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Late Tournaisian (Carboniferous) brachiopods from Mouydir (Central Sahara, Algeria)

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A small-sized brachiopod fauna, representing an orthid, rhynchonellid and spiriferid community which lived in a low-energy environment, is reported from the lower part of the Argiles de Teguentour and was collected around Oued Tamertasset (or Temertasset) and Oued Habadra in north-western Mouydir (Algerian Sahara). Associated goniatites indicate an early Late Tournaisian age (*Pericyclus–Progoniatites* assemblage). Thirteen brachiopod species belonging to 12 genera and 5 orders (Productida, Orthida, Rhynchonellida, Athyridida and Spiriferida) are described. *Mouydirhynchus* is proposed as a new rhynchonellid genus and the species *Rhipidomella prolifica*, *Mouydirhynchus quietus* and *Eomartiniopsis mouydirensis* are new. The other described taxa are the following: *Chonetipustula*? sp., strophalosioid gen. et sp. indet., *Schizophoria* sp., trigonirhynchiid gen. indet. sp. A, trigonirhynchiid gen. indet. sp. B, *Hemiplethorhynchus*? sp., *Coveenia*? sp., *Crurithyris* cf. *fissa*, *Punctothyris*? sp., and elythid gen. et sp. indet.

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KEY WORDS brachiopods; late Tournaisian; Mouydir; Algeria; low-energy environment

1. INTRODUCTION

As recently observed by Korn *et al*. (2007), the Carboniferous marine faunas from North Africa have been considerably less investigated than those of Devonian age. This is especially the case for Tournaisian brachiopods from Algeria, which still remain rather poorly documented. This is probably due to the sporadic occurrence of fossils within the thick detrital sequences characterizing the Tournaisian succession on the northern margin of Gondwana. The discovery of a moderately well-preserved, poorly diversified and small-sized brachiopod fauna within the Tournaisian Argiles de Teguentour in Mouydir (southern Algeria) which is well-dated by goniatites (*Pericyclus–Progoniatites* assemblage) is therefore of some interest. Until now, Lower Carboniferous brachiopod faunas recorded from the Sahara, on siliciclastic to carbonate platforms, consisted of normal-sized shells and more diverse associations. The brachiopods that form the subject of this paper were collected in 2002 by a team of German palaeontologists including D. Korn, D. Weyer, J. Bockwinkel and V. Ebbighausen whose investigations were mainly related to ammonoids and focused on the location of the early Late Tournaisian *Pericyclus–Progoniatites* assemblage. The latter was defined originally by Korn *et al*. (2003, 2007) in Tafilalt (southern Morocco), but characteristic goniatites of this assemblage were previously reported in the Argiles de Teguentour, notably by Conrad and Pareyn (1968).

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2. GEOLOGICAL SETTING

2.1. General context

The material studied is from 10 localities (Appendix) around Oued Tamertasset (or Temertasset on old maps) and Oued Habadra in north-western Mouydir, northern central Sahara (Figure 1). The Mouydir is presently separated westwards from the 'Ahnet–Timimoun–Bechar' main Central Saharan basin (Conrad and Lemosquet, 1984) by one of the submeridian linear faults related to the Targui Shield: the Arak–Foum Belrem structural high. This uplift, which was active during the early Palaeozoic and the late Hercynian, was probably not an obstacle to Carboniferous transgressions arriving from the North (Conrad, 1985, p. 317). Eastwards, the Mouydir is limited by the Amguid uplift, another major meridian structure, partly isolating the Central Sahara from the Eastern Saharan 'Illizi–Rhadames'

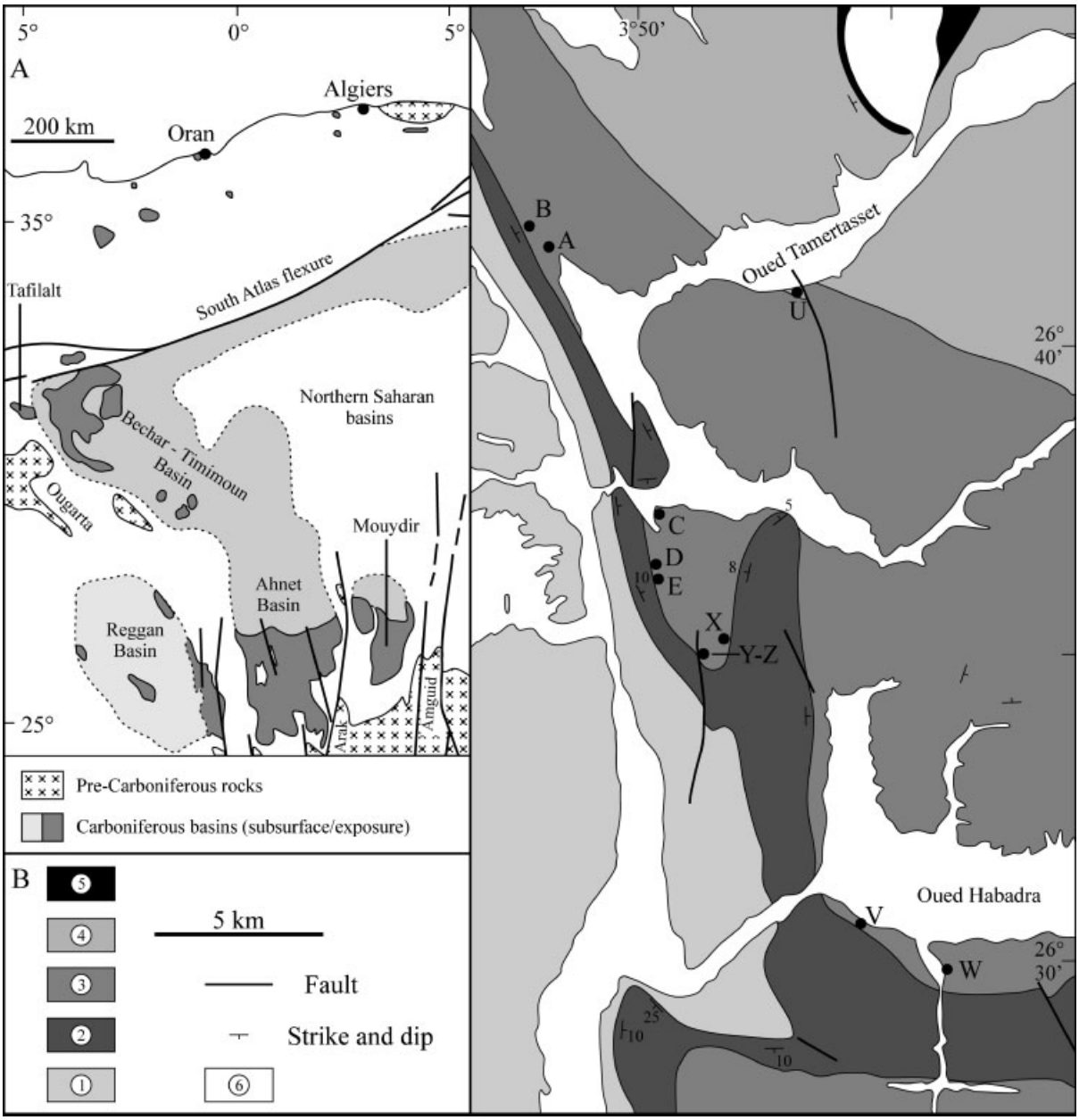

Figure 1. (A) Schematic map with location of the Carboniferous basins of northern Algeria and eastern Morocco (modified from Conrad, 1985). (B) Geological map (after Bensalah *et al*., 1974) with location of the fossiliferous localities sampled by Korn and colleagues in 2002. 1. Upper Devonian; 2. Upper Famennian to lower Tournaisian (Grès du Khenig); 3. Upper Tournaisian (Argiles de Teguentour and Grès de Tibaradine); 4. Lower Viséan; 5. Upper Viséan and 6. Quaternary.

basin. According to the palaeogeographic reconstruction of Torsvick and Cocks (2004), the Mouydir, which was part of NW Gondwana, was located at about 50° S during the Tournaisian (see also discussion in Wendt *et al*., 2009).

