 (= R3) (Fig. 11F–J), LPB 15259 (= R4) (Fig. 12), LPB 15260–LPB 15263 [= R5–R7, R11 (juvenile specimen)], same locality and level as the holotype.

Type horizon and locality. – Lowest part of Chefar el Ahmar Formation (uppermost Emsian) (Paris et al. 1997, fig. 1), Marhouma section (Ougarta), levels MH 19–28.

Material. – Fifty-one specimens and one fragment; eleven specimens from the Marhouma section, Racheboeuf's 2005 collection; two illustrated specimens GFCL 421, 422, Marhouma section ('km 30' section of the literature); ten specimens from El Kseib (EK 21); eighteen specimens from Erg Djemel: eight specimens (ED 14), one specimen (ED 35), seven specimens (ED 62), two specimens (ED 101), Le Maître's (1952) collection; ten specimens from El Kseib: one specimen (LK 82), one specimen (LK 85–86), four specimens (LK 86), three specimens (LK 87–88), one specimen (LK 91), Boumendjel et al. (1997b) collections.

Etymology. – After the Ougarta area (North Africa, Algeria).

Diagnosis. – Shell small, wider than long, with median ventral crest and median dorsal furrow. Sulcus and fold originating at or near beaks. Apical angle ranging between 103° and 108°. Costae numerous with divisions and intercalations, originating at or near beaks, presence of bundles of costae on flanks in 18 per cent of the shells. *Paries geniculatus*. Lateral costae flattened with marginal spine-like projections. Front depressed with two 'M'-shaped cavities present in 93 per cent of the shells. Shell thick, dental plates absent, apical cavities obsolete. Hinge plate undivided, thick cardinal process with numerous ridges.

Description. – Shell small, strongly dorsibiconvex, wider than long (L/W: 0.73–0.99, often 0.80–0.99; T/W: 0.69–0.9, often 0.76–0.9; T/L: 0.79–1.02, often 0.85–1.02).

Ventral valve with wide sulcus (Ws/W: 0.55–0.80, 0.60–0.70), well-delimited, with median ridge always present and reaching anterior margin in 95 per cent of the specimens where it almost stretches for a third of the width of the rectangular tongue; 'M'-shaped cavities present in 93 per cent of shells, apical angle varying between 103°–118°. Dorsal valve with well-developed fold always bearing a median furrow.

Number of costae variable (MPC: 20–35, PC: 3–4, LC: 18–24); costae bundles on flanks in 18 per cent of the shells.

Ventral interior (Fig. 12) lacking dental plates; lateral apical cavities vestigial and central apical cavity subrectangular; deltidial plates observed in serial sections. Dorsal interior (Fig. 12) with undivided hinge plate; thick cardinal process with numerous ridges.

Measurements. – See Table 6.

Remarks. – *Cuninulus ougartaensis* is similar to *C. leonensis* Sartenaer, 2005 and *C. assaensis* Sartenaer, 2005. The three species differ by the percentage of bundles on flanks, the number of costae and their apical angle (see Table 7). *C. melanopotamicus* Sartenaer, 2005 can be distinguished from *C. ougartaensis* particularly by its ornamentation and more variable size, and from *C. assaensis* Sartenaer, 2005 by its large size and increased number of bundles of costae on the flanks as is the case in ?*C. arnoensis* Sartenaer, 2005, which has always bundles present on its flanks. *C. leonensis* Sartenaer, 2005 is similar to the new species in size (measurements and ratios are also comparable) but differs from the latter by the absence of bundles of costae on the flanks.

Occurrence. – *Cuninulus ougartaensis* sp. nov. is present in Ougarta (Fig. 2) as *Nucinulus orbignyianus crassicosus* in the lowest part of Chefar el Ahmar Formation of uppermost Emsian age (Paris et al. 1997, fig. 1) in Marhouma, El Kseib (Boumendjel et al. 1997a, figs 3b, 9c) and Erg Djemel sections (Le Maître 1952). In the latter, the new species was previously identified as *Uncinulus lodanensis*