2.2. *Stratigraphy and material*

The lithostratigraphic succession of Carboniferous sediments in Central Sahara (Conrad, 1973) established for the whole Reggane–Ahnet–Mouydir areas is as follows (in ascending stratigraphic order):

(1) The Grès du Khenig (type locality at Hassi el Khenig, E. Ahnet) consist of massive clastic sands, deltaic to continental in their lower part, marine in their upper part, yielding at their top brachiopod coquinas and rare ammonoids. The age of the brachiopod assemblages differs from S to N (Legrand-Blain, 1995a): uppermost

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Famennian (Strunian) to early Tournaisian (Hastarian). The Upper Devonian sedimentary evolution of the Ahnet and Mouydir areas has been recently discussed by Wendt *et al*. (2006). At Oued Tamertasset (Conrad, 1984, figure 11), the Grès du Khenig are 140 m thick. At their top, a thin bed of sandy claystone yielded a few brachiopods (sample JC 850 *in* Legrand-Blain, 1995a, figure 3, table 8; 1995b, p. 432): *Acanthatia placita* Mergl (?), *Spinocarinifera* sp. 2 (?), *Unispirifer* sp. 1—the latter identified as 'aff. *tornacensis*' by Legrand-Blain (1985, plate 11, figure 8). This association, despite the limited number of specimens, may be compared to those described from the Tournaisian of the Timimoun area (Grès supérieurs de Kahla) and Libya (basal M'Rar Formation) (Mergl and Massa, 1992).

(2) The Argiles de Teguentour (type locality at Erg Teguentour, E. Ahnet) consist of homogeneous grey/black shales which abruptly cap the Grès du Khenig; they are poorly exposed under Quaternary deposits. At Oued Tamertasset, the formation is about 160 m thick (Conrad, 1984, figure 10) but, according to Wendt *et al*. (2009, figure 8), it is about 240 m thick (Figure 2). Its lower part yields diverse and well-preserved ammonoids belonging successively to the *Kazakhstania–Acrocanites* and *Pericyclus–Progoniatites* assemblages (Conrad, 1984, p. 105; Wendt *et al*., 2009), of Mid- to early Late Tournaisian age according to Korn *et al*. (2003, 2007). The bulk of the investigated material, mainly preserved as haematitic internal moulds (shell remains rarely preserved), was collected in the shales of the lower 70 m of the formation where internal moulds of small goniatites are extremely abundant. At Oued Tamertasset, the brachiopods are from a narrow interval corresponding to units 6–12 of Wendt *et al*. (2009). Due to poor exposures, the internal stratigraphy of this interval has not been fully resolved, but all brachiopod localities belong to the *Pericyclus–Progoniatites* assemblage (personal communication, Korn D, 2009). Larger goniatites, preserved with their shell, also occur within the lower part of the Argiles de Teguentour, but in levels rich in limestone nodules yielding the conodonts *Polygnathus communis* and *P.* gr. *inornatus* (Conrad, 1984). In Mouydir, the Argiles de Teguentour belong to the *Scaliognathus anchoralis* conodont Zone (Wendt *et al*., 2009). Normal-sized brachiopods, such as spiriferids and productids from Tibaradine (Ahnet) illustrated by Legrand-Blain (1985, plate 11, figure 9), probably occurred in the same type of carbonate nodule levels, but do not occur in Mouydir. The upper part of the Argiles de Teguentour, with lenses of fine sandy beds, is markedly less fossiliferous than the lower one.

(3) The Grès de Tibaradine (type locality at Tibaradine, central Ahnet) consist of coquinoid calcareous sandstones, yielding, in the Ahnet and Reggane areas, abundant brachiopod faunas: *Keokukia*? *betainensis* (Hollard), *Syringothyris folloti* Legrand-Blain, *Histosyrinx vautrini* Termier. In Mouydir, these sandstones are up to 220 m in thickness and are poorly fossiliferous (Conrad, 1984, p. 120).

(4) The 'Dalle des Iridet' caps the Grès de Tibaradine; this widespread key bed is a decimetric to metric layer of oolitic limestone rich in phosphatic nodules and yielding ammonoids, corals, conodonts and foraminiferans characteristic of the basal Viséan as well as the productid-spiriferid fauna. Wendt *et al*. (2009) have recently proposed the term Formation des Iridet (total thickness: 1–170 m) as there are several limestone beds separated by shales and not a single one (see these authors for more details).

3. PALAEOENVIRONMENTAL CONSIDERATIONS

The open-marine Argiles de Teguentour yield, especially in their lower part, a very rich fauna dominated by pelagic organisms (mainly small goniatites). Where the shales contain large calcareous nodules, benthic faunas are associated with goniatites and include brachiopods, bryozoans, bivalves, gastropods, corals (Cyathaxoniidae) and nautiloids (Conrad, 1984). The lower part of this lithostratigraphic unit was deposited in a low-energy environment, which, however, was not very deep, during a major transgressive phase (Conrad, 1984; Wendt *et al*., 2009). Its upper part is characterized by an impoverishment of the fauna and the appearance of sandy levels, which are more and more numerous upwards, heralding the overlying Grès de Tibaradine or the progradation of prodeltaic facies (Conrad, 1984).

The poorly diversified brachiopod fauna described below is predominantly an *in situ* orthid, rhynchonellid and spiriferid community, as the specimens are not disarticulated, size sorted or broken. The most common genera include *Rhipidomella*, *Mouydirhynchus* gen. nov., an unidentified trigonirhynchiid genus, *Crurithyris*, *Eomartiniopsis* and clearly less abundant *Chonetipustula*?, an unidentified strophalosioid genus, *Schizophoria*, *Hemiplethorhynchus*?, *Coveenia*?, *Punctothyris*? and an unidentified elythid genus. Most of these suspension-feeders were pedically attached to the substrate and all are small-sized. Some mature specimens of *Mouydirhynchus quietus* gen. nov., sp. nov. exceptionally reach *c*. 24 mm in width.

The abundance of immature specimens and the small size of brachiopods among the studied material may be due to the combination of several biological (e.g. nutrient availability) and physico-chemical controlling factors (e.g. water oxygenation and depth, substrate structure). Low land-

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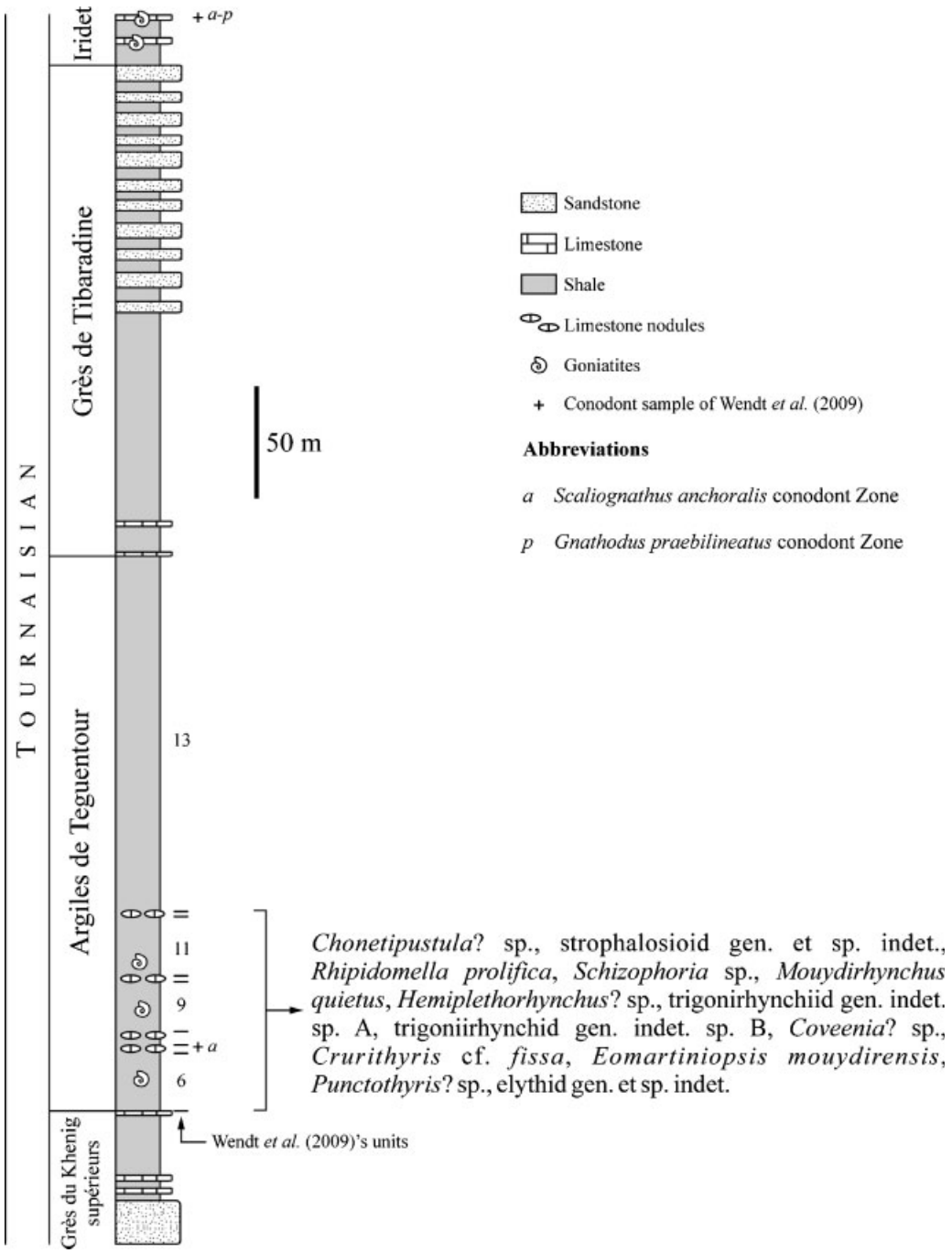

Figure 2. Tournaisian lithostratigraphic succession around Oued Tamertasset (modified from Wendt *et al*., 2009) and schematic distribution of the studied brachiopod species.

derived nutrient supply, resulting from the offshore situation of the north-western Mouydir during the deposition of the Argiles de Teguentour, probably played an important role in the control of the body size. Indeed, Pérez-Huerta and Sheldon (2006) stressed the strong relationship between the nutrient availability and the body size of spire-bearers such as athyridids and spiriferids. Small body size and thin shell may also permit brachiopods to raft on muddy substrate, but they were highly sensitive to sediment disturbance due to their motionlessness or poor mobility (see references in Tomašých, 2006). The minute size of the dorsal adductor muscle scars of *Rhipidomella prolifica* suggests that the living brachiopods did not need to close the valves rapidly to protect against environmental disturbances (Ackerly, 1990),

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but it may also represent an adaptation to muddy substrate with low nutrient flux. Furthermore, the large number of immature shells is also probably related to juvenile mortality that partly resulted from burial due to resuspension of unconsolidated sediments and water turbidity, as is generally the case in muddy environments (see Richards and Bambach, 1975). However, temporary deterioration of the deep water oxygenation, resulting from fluctuations of the anaerobic/dysaerobic boundary in the water column (Kammer, 1985), may have influenced the colonization of the sea floor during the deposition of the Argiles de Teguentour. Rhynchonellids such as pugnacids, which are well-represented in our material, are frequently the major constituents of Late Palaeozoic dysaerobic communities (e.g. Racki, 1989; Alexander, 1994). Moreover, the smooth spiriferid genus *Crurithyris* is generally considered as an opportunistic eurytopic taxon characteristic of stressful and/or dysaerobic environments (e.g. Kammer *et al*., 1986; Lebold and Kammer, 2006; Campi and Shi, 2007).

4. SYSTEMATIC DESCRIPTIONS

All specimens are stored at the Museum für Naturkunde der Humboldt-Universität zu Berlin (MB.B.). Material from the Institut royal des Sciences naturelles de Belgique (IRScNB), Brussels, is also illustrated.

The orders Productida and Orthida have been investigated by M. Legrand-Blain, the orders Rhynchonellida, Athyridida and Spiriferida by B. Mottequin.

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959
Suborder STROPHALOSIIDINA Schuchert, 1913a
Superfamily STROPHALOSIOIDEA Schuchert, 1913a
Family ARAKSALOSIIDAE Lazarev, 1989
Subfamily QUADRATIINAE Lazarev, 1989
Genus *Chonetipustula* Paeckelmann, 1931

Type species. *Productus plicatus* Sarres, 1857, emend. Kayser, 1882; from the Viséan Posidonia Shale of Aprath, Germany.

Chonetipustula? sp.
Figure 3A–B

Material. Thirteen internal moulds showing ventral and dorsal characters, but worn or broken at anterior and lateral extremities from localities A (MB.B.2829), B (MB.B.2830.1–2), C (MB.B.2831.1–2), D (MB.B.2832.1, Figure 3A–B; MB.B.2832.2–4, and fragments; MB.B.2833), E (MB.B.2834), W (MB.B.2835) and Z (MB.B.2836).

Description. Shell small-sized (internal mould width: 11–15 (or more) mm; internal mould length: 7–11 mm), transverse in outline; posterolateral extremities broken; hinge line straight (lateral extremities not observed); endospines irregularly sized and distributed on the whole surface of internal moulds.

Ventral valve moderately and regularly convex, bearing sharp irregular rugae and scattered spine bases; hinge spine bases not preserved on internal moulds; beak small, prominent, overhanging delthyrium closed by cardinal process, dental impressions small; interarea narrow (MB.B.2830.1, MB.B.2832.2); muscle scars obscure; posterior median groove visible in some specimens (MB.B.2832.3).

Dorsal valve slightly concave, never geniculated, bearing rugae but no spine bases; median breviseptum extending to less than half of shell length; adductor scars consisting of a pair of oval anterior scars (Figure 3B) and a pair of slightly dendritic, obscure posterior scars nearly reaching the hinge (MB.B.2829, MB.B.2836).

Discussion. The generic identification of these incomplete internal moulds is tentative. Their outline and ornamentation bear a resemblance to those of the productellid *Absenticosta* Lazarev, 1991 but the latter is geniculated and provided with dorsal spines, contrarily to the Mouydir specimens. The dorsal adductor scars (Figure 3B), which have never been described in typical *Chonetipustula*, resemble those figured in araksalosiids, such as *Hamlingella* and *Quadratia* (Brunton *et al*., 2000, figures 410–2b, 416–1e). The genus *Chonetipustula* is reported mainly from Culm deposits in the Viséan of Germany (Winkler Prins and Amler, 2006). In the Spanish Cantabrian Zone, it occurs in the middle to late Tournaisian Vegamian Formation consisting of black to grey shales (Sánchez de Posada *et al*., 2002, p. 65) with 'quiet-water faunas' (Martínez Chacón and Winkler Prins, 1993; Sánchez de Posada *et al*., 2001, figure 6a).

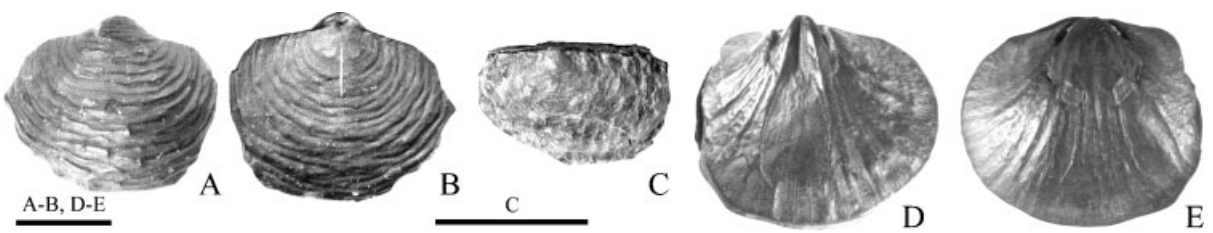

Figure 3. (A–B) *Chonetipustula*? sp. MB.B.2832.1 (internal mould with posterolateral extremities broken) in ventral and dorsal views; locality D. (C) Strophalosioid gen. et sp. indet. MB.B.2845.2b (articulated shell ventrally cemented on a dorsal valve of *Rhipidomella prolifica*) in dorsal view (see also Figure 4E–F); locality V. (D–E) *Schizophoria* sp. MB.B.2847 (internal mould) in ventral and dorsal views; locality D. All scale bars are 5 mm.

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Strophalosioid gen. et sp. indet.
Figures 3C, 4E–F

Material. From Oued Habadra area, locality V, one specimen cemented on a dorsal valve of *Rhipidomella* (MB.B.2845.2b) and another small fragment.

Description. Shell small-sized (width: 6.5 mm, length: 4.5 mm), finely pseudopunctate, ventrally cemented; profile weakly concavo-convex, following the substrate. Hinge line straight.

Ventral valve slightly concave; interarea poorly preserved with a probable broad delthyrium covered by the beak of opposite valve. Internal characters not observed.

Dorsal valve slightly convex, bearing irregular rugae (no radial ornamentation); beak small; obscure hinge spine bases. Internal features not observed.

Discussion. These small brachiopods cemented on shells of *Rhipidomella* are comparable to *Parmephrix*? *aprathensis* (Paul, 1939) and its junior synonym *P*? *culmica* (Nicolaus, 1963) and to *P*? *bunnahonensis* (Brunton and Mundy, 1986), known from Germany, British Isles and Spain. However, a new genus (not yet established), different from *Parmephrix* Brunton and Mundy (in Brunton *et al*., 1994), is necessary for these species (Martínez Chacón *et al*., 2003). The species mentioned above may be related to the araksalosiid genus *Plicaea* Aisenverg, 1992, described from the Viséan of Ukraine (personal communication, Winkler Prins CF, 2008).

Order ORTHIDA Schuchert and Cooper, 1932
Suborder DALMANELLIDINA Moore, 1952
Superfamily DALMANELLOIDEA Schuchert, 1913b
Family RHIPIDOMELLIDAE Schuchert, 1913b
Genus *Rhipidomella* Oehlert, 1890

Type species. *Terebratula michelini* Léveillé, 1835; from the Tournaisian of Belgium.