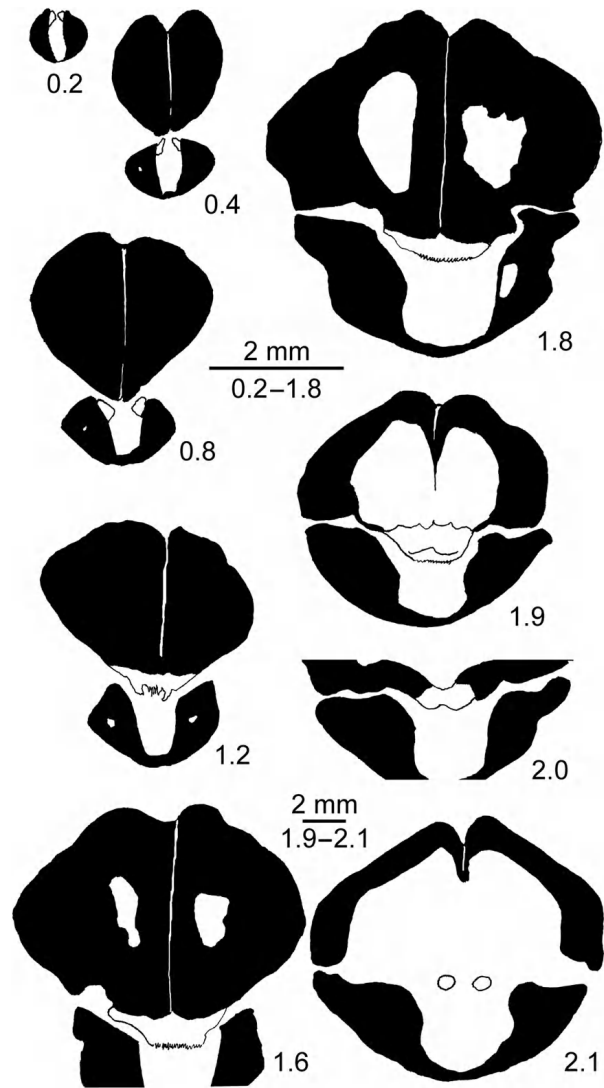
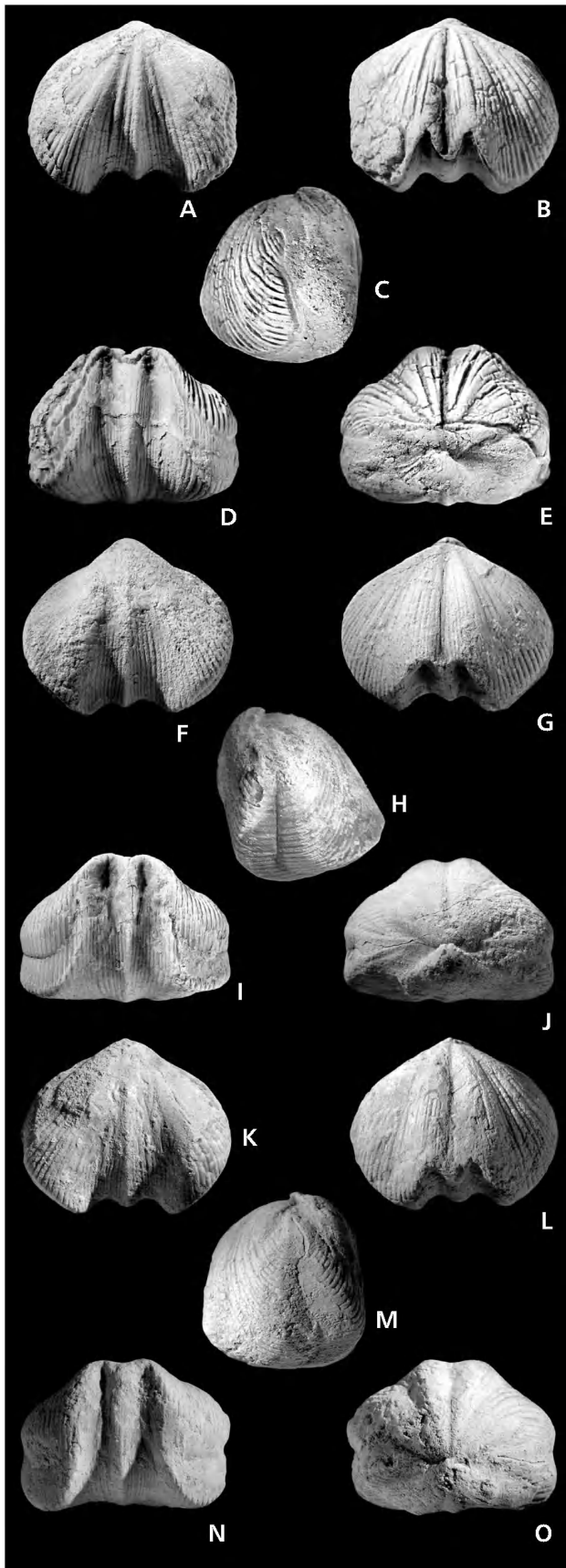


Figure 12. Transverse serial sections of *Cuninulus ougartaensis* sp. nov. Numbers refer to distances in mm from the top of the ventral umbo; LPB 15259 from the Marhouma section (Ougarta, Algeria), lowest part of Chefar el Ahmar Formation, upper Emsian.

(Burhenne, 1899) and included in the lower Eifelian by Le Maître (1952). Ouali Mehadji (2003, p. 135, pl. 3, fig. 5a–c) describes and figures *Uncinulus lodanensis* (Burhenne, 1899) (= *C. ougartaensis* sp. nov.) from Erg Djemel, Hacı Fegaguira, and ‘km 30’ sections, upper and uppermost Emsian, associated with *Glossinulus mimicus*

Figure 11. A–O – *Cuninulus ougartaensis* sp. nov. Ougarta, Marhouma section (MH 19–28), lowest part of Chefar el Ahmar Formation, upper Emsian. • A–E – articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, holotype LPB 15256. • F–J – articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, paratype LPB 15258. • K–O – articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, paratype LPB 15257. All × 2.

Table 6. Measurements in mm of type specimens of *Cuninulus ougartaensis* sp. nov.

LPB	15257	15256	15258	15259	15260	15261	15262	15263
L	12	13.2	12.3	12.55	13.7	13	11.8	9.1
W	15	14.2	14.2	15?	14.1	13.1	14.4	10.5
T	12.2	12.2	11.5	12.7	12.7	11.8	?	8.2
AA	114°	115°	115°	118°?	109°	109°	114°	109°
MPC	32–35	32–35	30	32	28+	28?	30	22
LC	22–24	22	20?	22	18-	?	22?	18?
L/W	0.8	0.93	0.87	0.87?	0.97	0.99	0.82	0.86
T/w	0.81	0.86	0.81	0.85?	0.90	0.90	?	0.78
T/L	1.02	0.92	0.93	1.01	0.93	0.91	?	0.90

and *Nucinulus orbignyianus crassicosatus* (Ouali Mehadjji 2003, figs 15–17).