Rhipidomella prolifica sp. nov.
Figures 4A–B, E–I, L–X, 5A–B, Table 1

Holotype. An articulated internal mould (MB.B.2843.47, Figures 4O–P and 5A) from locality D.

Paratypes. Fifteen measured specimens with shell preserved, MB.B.2843.1–15, including 9 complete flattened shells (Figure 4B, L) and 6 isolated valves (Figure 4A, H–I) as well as 37 articulated internal moulds, MB.B.2843.16–59 (Figure 4S–T, U–V). All from locality D.

Type locality and horizon. Oued Tamertasset area (locality D). Argiles de Teguentour of Late Tournaisian age (*Pericyclus–Progoniatites* assemblage of Korn *et al*., 2007).

Measured specimens from same horizon. From localities A (5 flattened shells and 31 articulated internal moulds: MB.B.2837.1–36 (Figure 4M–N, Q–R)), B (2 flattened shells and 14 articulated internal moulds: MB.B.2838.1–13 (Figure 4X), MB.B.2839.1–3), C (13 flattened shells and 28 articulated internal moulds: MB.B.2840.1–15 (Figure 4W), MB.B.2841.1–20, MB.B.2842.1–6), E (eight articulated internal moulds: MB.B.2844.1–8) and V (three shells of which one not flattened (Figure 4E–G) and two articulated internal moulds, MB.B.2845.1–5).

Additional material. More than 300 fragmentary or abraded internal moulds, from the localities listed with the measured specimens.

Name. From Latin *Proles*, lineage and posterity: allusion to the abundant populations of the species.

Diagnosis. Shell small-sized for genus. Ventral muscle field length/shell length ratio < 0.5. Dorsal interior with a low notothyrial platform passing to a broad short median ridge; left/right anterior adductor muscle scars far from each other, oval and small-sized. Mantle canals finely pinnate to lemniscate, showing diverse developments of *vascula genitalia*, independently from size; *vascula media* short and conspicuous to obscure.

Description. Shell small-sized, (width: 7–17 mm, length: 6–15 mm) (Figure 5, Table 1), longer than wide, to wider than long, widest at about mid-length, dorsibiconvex, currently slightly transverse in outline; hinge line shorter than greatest width (width of interarea/width ratio range of 0.42–0.64); cardinal angles rounded, anterior commissure rectimarginate and anterior internal marginal crenulations containing follicular embayments, rounded at both valves, correspond to the distal extremities of external costellae.

Ventral valve with slightly prominent umbo; beak straight; interarea low, concave and apsacline; large flabellate diductor scars enclosing narrow adductor scars (Figure 4O, Q, S, U); muscle field usually occupying less than half of the internal mould length, rarely 50–51% (Figure 5A) and 36–41% of the internal mould width and teeth not observed.

Dorsal valve with slightly prominent umbo; interarea linear, concave and orthocline; dental sockets large (Figure 4I); notothyrial platform low and thick, developed between brachiophore bases and passing anteriorly to a large prominent ridge (Figure 4I); cardinal process and chilidial plates poorly preserved; muscle scars located on both sides of a broad short median ridge (corresponding to a depression on internal moulds), extending anteriorly to 25–29% of length; anterior scars small-sized, oval oblique and sharply outlined (Figure 4P, R, T, V) and posterior scars smaller, sometimes indistinct and in posterolateral position (Figure 4P, R, T).

Between 13 and 18 rounded costellae per 5 mm on whole shell surface, increasing by common bifurcation; growth lamellae common; endopunctae fine and aditicules abundant through tops of hollow costellae (Figure 4L) especially near anterior commissures of both valves.

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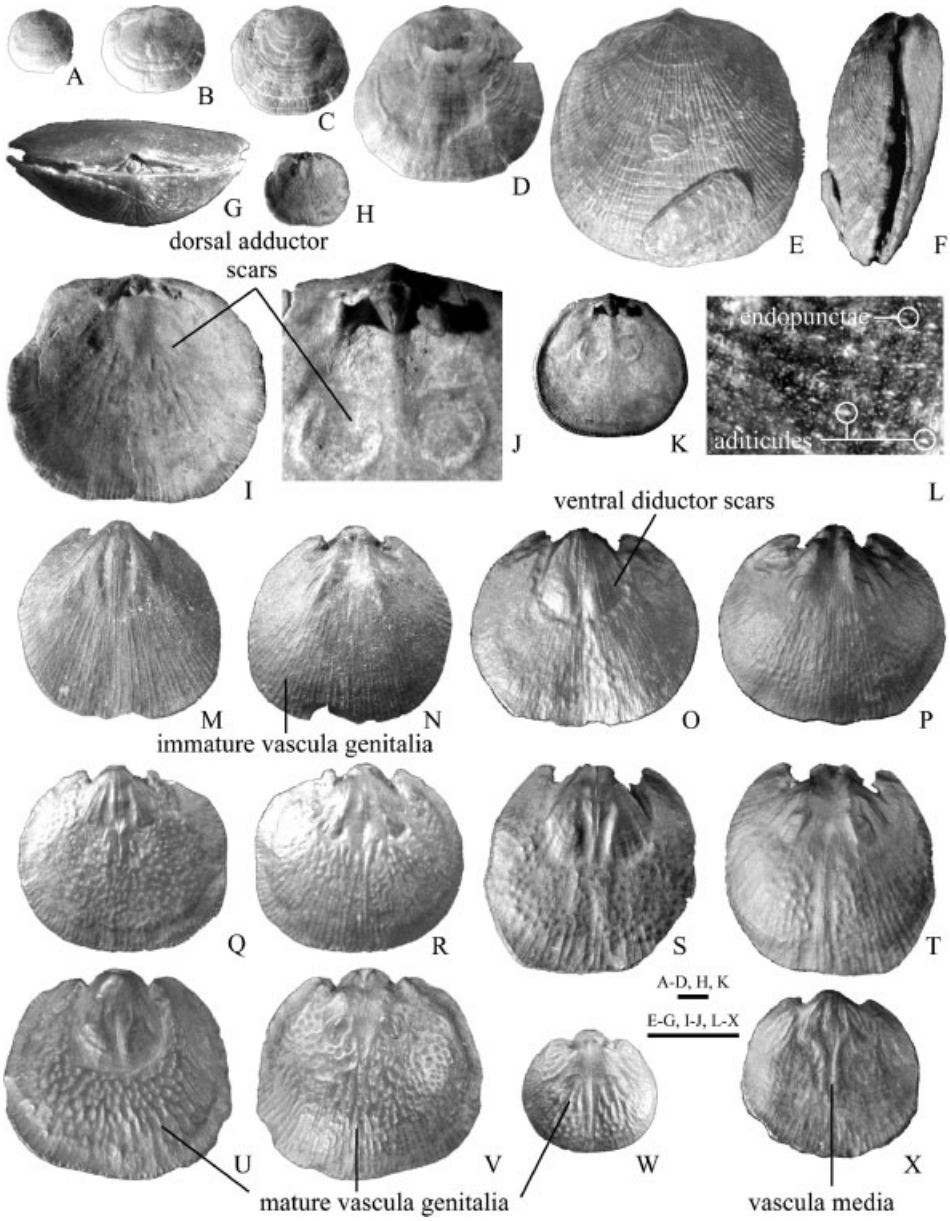

Figure 4. (A–B, E–I, L–X) *Rhipidomella prolifica* sp. nov. (A) MB.B.2843.4, (B) MB.B.2843.15, paratypes (dorsal valves) in external views, respectively the smallest and largest measured shells from locality D. (E–G) MB.B.2845.2a (complete undeformed shell with strophalosioid gen. et sp. indet. (MB.B.2845.2b) on the dorsal valve) in posterior, dorsal and lateral views; locality V. (H–I) MB.B.2843.11, paratype (dorsal valve), internal views; locality D. (L) MB.B.2843.7, paratype (dorsal valve) anterior external surface showing endopunctae and aditicules; locality D. (M–N) MB.B.2837.21 (internal mould) in ventral and dorsal views; locality A. (O–P) MB.B.2843.47, holotype (internal mould) in ventral and dorsal views; locality D. (Q–R) MB.B.2837.22 (internal mould) in ventral and dorsal views; locality A. (S–T) MB.B.2843.20, paratype (internal mould) in ventral and dorsal views; locality D. (U–V) MB.B.2843.34, paratype (internal mould) in ventral and dorsal views; locality D. (W) MB.B.2840.9 (internal mould) in dorsal view; locality C. (X) MB.B.2834.4 (internal mould) in ventral view; locality B. (C–D) *Rhipidomella* sp. (C) MB.B.2846.3 (D) MB.B.2846.11 (dorsal valves) in external views, locality U, Formation des Iridet, Tournaisian-Viséan boundary. (J–K) *Rhipidomella michelini* (Léveillé, 1835). IRScNB a5838 (dorsal valve, topotype figured *in* Demanet (1934, plate 2, figure 6a)), detail of dorsal cardinalia and muscle field and internal view; Tournai (Belgium). All scale bars are 5 mm, except L (1 mm).