Genus *Palinulus* Sartenaer, 2005

Type species. – *Palinulus zairensis* Sartenaer, 2005.

Palinulus saharaensis sp. nov.

Figures 2, 4L–Q, 13A–E, 14, Table 8

v. 1944 *Uncinulus pilus* Schmur. – Le Maître, pp. 49–51, pl. 7, figs 26–36.

Types. – Holotype: GFCL 36 illustrated by Le Maître (1944, pl. 7, figs 29–32). Paratypes: GFCL 35 (Le Maître 1944, pl. 7, figs 26–28), GFCL 37 (Le Maître 1944, pl. 7, fig. 33; Fig. 4P–Q), GFCL 38 (Le Maître 1944, pl. 7, figs 34–36), GFCL 468 (Fig. 4L–O)–469, 471, 472 (Fig. 13A–E), 473 (this paper).

Type horizon and locality. – Term 5 of ‘Coblencian’ age according to Le Maître (1944) [= upper lower Emsian or lower upper Emsian (see below)], section in front of the Haci Remlia cliff (Morocco, Tafilalt).

Material. – Thirty-one specimens from Haci-Remlia (Tafilalt, Morocco); two dubious specimens from Erg Djemel (Ougarta, Algeria), Le Maître’s (1952) collection; one dubious specimen from Marhouma section, Racheboeuf’s (2005) collection.

Etymology. – The name refers to the area in Western Sahara, Morocco (Haci-Remlia, Tafilalt), where the species is abundant.

Diagnosis. – Shell small, moderately dorsibiconvex, subrounded in outline. Sulcus without crest (or exceptionally developed), obsolete fold with shallow median depression (sometimes absent) originating between umbo and

Table 7. Synthesis of important characters and ratios of *C. ougartaensis* sp. nov., *C. leonensis*, and *C. assaensis*.

	<i>ougartaensis</i>	<i>leonensis</i>	<i>assaensis</i>
Presence of median ridge in sulcus	100%	100%	100%
Median ridge reaching front	95%	90%	90%
Median furrow on fold	100%	100%	100%
Percentage of costa bundles on flanks	18%	0%	50%
MPC	20–35	20–26	23–43
PC	3–4	5–6	5–8
LC	18–24	16–27	17–29
AA (°)	103–118	105–125	116–124
L/W	0.73–0.99	0.83–1	0.72–0.93
T/W	0.69–0.9	0.68–0.85	0.65–0.78
T/L	0.79–1.02	0.76–0.93	0.76–0.95
Ws/W	55–80%	55–77%	59–78%

the half length of the dorsal valve. Bundles never present. Central part of tongue depressed without ‘M’-shaped cavities.

Description. – Shell small-sized (L: 10.5–15.3 mm, usually 12.2–14.8 mm; W: 11.8–17.3 mm, usually 12.1–15.6 mm; T: 8.9–13.2 mm, usually 9.9–11.4 mm), moderately dorsibiconvex (T/W: 0.70–0.89; T/L: 0.75–0.94), subrounded in outline with length and width almost equal (L/W: 0.83–1.01); central part of the tongue often depressed; hinge line narrow, convex; anterior and lateral commissures depressed.

Ventral valve with small beak slightly curved; sulcus wide (Ws/W: 0.42–0.72, generally 0.45–0.53), lacking median crest (or exceptionally present), originating imperceptibly at about mid-length; apical angle ranging between 106° and 118°, usually between 108° and 115°. Dorsal valve with maximum height almost at anterior margin; fold generally with a slight median depression, starting imperceptibly at about mid-length.