The mantle canals, dominated by *vascula genitalia*, display various types of development:

(1) 'Immature pinnate' pattern (Figure 4M–N), rarely observed: the internal moulds of both valves, apart from the muscle scars, are covered by fine radial canals, each one directly connected distally to a follicular crenulation. These smooth canals, increasing in number by intercalations, correspond probably in position to the external costellae. All canals are identical: the major

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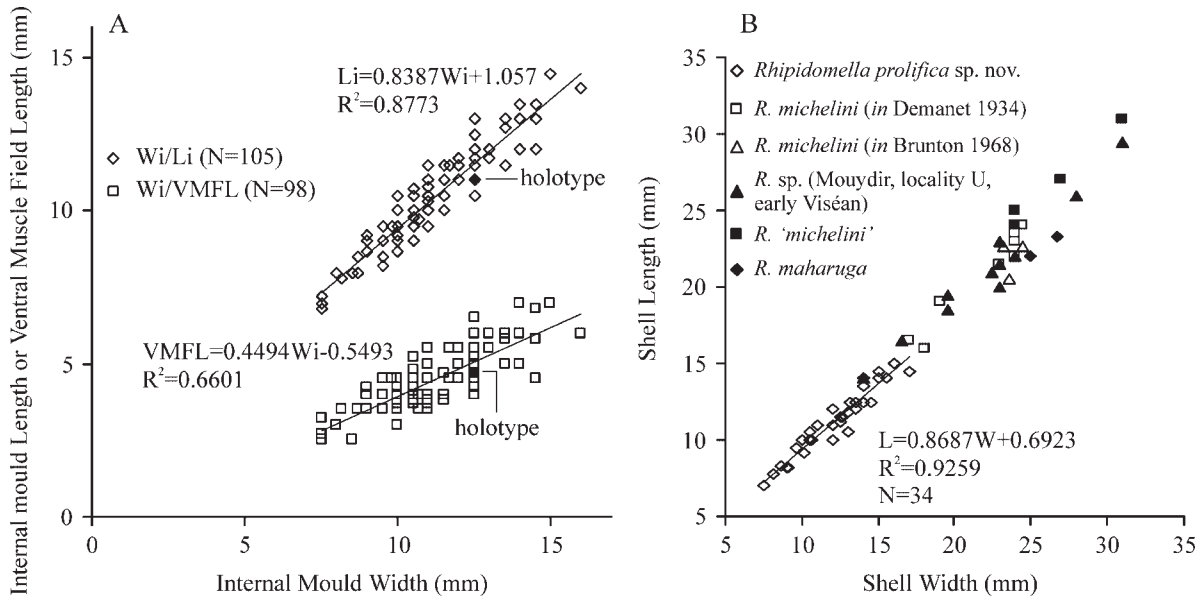

Figure 5. (A) Distribution of shell dimensions for internal moulds of *Rhipidomella prolifica* sp. nov. (B) Distribution of shell dimensions for specimens of *R. prolifica* sp. nov.; *R. michelini* (Léveillé, 1835), *R. 'michelini'* (*in* Haug, 1905), *R. maharuga* Havlíček, 1984 and *R.* sp. L = shell length; Li = internal mould length; VMFL = ventral muscle field length; W = shell length and Wi = internal mould length.

vascula described by Kemezys (1968) in typical rhipidomellid mantle canal system (*vascula central*, *vascula media* and *vascula myaria*) are absent.

(2) 'Intermediate lemniscate' pattern, observed in numerous internal moulds (holotype, Figure 4O–P, paratype, Figure 4S–T) and on the unique internal shell surface (paratype, Figure 4I): the radial canals are filled with genital granules, finer and finer towards anterior margin. These granular canals are broader than anterior crenulations, which constitute a distinct marginal ring. Where the latter is absent, it means that the anterior part of the mould is broken or worn.

(3) 'Mature lemniscate' pattern (Figure 4U–V, W): conspicuous granules, no longer included in canals, fill the

Table 1. Dimensions of some selected *Rhipidomella* specimens

	Loc.	Specimen	Fig.	L	Li	Lm	Lm/Li	W	Wi	T or Ti
Rhipidomella prolifica (Argiles de Teguentour)										
Shells	D	MB.B.2843.4	4A	11				11		?
	D	MB.B.2843.7	4L	11.5				12.5		?
	D	MB.B.2843.11	4HI	12				13.5		?
	D	MB.B.2843.15	4B	14.5				17		?
	V	MB.B.2845.2a	4EFG	14				14		5.9
im+s	A	MB.B.2837.4		>10.5	10.5	4.7	0.45	13	11.5	4.2
Internal moulds	A	MB.B.2837.21	4MN		11.5	5	0.43		11	3.4
	A	MB.B.2837.22	4QR		10	3.8	0.38		11.5	3.3
	B	MB.B.2838.4	4X		9	3.5	0.39		10	3
	C	MB.B.2840.9	4W		6.8	2.5	0.37		7.5	2.6
	D	MB.B.2843.20	4ST		11.7	5.5	0.47		12	3.6
	D	MB.B.2843.34	4UV		12	5	0.42		12.5	4.1
	D (H)	MB.B.2843.47	4OP		11	4.7	0.43		12.5	3.5
	A	MB.B.2837.6			7	3.2	0.46		7.5	2
	C	MB.B.2841.12			10.8	5.5	0.51		11	3.7
Rhipidomella sp. (Formation des Iridet)										
Shells	U	MB.B.2846.3	4C	18.5				19.5		?
	U	MB.B.2846.11	4D	29.5				31		?

H = holotype; im+s = internal mould with shell remains: L = shell length; Loc. = locality; Li = internal mould length; Lm = length of ventral muscle field; T = thickness; Ti = internal mould thickness; W = shell width; Wi = internal mould width.

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median part of both valves. This mature genital development seems independent of the size as the smallest mature internal mould (Figure 4W) is less than 7.5 mm wide. The v*ascula media* are currently absent in 'immature' (Figure 4M–N) and 'mature' (Figure 4U) internal moulds, or rarely short and conspicuous (Figure 4X—similar to *Rhipidomella* sp. *in* Lazarev (1976, plate 15, figure 1)); they are replaced by imprecise broad and short radial ridges (Figure 4Q, S).

Discussion. The distinctive characters of the new species, apart from the minute size of adult shells are: ventral interior of *Rhipidomella* type with the ventral muscle field length/internal mould length ratio usually less than 0.5; dorsal anterior with a low notothyrial platform passing to a broad short median ridge, and minute oval muscle scars. A notothyrial platform and conspicuous internal dorsal 'median ridge' are reported in the rhipidomellid genus *Aulacella* Schuchert and Cooper, 1931 (Harper *in* Williams and Harper, 2000, p. 818; Biernat, 1959). However, the external characters of the new taxon are typical of *Rhipidomella*, whereas *Aulacella* is unisulcate and fascicostellate. The dorsal median ridge in *Aulacella,* reaching the anterior margin, is markedly longer than the short ridge of *R. prolifica*. *Rhipidomella* is a cosmopolitan genus, widely reported from Middle Devonian to Permian, with over 40 species described. *Aulacella* is known from Mid-Devonian to latest Famennian (Strunian), and maybe even the earliest Tournaisian.

The original syntypes of the type species of *Rhipidomella*, namely *R. michelini* (Léveillé, 1835), are lost but topotypical material from the Tournaisian of Tournai (southern Belgium) has been illustrated by Demanet (1934, plate 2, figures 1, 2, 4–9) and Brunton (1968, plate 3, figures 1–6) (Figure 5B). After examination of Demanet's (1934) topotypes housed at the IRScNB, *R. michelini* can be easily differentiated from *R. prolifica* by its larger size (width: 17–24 mm, length: 16–24 mm), its longer ventral muscle field, its narrower internal dorsal median ridge, and its larger rounded anterior muscle scars (Figure 4J–K). However, the mantle canals are poorly preserved in silicified shells from Tournai. Among specimens from Scotland, identical to *R. michelini* topotypes in terms of size and muscle scars, the mantle canals resemble *R. prolifica* patterns: 'intermediate lemniscate' and 'mature lemniscate' (Davidson, 1861, plate 30, figures 10 and 11). Some *R. michelini* (juveniles?) from the Viséan of Northern Ireland (3.4–10.9 mm long, with a 'low wide ridge' separating the dorsal adductors) (Brunton, 1968, plate 3, figure 16) and from the Bashkirian of Spain (Martínez Chacón, 1979, plate 4, figure 11) are comparable to *R. prolifica* in their small size. Nevertheless, the dorsal median ridge of *R. prolifica* is broader and thicker, and its anterior scars are comparatively smaller than in the Irish juvenile specimens.