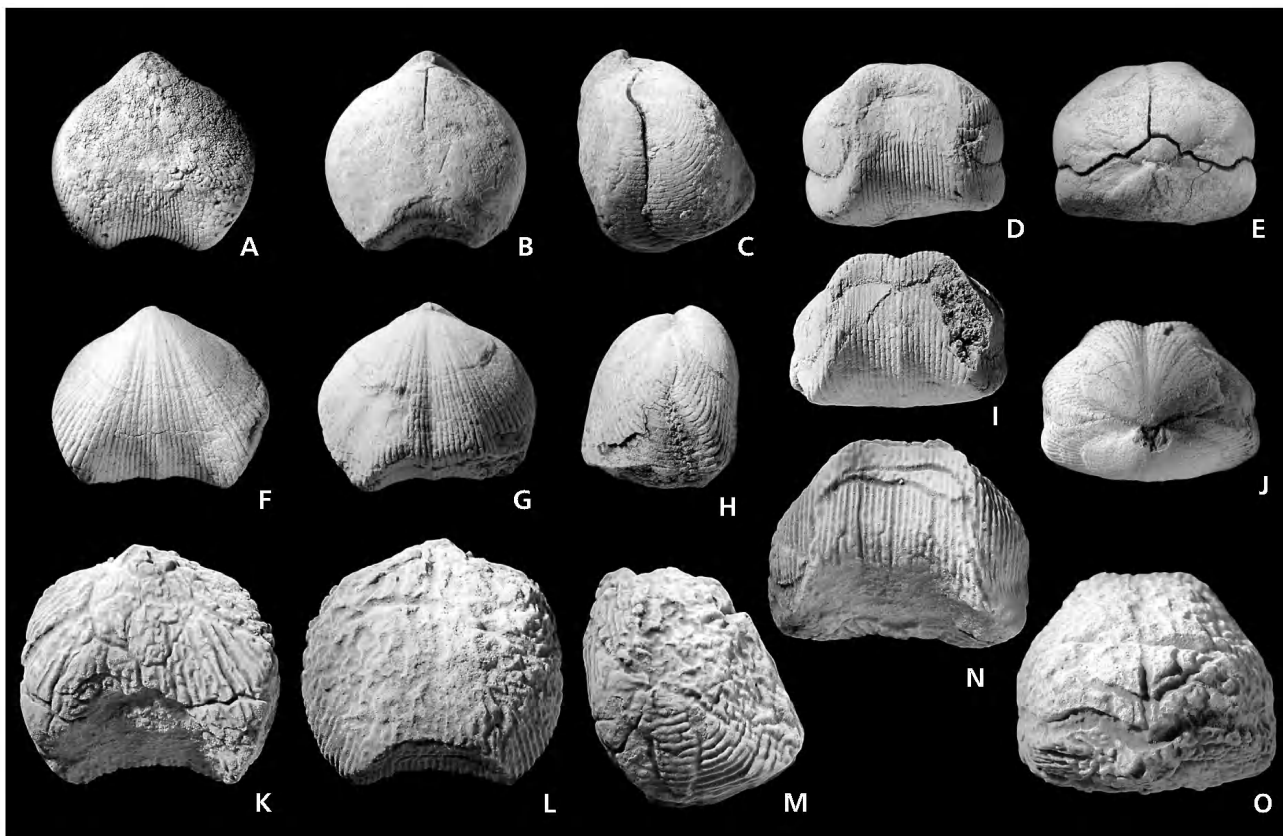


Figure 13. A–E – *Palininulus saharaensis* sp. nov. Tafilalt, section in front of the Haci Remlia cliff, upper lower Emsian or lower upper Emsian. Articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, paratype GFCL 472 (= HR 20.20). • F–J – ?*Palininulus* sp. Ougarta, Marhouma section, lowest part of Chefar el Ahmar Formation (MH 19–28), upper Emsian levels MH 19–28. Articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, LPB 15264. • K–P – *Lapinulus* sp. Ougarta, ‘km 30’ section, uncertain lithostratigraphic unit, ?upper Emsian. Articulated specimen in ventral, dorsal, lateral, anterior, and posterior views, GFCL 475 (= MA 98.2). All $\times 2$.

Median, parietal and lateral costae thin, regular, numerous, low, slightly convex and showing divisions often in posterior region, intercalations not observed; costae starting at or near beaks. Separate counts of parietal and median costae are impossible; PMC and LC varying between 24–32 and 23–27, respectively; bundles always absent. On *paries geniculatus* costae are flattened with median grooves corresponding to spine projections.

Ventral interior (Figs 4L–Q, 14) with large deltidial plates; dental plates absent; vestigial cavities developed in lateral apical callosities; central apical cavity rectangular in transverse section, longer than wide with parallel lateral margins posteriorly then convex anteriorly; teeth stout. Dorsal interior (Figs 4L–Q, 14) with callosity strongly developed; hinge plate indistinct posteriorly, divided by a cup-shaped septalium filled by callus, covered until about mid-width of apical cavity by a thick ‘T’-shaped cardinal process with about 22 ridges, limited laterally by large dental cavities.

Measurements. – See Table 8.

Remarks. – *Palininulus saharaensis* is similar to the type species *P. zairensis* Sartenaer, 2005, but the new species differs by a narrower sulcus [Ws/W : 0.42–0.72 (usually 0.45–0.53) vs 0.54–0.71 for Sartenaer’s species] and lacks a crest in sulcus. Moreover, the median costae are also slightly more numerous in *P. saharaensis*.

Occurrence. – *Palininulus saharaensis* is abundant in the upper Emsian (‘Coblencian’–lower ‘Couvianian’ according to Le Maître 1944) of western Sahara in eastern Morocco (Tafilalt – Haci-Remlia). It is associated with ‘*Spirifer (Acrospirifer) arduennensis* Schnur (1853) and two rhynchonellids also present in the upper Emsian-aged ‘assise El-Ansar’ according to Drot (1964, p. 115, 155), namely *Uncinulus princeps* (Barrande, 1847) *sensu* Le Maître (1944) (= *Eoglossinotoechia sylphydea marocanensis* Drot, 1964) and *Rhynchonella (Camarotoechia?) mariana* de Verneuil & Barrande (1855) *sensu* Le Maître (1944), which probably corresponds to *Straelenia* sp. eg. *losseni* (Kayser, 1880) in Drot (1964). Hollard (1974, pp. 12, 13) emphasized the similarity between Haci Remlia faunas and the ‘assise El-Ansar’ faunas, which are upper lower Em-

Table 8. Measurements in mm of types of *Palinulus saharaensis* sp. nov.

GFCL	35	37	38	36	468	469	470	471	472
L	15.3	12.2	14.8	14	12.7	11.9	12.7	12.7	12.65
W	17.3	14.2	15.3	15.4	13.65	12	13.3	12.7	13.4
T	13.25	10.8	13.2	11.3	9.9	9	11.6	10.75	11.65
AA	118°	112°	115°	114°	105°	108°	109°	113°	105°
MPC	32	26?	28	32	22+?	21?	21?	22?	23?
LC	27	23	21	25	27?	17+	24	24?	26?
L/W	0.88	0.86	0.97	0.91	0.93	0.99	0.95	1	0.94
T/W	0.77	0.76	0.86	0.73	0.73	0.75	0.87	0.85	0.87
T/L	0.87	0.89	0.89	0.81	0.78	0.76	0.91	0.85	0.92

sian or lower upper Emsian according to Carls *et al.* (1972, p. 138) concerning *Ardupirifer arduennensis arduennensis* figured by Drot (1964, pl. 3) from El-Ansar faunas. The presence of *P. saharaensis* in Algeria (Ougarta) in Erg Djemel and Marhouma sections are uncertain.