Several *Rhipidomella* species have been already described in Mississippian rocks of the Sahara (Figure 5B), notably in the Viséan-Serpukhovian of the Illizi Basin (south-eastern Algeria) by Haug (1905, plate 14, figures 1–5) (? = aff. *R. penniana* (Derby) *in* Dresser, 1954), whose material was examined at the Muséum national d'Histoire naturelle in Paris, but also in western Libya (Massa, *et al.* 1974, plate 6, figure 3, text-plate 2, figures 9 and 10;, 1987, plate 15, figure 1; Mergl and Massa, 1992, plate 2, figures 14–16). All these specimens are larger than *R. prolifica* (24–31 mm long) and display dorsal muscle scars similar to *R. michelini* topotypes. *R. maharuga* Havlíček, 1984 from the Tournaisian of western Libya (Havlíček and Röhlich, 1987, plate 9, figures 1–4; Mergl and Massa, 1992, Plate 2, figures 10–13) is larger (23–35.5 mm in width) than *R. prolifica* and its ventral muscle field occupies about 60% of the shell width (dorsal muscle field unknown). An unidentified species of *Rhipidomella* (MB.B.2846: Figure 4C, D; Table 1) was collected in the 'Dalle des Iridet' limestone of early Viséan age in the Tamertasset area (locality U: N 26°40.670′ E 3°52.770′). At first sight, it differs from *R. prolifica* by its larger size (flattened shells: 14–31 mm wide, 14–29.5 mm long), but its internal morphology is still unknown.

R. prolifica is close to *R. tenuicostata* Weller, 1914 from the North American mid-Tournaisian Chouteau Limestone (Weller, 1914, p. 158, plate 20, figures 27–29): same dimensions and outline, broad median ridge inside dorsal valve. It differs in its coarser costellae (4–5 per mm on *R. tenuicostata*), and probably a smaller cardinal process; the muscle scars of the American species are poorly known.

Taphonomic remarks. Most of the internal moulds of *Rhipidomella prolifica* have retained the original biconvex profile of the shell, with internal relief finely preserved in haematitic material. Shell remains are absent, except on a few specimens: MB.B.2837.4 (Table 1), internal mould with dorsal valve fairly well preserved (some aditicules observable); MB.B.2841.12 and MB.B.2843.16, internal moulds retaining worn shell material on posterior part. Finely preserved internal moulds of goniatites (Conrad and Pareyn, 1968; Wendt *et al*., 2009) are found in the same horizon as *R. prolifica*. An open question for Palaeozoic small-sized articulate brachiopods is their possible facultative pseudoplanktonic mode of life (Wignall and Simms, 1990; Sánchez de Posada *et al*., 2001, figures 6a and b).

Specimens with preserved shell represent about 7% of the whole *R. prolifica* material. Except for a single biconvex exemplar from locality V (Figure 4E–G), all display a compacted profile: dorsal valve convex, ventral valve flattened or sunken into the dorsal. A similar deformation is reported in *Rhipidomella* (Demanet, 1934, plate 2, figures 7, 9), for which Alexander (1986, table 2) cited a frequent 'splayed' deformation. It means that these *Rhipidomella* shells, probably toppled from life position, were quickly

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buried after death: dorsal valve down, more or less setting in soft sediment, ventral valve up. We can probably assume that the flattened *R. prolifica* shells were buried in thin siltstone beds interstratified within the Teguentour shales.

Superfamily ENTELETOIDEA Waagen, 1884
Family SCHIZOPHORIIDAE Schuchert and LeVene, 1929
Genus *Schizophoria* King, 1850

Type species. *Conchyliolithus (Anomites) resupinata* Martin, 1809; from the Viséan of Dovedale, Derbyshire, England.

Schizophoria sp.
Figure 3D–E

Material. One articulated internal mould (MB.B.2847) from locality D.

Description. Shell small-sized (width: 16 mm, length: 11 mm, hinge line width: *c*. 9 mm), wider than long, widest at about mid-length, moderately biconvex, oval in outline; cardinal extremities rounded and anterior commissure rectimarginate.

Ventral valve with slightly prominent beak; interarea concave, low (1.4 mm high), slightly apsacline; delthyrium narrow, open; dental plates short; muscle field small; pair of strong radial *vascula media* arising from diductor margins, becoming thinner anteriorly, curving slightly in median direction and disappearing finally; posterolateral areas covered by radial fasciculate canals, more or less granular, probable *vascula genitalia* and on anterior margins, indistinct small canals may join follicular embayments.

Dorsal valve with low, concave orthocline interarea; chilidium narrow, open; pair of thin *vascula media* arising from the anterior muscle scars and curving distally in external direction and fasciculate granular canals abundant on median and lateral areas.

Ornamentation unobserved.

Discussion. In the absence of external ornamentation, any specific determination is impossible. The morphology of the ventral mantle canals is similar to that described in small specimens of *Schizophoria verulamensis*, type A (Roberts, 1968, text-figure 5A, 6A).

Order Rhynchonellida Kuhn, 1949
Superfamily Pugnacoidea Rzhonsnitskaya, 1956
Family Pugnacidae Rzhonsnitskaya, 1956
Genus *Mouydirhynchus* gen. nov.

Type species. *Mouydirhynchus quietus* sp. nov. by monotypy.

Diagnosis. Shell medium-sized, dorsibiconvex, subcircular to transversally ovate in outline and wider than long; anterior commissure uniplicate; foramen permesothyrid; fold and sulcus originating at some distance from umbones; flanks smooth or with 1–2 low costae perceptible close to anterolateral margins; fold and sulcus with 3–5 and 2–4 low costae arising in shell anterior part, respectively; dental plates short and mostly fused to shell walls and dorsal median septum and septalium absent (myophragm rarely developed).

Name. After the Mouydir area (Algerian Sahara) where the type locality of its type species is located.

Discussion. *Mouydirhynchus* belongs to the Pugnacidae because of its short dental plates, the absence of a dorsal median septum and its external morphology. *Mouydirhynchus* differs from *Chapinella* Savage, Eberlein and Churkin, 1978 from the Famennian of Alaska by its markedly less pronounced medial and lateral costae and, thus, a less plicated tongue. The new genus displays some external similarities in terms of outline and valve convexity with the type species of *Evanidisinurostrum* Sartenaer, 1987, *E. zemoulensis* Drot, 1964 from the Famennian of Morocco. However, characters such as the lower number of costae on the fold and in the sulcus as well as the absence of dental plates in *Evanidisinurostrum* easily differentiate it from *Mouydirhynchus*. *Ovlatchania* Abramov and Grigorjewa, 1986 from the Lower Carboniferous of eastern Siberia is markedly larger than *Mouydirhynchus* and has well-developed dental plates as well as a septalium.

Occurrence. Argiles de Teguentour (late Tournaisian), Mouydir, Algeria.

Mouydirhynchus quietus sp. nov.
Figures 6 and 7

Holotype. A complete shell (MB.B.2851.1) from locality V.

Material. Three hundred and eight specimens mostly articulated but commonly crushed and/or incomplete from localities A (44 articulated specimens, 1 dorsal valve), B (15 articulated specimens), C (40 articulated specimens), D (128 articulated specimens, 1 ventral and 3 dorsal valves), E (33 articulated specimens, 1 ventral valve), V (38 articulated specimens), W (1 articulated specimen), Y (1 articulated specimen) and Z (3 articulated specimens). Of these, 25 specimens from localities A (MB.B.2848.1–2), D (MB.B.2849.1–9), E (MB.B.2850.1–3) and V (MB.B.2851.1–11) are measured and MB.B.2851.12 is sectioned.

Type locality and horizon. Oued Habadra (locality V), Argiles de Teguentour of late Tournaisian age (*Pericyclus–Progoniatites* Assemblage of Korn *et al*., 2007).

Name. From Latin *quietus*, peaceful; allusion to the peacefulness of the locus typicus located in the Sahara.

Diagnosis. As for the genus.

Description. Shell medium-sized (up to 24.1 mm in width), sharply dorsibiconvex, wider than long, widest anteriorly to mid-length and subcircular to transversally ovate in outline; anterior commissure uniplicate and anterior margin moderately to sharply emarginate.