?*Palinulus* sp.

Figures 2, 13F–J, Table 9

Material. – One specimen (LPB 15264) from Marhouma section (Algeria, Ougarta), levels (MH 19–28), Racheboeuf's 2005 collection and unpublished data; two specimens (GFCL 473–474 [= ED 35]) from Erg Djemel (Algeria, Ougarta), Le Maître's (1952) collection.

Measurements. – See Table 9.

Remarks. – These specimens are tentatively assigned to the genus *Palinulus* because they are similar in their small size, outline, and ornamentation, but they differ by the presence of a short and low crest in ventral sulcus, which is developed only in eleven per cent of *P. zairensis* according to Sartenaer (2004), and exceptionally in *P. saharaensis* sp. nov. Furthermore, the specimens GFCL 473 and LPB 15264 display a bundle of costae on their flank; this feature is always absent in *Palinulus* according to Sartenaer (2004) but frequently developed in the genus *Cuninulus*, for which, species are usually larger than the forms identified here as ?*P.* sp.

Occurrence. – ?*Palinulus* sp. occurs in the Marhouma section (Fig. 2) within the lowest part of Chefar el Ahmar Formation of upper Emsian age (Paris *et al.* 1997, fig. 1) and in the Erg Djemel section where its position is uncertain.

Genus *Lapinulus* Sartenaer, 2005

Type species. – *Terebratula pila* Schnur, 1851.

Lapinulus sp.

Figures 2, 13K–O, Table 10

1952 *Uncinulus pila* Schnur – Le Maître, pp. 114, 115.

Material. – Four poorly preserved specimens (GFCL 476 [= MA 95], GFCL 475, 477–478 [= MA 98]) from 'km 30' section, Saoura, Le Maître's (1952) collection.

Description. – Shell small (L: 13.2–17.3 mm, W: 16.3–19.3 mm, T: 13.7–14.9 mm), wider than long (L/W: 0.81–0.99), maximum width at about mid-length to almost anterior margin, strongly dorsibiconvex, rounded subpentagonal outline with *paries geniculatus*; lateral commissures slightly depressed, anterior commissure straight, sometimes slightly grooved.

Ventral valve with beak curved in contact to reach the dorsal umbo, apical angle ranging between 104° and 114°; sulcus wide (Ws/W: 0.62–0.78), moderately deep, originating anteriorly to umbo and with a median swelling (except GFCL 476) not reaching the anterior margin; tongue high, subrectangular in outline. Dorsal valve with maximum height almost at anterior margin; fold very low, originating close to umbo, with a median furrow extending from beak to front.

Costae fine, regular, low, rounded, numerous, originating near beaks showing divisions and rare intercalations, flattened with median grooves corresponding to spine projections on *paries geniculatus*, bundles of costae absent; separate counts of parietal and median costae are difficult; number of median and parietal costae ranging between 22?–28, lateral costae numbering around 23.

Ventral interior with deltidial plates observed in transverse serial sections; dental plates subparallel; large, rectangular central apical cavity and small lateral apical cavities, teeth short. Dorsal interior with thick hinge plate with a small septalium filled by callus; cardinal process thick, with 20 short ridges, covering the whole hinge plate; apical cavity filled by callus; short wedge-shaped septum engulfed by callus.

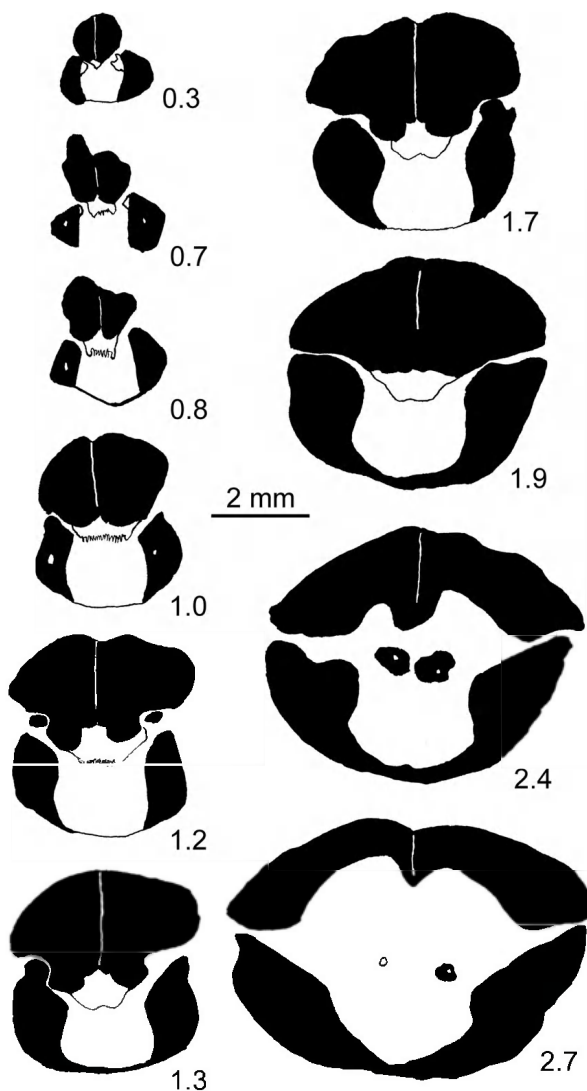


Figure 14. Transverse serial sections of *Palinulus saharaensis* sp. nov. Numbers refer to distances in mm from the top of the ventral umbo; GFCL 473 from the Haci Remlia section (Tafilalt, Morocco), upper lower Emsian or lower upper Emsian.

Measurements. – See Table 10.

Remarks. – These specimens are similar to species of *Lapinulus* in their external and internal characters. However, the paucity of the material and its poor preservation do not permit to identify more precisely these specimens although they resemble *L. pila* (Schnur, 1851), but they differ in a wider sulcus and less open apical angle.

Occurrence. – *Lapinulus* sp. occurs in the Marhouma section, where its position is uncertain, associated with *Nucinulus orbignyanus crassicostratus* and *Cuninulus ougartaensis* (respectively identified as *Uncinulus orbignyanus* and *U. lodanensis* by Le Maître 1952, pp. 114, 115, see above).

Table 9. Measurements in mm of ?*Palinulus* sp.

GFCL	473	474	15264
L	10.7	13.3+?	11.5
W	13.2	17.1	14
T	9.5	14.3+?	11.45
AA	105°	115°?	109°
MPC	23	23?	26
LC	20	?	19

Family and genus undetermined

v. 1997b *Oligoptycherhynchus daleidensis* (C.F. Roemer, 1844). – Brice (in Boumendjel et al.), p. 106.

Material. – One incomplete ventral valve, one ventral internal mould, two dorsal valves and one dorsal internal mould from El Kseib section (LK 25), Ougarta.

Remarks. – These poorly preserved disarticulated valves cannot be assigned to a genus. Valves wider than long (maximum width: 15 mm), ornament of simple strong costae (three VMC, four DMC, four LC) originating at beaks, dorsal fold and ventral sulcus originate at beaks. The single dorsal internal mould available shows the impression of a dorsal septum.

Their poor state of preservation precludes a generic and specific assignment, but they are separable from *Oligoptycherhynchus daleidensis* (Roemer, 1844) by their small size which reminds that of *Xahetomus hexadaleidensis* Sartenaer, 2009, however their ornamentation is very different.

Conclusions

Among the nine described and a single provisionally unidentified taxa, three belong to the Family Hebetoechiidae, namely *Lanceomyonia occidentalis* Drot, 1964, *L. aff. occidentalis*, and ?*L. borealiformis* (Siemiradzki, 1906). The others belong to the Family Trigonirhynchiidae, namely *Stenorhynchia briceae* García-Alcalde (in Truyols-Massoni & García-Alcalde, 1994), to the Family Glossinotoeciidae, namely *Glossinulus mimicus* (Barrande, 1879), and to the Family Nucinulidae (*Nucinulus orbignyanus crassicostratus* subsp. nov., *Cuninulus ougartaensis* sp. nov., *Palinulus saharaensis* sp. nov., ?*Palinulus* sp., and *Lapinulus* sp.). The three new taxa of the Nucinulidae, namely *N. orbignyanus crassicostratus*, *C. ougartaensis*, and *P. saharaensis*, are similar to their type species but with differences that warrant our identification. However, the nucinulid species belong to the Ibarmaghian Domain (*sensu* Plusquellec 1987) by many similarities, for instance *N. orbignyanus crassicostratus* is similar to the

Table 10. Measurements in mm of *Lapinulus* sp. and comparison with measurements of type specimens of *Lapinulus pila* (Schnur, 1851).

	<i>Lapinulus</i> sp.				<i>Lapinulus pila</i>
GFCL	476	477	475	478	
L	16	16.7	17.3	13.2	–
W	17.1	16.9	19.3	16.3	–
T	14.2	14.9	13.7	13.9	–
AA	105°	104°	111°	114°	115°–120°
MPC	22+	28	23?	23?	18–25 (5–7 PC)
LC	?	19+	?	23?	20–28
L/W	0.94	0.99	0.89	0.81	0.86–0.98, often 0.90–0.96
T/W	0.83	0.88	0.71	0.85	0.68–0.97, often 0.84–0.97
T/L	0.89	0.89	0.79	1	0.97–1.07
Ws	13.4	12.4	12	11.5	–
Ws/W	0.78	0.73	0.62	0.70	–

type species *N. orbignyana* from Sabero in Spain. *C. ougartaensis* is also similar to *C. leonensis* from the Leon Province in Spain and *C. assaensis* from the Assa region in southern Morocco. Nevertheless, on the basis of the available data, *P. saharaensis* is only recognized with certainty in western Sahara (Morocco) while the hebetoecchids described in this paper only occur in North Africa.

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References

ALIMEN, H., LE MAÎTRE, D., MENCHIKOFF, N., PETTER, G. & POUYTO, A. 1952. *Les chaînes d'Ougarta et la Saoura. Actes du XIX^{ème} Congrès géologique International. Monographies Régionales 1^{ère} série, Algérie, No. 15.* 114 pp. La Typo-litho et Carbonel, Alger.

BARRANDE, J. 1847. Über die Brachiopoden der silurischen Schichten von Böhmen. *Naturwissenschaftlichen Abhandlungen 1*, 357–475.

BARRANDE, J. 1879. *Système silurien du centre de la Bohême. 1^{ère} partie. Recherches Paléontologiques, volume 5. Classe des Mollusques. Ordre des Brachiopodes.* 226 pp. Published by the author, Paris.

BAYLE, E. 1878. Fossiles principaux des terrains de la France. *Explication de la Carte Géologique de la France, Mémoire 4*, 158 pls.