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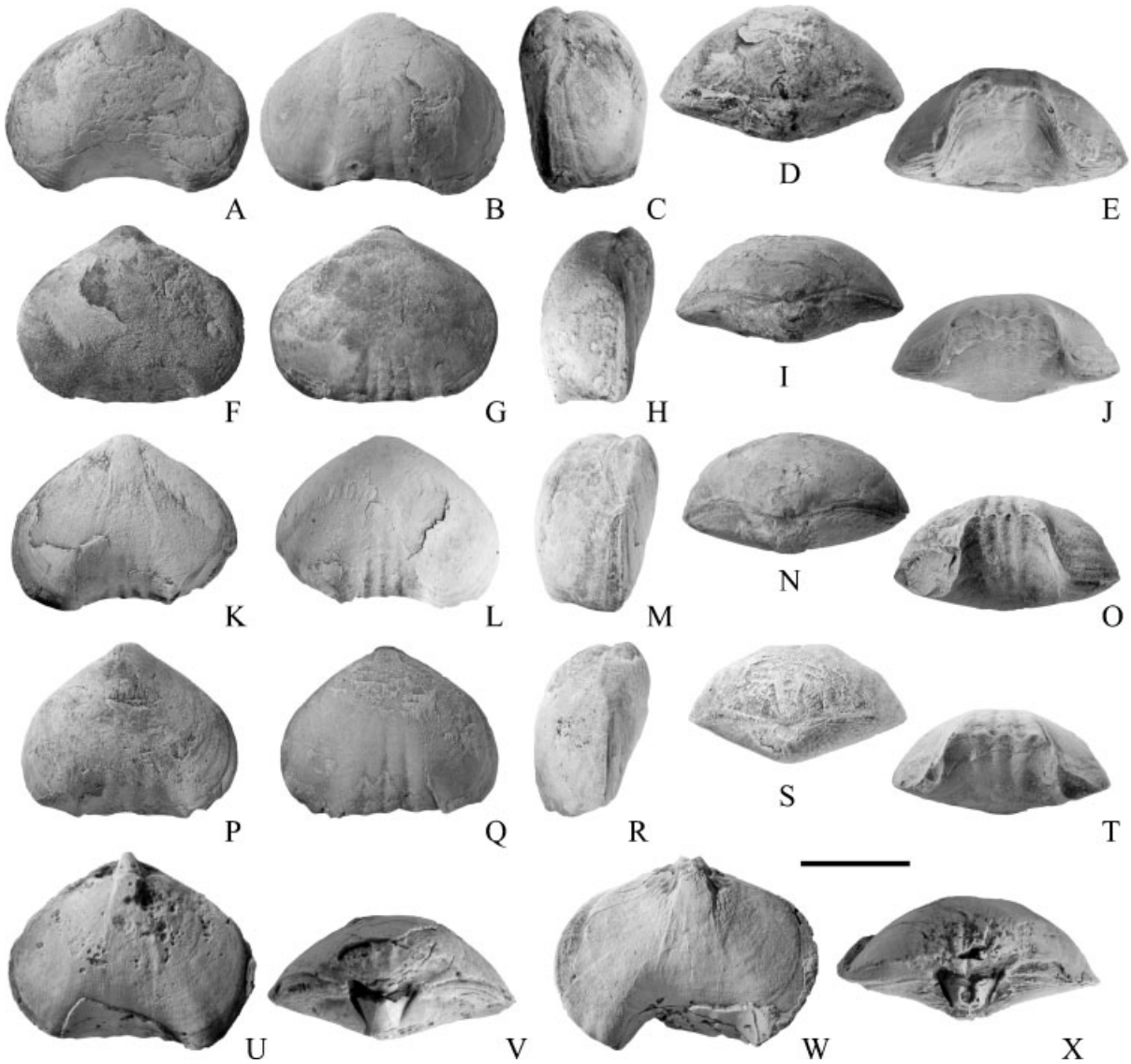

Figure 6. *Mouydirhynchus quietus* sp. nov. (A–E) MB.B.2851.1 (holotype) in ventral, dorsal, lateral, posterior and anterior views; locality V. (F–J) MB.B.2851.2 in ventral, dorsal, lateral, posterior and anterior views; locality V. (K–O) MB.B.2851.3 in ventral, dorsal, lateral, posterior and anterior views; locality V. (P–T) MB.B.2851.4 in ventral, dorsal, lateral, posterior and anterior views; locality V. (U–V) MB.B.2850.1 (internal mould) in ventral and posterior views; locality E. (W–X) MB.B.2850.2 (internal mould) in ventral and posterior views; locality E. All whitened with ammonium chloride. Scale bar = 10 mm.

Ventral valve gently inflated in both posterior and lateral profiles; anterolateral margins inclined to become flat; beak small, suberect; foramen permesothyrid; sulcus wide, deep, originating at about mid-valve or more anteriorly, with blunt margins and flat bottom at front; tongue 1.55–2.73 times wider than high (average 2.17; $n = 7$—tongue height measured perpendicularly to anterior commissural plane), perpendicular to commissural plane or bent dorsally, trapezoidal; dental plates short, mostly fused to shell walls; teeth stout; muscle field slightly impressed, triangular in outline and occupying posterior third of valve floor.

Dorsal valve evenly convex in both lateral and posterior profiles, highest at about mid-valve, then curving towards anterior margin; fold originating at about mid-valve or more anteriorly, low, flat-topped at front (apart from the costae); hinge plates divided; dental sockets deep, narrow and myophragm short, rarely developed.

Shell posteriorly smooth; flanks usually smooth (exceptionally with 1–2 low costae); 3–5 costae on the fold and 2–4 costae in the sulcus, arising in the anterior part of the shell, round-top, low; parietal costae absent and growth lamellae irregularly spaced, crowded close to anterior and lateral commissures.

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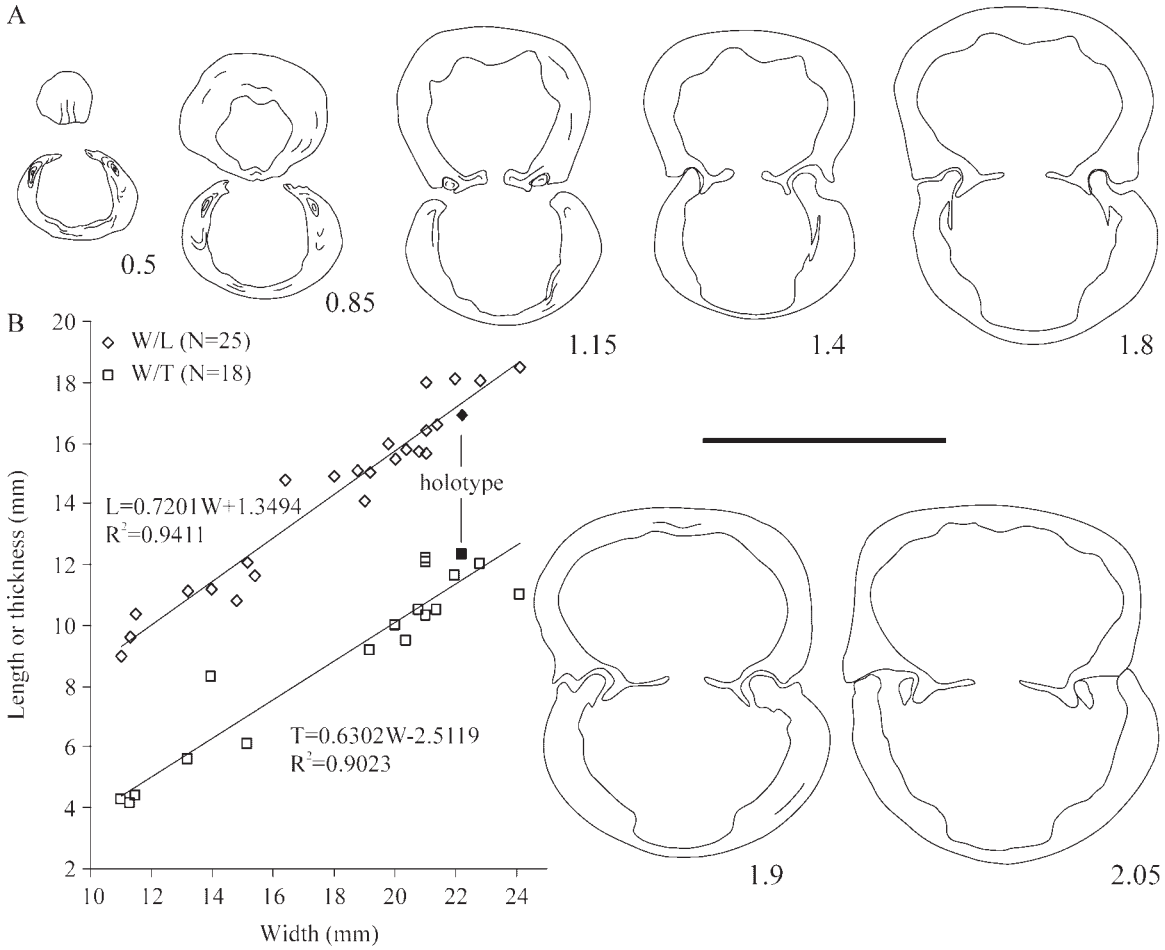

Figure 7. (A) Selected transverse serial sections illustrating the internal structures in *Mouydirhynchus quietus* sp. nov., MB.B.2851.12 (locality V); distances measured in mm from the posterior end of the shell. Scale bar = 5mm. (B) Distribution of shell dimensions for *Mouydirhynchus quietus* sp. nov. L = shell length; T = shell thickness; W = shell width.