BOUMENDJEL, K., MORZADEC, P., PARIS, F. & PLUSQUELLEC, Y. 1997a. Le Dévonien de l'Ougarta (Sahara Occidental, Algérie). *Annales de la Société géologique du Nord (2^{ème} série) 5*, 73–87.

BOUMENDJEL, K., BRICE, D., COPPER, P., GOURVENNEC, R., JAHNKE, H., LARDEUX, H., LE MENN, J., MELOU, M., MORZADEC, P., PARIS, F., PLUSQUELLEC, Y. & RACHEBOEUF, P.R. 1997b. Les faunes du Dévonien de l'Ougarta (Sahara occidental, Algérie). *Annales de la Société géologique du Nord (2^{ème} série) 5*, 89–116.

BRICE, D. 1981. Les brachiopodes Pentamerida, Rhynchonellida et Terebratulida, 193–217. In MORZADEC, P., PARIS, F. & RACHEBOEUF, P.R. (eds) *La tranchée de La Lézaïs, Emsien supérieur du Massif Armoricain. Sédimentation, Paléontologie, Stratigraphie. Mémoire de la Société géologique et minéralogique de Bretagne 24*.

BURHENNE, H. 1899. Beitrag zur Kenntniss der Fauna Tentaculatschiefer im Lahngebiet mit besonderer Berücksichtigung der Schiefer von Leun unweit Braanfels. *Abhandlungen der Königlich Preussischen geologischen Landesanstalt, Neue Folge 29*, 1–56.

CARLS, P., GANDL, J., GROOS-UFFENDORFE, H., JAHNKE, H. & WALLISER, O.H. 1972. Neue Daten zur Grenze Unter-/Mittel Devon. *Newsletter Stratigraphy 2*, 115–147.

DROT, J. 1964. Rhynchonelloidea et Spiriferoidea siluro-dévonien du Maroc présaharien. *Notes et Mémoires du Service géologique du Maroc 178*, 1–287.

DROT, J. 1971. Rhynchonellida siluriens et dévonien du Maroc pré-saharien. Nouvelles observations. *Notes et Mémoires du Service géologique du Maroc 237*, 65–108.

GHIENNE, J.F., BOUMENDJEL, K., PARIS, F., VIDET, B., RACHEBOEUF, P.R. & SALEM, H.A. 2007. The Cambrian-Ordovician succession in the Ougarta Range (western Algeria, North Africa) and interference of the Late Ordovician glaciation on the development of the Lower Palaeozoic transgression on northern Gondwana. *Bulletin of Geosciences 82*, 183–214. DOI 10.3140/bull.geosci.2007.03.183

GIGOUT, M. 1951. Etudes géologiques sur la Meseta marocaine occidentale (arrière-pays de Casablanca, Mazagan et Safi). *Notes et Mémoires du Service géologique du Maroc 86*, 1–507.

HAVLÍČEK, V. 1960. Bericht über die Ergebnisse der Revision der Böhmisches Altpäozoischen Rhynchonelloidea. *Věstník Ústředního ústavu geologického 35*, 241–244.

HAVLÍČEK, V. 1961. Rhynchonelloidea des böhmischen älteren Paläozoikums (Brachiopoda). *Rozpravy Ústředního ústavu geologického 27*, 1–211.

HAVLÍČEK, V. 1992. New Lower Devonian (Lochkovian-Zlíchovian) rhynchonellid brachiopods in the Prague Basin. *Sborník geologických věd, Paleontologie 32*, 55–122.

HOLLARD, H. 1974. Recherches sur la stratigraphie des formations du Dévonien moyen, de l'Emsien supérieur au Frasnien, dans le sud du Tafilat et dans le Ma' der (Anti-Atlas oriental). *Notes du Service géologique du Maroc 36*, 7–68.

JANSEN, U., LAZREQ, N., PŁODOWSKI, G., SCHEMM-GREGORY, M., SCHINDLER, E. & WEDDIGE, K. 2007. Neritic-pelagic correla-

- tion in the Lower and basal Middle Devonian of the Dra Valley (Southern Anti-Atlas, Moroccan Pre-Sahara), 9–37. In BECKER, R.T. & KIRCHGASSER, W.T. (eds) *Devonian Events and Correlations*. Geological Society, London, *Special Publications* 278.
- KAYSER, E. 1880. Über hercynische und silurische Typen im rheinischen Unterdevon. *Zeitschrift der Deutschen Geologischen Gesellschaft* 32, 819–821.
- LE MAÎTRE, D. 1944. Contribution à l'étude du Dévonien du Tafilalet. I. – La faune coblencienne de Haci Remlia (SW de Taouz). *Mémoire du Service des Mines et de la Carte géologique du Maroc* 61, 1–102.
- LE MAÎTRE, D. 1952. La faune du Dévonien inférieur et moyen de la vallée de la Saoura et des abords de l'Erg el Djemel (Sud Oranais). *Mémoire de la Carte géologique de l'Algérie* 12, 1–170.
- MURPHY, M.A., VALENZUELA-RÍOS, J.I. & CARLS, P. 2004. On classification of Pridoli (Silurian)–Lochkovian (Devonian) Spathognathodontidae (Conodonts). *University of California, Riverside, Campus Museum Contribution* 6, 1–25.
- OUALI MEHADJI, A. 2003. *Les brachiopodes du niveau majeur Emsien supérieur-Eifelien inférieur de la Saoura (Sahara nord-occidental, Algérie). Marqueur événementiel de la transgression fini-emsienne (Paléontologie, Biostratigraphie, Taphonomie, et Environnements sédimentaires)*. 229 pp. PhD thesis, Oran University.
- OUALI MEHADJI, A., ELM, S., RACHEBOEUF, P.R. & MEKAHLI, L. 2004. Caractéristiques et signification d'un niveau coquillier majeur à brachiopodes, marqueur événementiel dans l'évolution dévonienne de la Saoura (Sahara du nord-ouest, Algérie). *Comptes Rendus Géoscience* 336, 1283–1292.
- PARIS, F., BOUMENDJEL, K., MORZADÉC, P. & PLUSQUELLEC, Y. 1997. Synthèse chronostratigraphique du Dévonien de l'Ougarta (Sahara Occidental, Algérie). *Annales de la Société géologique du Nord (2^{ème} série)* 5, 117–121.
- PLUSQUELLEC, Y. 1987. Révision de *Michelinia transitoria* Knod. *Annales de la Société géologique du Nord* 105, 249–252.
- RZHONSNITSKAIA, M.A. 1956. Systematization of Rhynchonellida, 125–126. In GUZMAN, E. (ed.) *Resumenes de Los Trabajos Presentados*. International Geological Congress, Mexico, Report 20.
- SARTENAER, P. 2004. Restatement of *Terebratulina Orbignyana* De Verneuil, 1850 on the basis of the original collection. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* 74 (supplément), 81–88.
- SARTENAER, P. 2005. New middle and late Emsian, and early Eifelian rhynchonellid (brachiopod) genera of the Family Nucinulidae Sartenaer, 2004. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* 75, 25–52.
- SARTENAER, P. 2009. Two new Emsian rhynchonellid (brachiopod) genera from the Eifel area (Germany). *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* 79, 27–42.
- SAVAGE, N.M. 1996. Classification of Paleozoic Rhynchonellid Brachiopods, 249–260. In COPPER, P. & JIN, J. (eds) *Proceedings of the third International Brachiopod Congress*. A.A. Balkema, Rotterdam.
- SAVAGE, N.M. 2002. Rhynchotrematoidea, 1047–1091. In KAESLER, R.L. (ed.) *Treatise on Invertebrate Paleontology. Part H. Brachiopoda (revised), Volume 4*. Geological Society of America & University of Kansas, Boulder, Colorado & Lawrence, Kansas.
- SCHMIDT, H. 1942. Beiträge zum Richtschnitt Unterdevon/Mitteldevon bei Wetteldorf. 3. Die Rhynchonelliden des Wetteldorfer Richtschnittes. *Senckenbergiana* 25, 389–404.
- SCHMIDT, H. 1965. Neue Befunde an Paläozoischen Rhynchonellacea (Brachiopoda). *Senckenbergiana lethaea* 46, 1–25.
- SCHMIDT, H. & MCLAREN, D.J. 1965. Paleozoic Rhynchonellacea, 552–597. In MOORE, R.C. (ed.) *Treatise on Invertebrate Paleontology. Part H. Brachiopoda*. Geological Society of America & University of Kansas Press, New York & Lawrence.
- SCHNUR, J. 1851. *Die Brachiopoden aus dem Uebergangsgebirge der Eifel. Programm der vereinigten höhern Bürger- und Provinzial-Gewerbeschule zu Trier für das Schuljahr 1851*. 16 pp. Linz, Trier.
- SCHNUR, J. 1853. Zusammenstellung und Beschreibung sämtlicher im Uebergangsgebirge der Eifel vorkommenden Brachiopoden. *Palaeontographica* 3, 169–254.
- SERVICE DE LA CARTE GÉOLOGIQUE DE L'ALGÉRIE 1952. [Carte de reconnaissance du Sahara algérien] (NH-30-SE) *Kerzaz, 1 : 500.000*.
- SIEMIRADZKI, J. 1906. Monografia warstw paleozoicznych Podola. *Sprawozdanie Komisji Fizjograficznej, Kraków* 39, 87–196.
- SOUGY, J. 1961. *Les formations paléozoïques du Zemmour noir (Mauritanie septentrionale). Etude stratigraphique, pétrographique et paléontologique*. 679 pp. PhD thesis, Nancy University.
- SZAJNOCHA, W. 1889. O stratygrafii pokladow sylurskich. *Sprawozdanie Komisji Fizjograficznej, Kraków* 23, 185–200.
- TRUYOLS, M. & GARCÍA-ALCALDE, J.L. 1994. Faune rhéno-bohémienne (Dacryoconarides, Brachiopodes) à la limite Emsien-inférieur/supérieur au Cabo la Vela (Asturies, Espagne). *Geobios* 27, 221–241. DOI 10.1016/S0016-6995(94)80008-1
- VERNEUIL, E. DE 1850. Note sur les fossiles dévoniens du district de Sabero (Léon). *Bulletin de la Société Géologique de France (2^{ème} série)* 7, 155–186.
- VERNEUIL, E. DE & BARRANDE, J. 1855. Description des fossiles trouvés dans les terrains silurien et dévonien d'Almaden, d'une partie de la Sierra Morena et des montagnes de Tolède. *Bulletin de la Société Géologique de France (2^{ème} série)* 12, 964–1025.
- WENDT, J., KAUFMANN, B., BELKA, Z., KLUG, C. & LUBESIEDER, S. 2006. Sedimentary evolution of Palaeozoic basin and ridge system: the Middle and Upper Devonian of the Ahnet and Mouydir (Algerian Sahara). *Geological Magazine* 143, 269–299. DOI 10.1017/S0016756806001737