Dimensions in mm. Width range 11.0–24.1, average 18.2 ($n = 25$); length range 9.0–18.5, average 14.4 ($n = 25$); thickness range 4.15–12.35, average 9.1 ($n = 18$); width of sulcus range 9.8–15.3, average 12.1 ($n = 10$); height of tongue range 3.0–7.25, average 5.7 ($n = 10$); width/length ratio range 1.11–1.37, average 1.26 ($n = 25$); width/thickness ratio range 1.69–2.72, average 2.11 ($n = 18$) and width of sulcus/width ratio range 0.50–0.73, average 0.61 ($n = 10$).

Superfamily Rhynchotrematoidea Schuchert, 1913b
Family Trigonirhynchiidae Schmidt, 1965
Trigonirhynchiid gen. indet.
Trigonirhynchiid gen. indet. sp. A
Figure 8A–G

Material. One hundred and seventeen internal moulds, generally incomplete and mainly juveniles from localities B (7 articulated specimens), C (25 articulated specimens, 1 dorsal valve), D (5 articulated specimens), E (30 articulated specimens, 4 dorsal valves) and X (45 articulated specimens). Of these, MB.B.2855–2856 are illustrated here.

Description. Shell medium-sized (*c*. 20 mm wide), slightly wider than long, dorsibiconvex, round-triangular in outline; maximum width anteriorly to mid-length; anterior commissure uniplicate and anterior margin straight.

Ventral valve convex posteriorly; anterolateral regions inclined to become flat; beak prominent, suberect; foramen unobserved; sulcus narrow, originating close to the anterior margin, shallow, flat-bottomed at front; tongue not perpendicular to commissural plane, rounded in outline, low; dental plates short, convergent ventrally; lateral umbonal cavities infilled by shelly material and teeth small.

Dorsal valve highest at about mid-valve then curving markedly towards the front; in posterior view, top of the valve rounded to slightly flattened; flanks sloping moderately towards lateral commissures; fold absent or low, slightly round-topped at front, originating close to anterior margin; median septum extending anteriorly to 33–50% of

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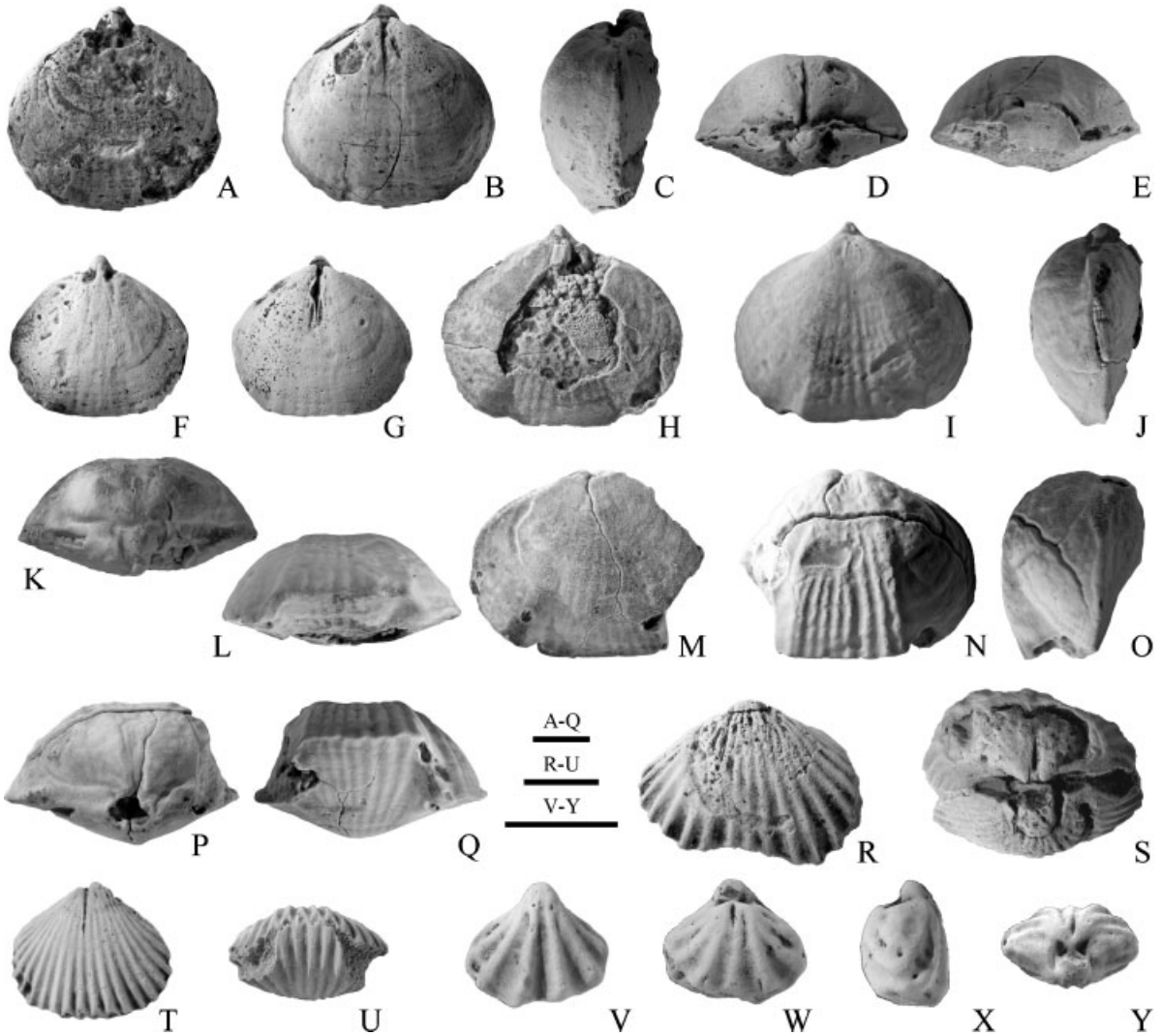

Figure 8. (A–G) Trigonirhynchiid gen. indet. sp. A. (A–E) MB.B.2855 (internal mould) in ventral, dorsal, lateral, posterior and anterior views; locality B. (F–G) MB.B.2856 (internal mould) in ventral and dorsal views; locality D. (H–Q) Trigonirhynchiid gen. indet. sp. B. (H–L) MB.B.2854.1 (internal mould with dorsal median septum preserved as shelly material) in ventral, dorsal, lateral, posterior and anterior views; locality C. (M–Q) MB.B.2854.2 (internal mould with dorsal median septum preserved as shelly material) in ventral, dorsal, lateral, posterior and anterior views; locality C. (R–U) *Hemiplethorhynchus*? sp. (R–S) MB.B.2852 (incomplete internal mould) in ventral and posterior views; locality A. (T–U) MB.B.2853 (incomplete internal mould) in dorsal and anterior views; locality D. (V–Y) *Coveenia*? sp. MB.B.2857 (incomplete internal mould) in ventral, dorsal, lateral and posterior views; locality C. All whitened with ammonium chloride. All scale bars are 5 mm.

valve unrolled length and septalium seemingly without cover plate.

Ornamentation poorly preserved but up to 4–6 low, round-topped costae on sulcus and originating far from umbo; poorly defined costae observed close to anterolateral margins and growth lamellae irregularly spaced.

Discussion. Despite the large number of specimens available, these internal moulds cannot be identified with confidence due to the poor preservation of most of them and also because their ornamentation is imperfectly known. They are reported to an unidentified genus of the family Trigonirhynchiinae and may be assigned to the subfamily Hemitoechiinae Savage, 1996 as their septalium seems to be devoid of cover plate. Nonetheless, material with preserved shell, which may be collected in the limestone nodule levels developed in the Argiles de Teguentour, is needed in order to resolve the question of their generic and specific assignment. In terms of shape (e.g. outline, low tongue), the specimens from Mouydir are close to those assigned to *Libyaerhynchus* Mergl and Massa, 1992 from the Frasnian and Famennian of Libya, but their costae are clearly less pronounced.

Trigonirhynchiid gen. indet. sp. B
Figure 8H–Q

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Material. Forty internal moulds, mostly incomplete and/or crushed from localities B (3 articulated specimens), C (25 articulated specimens, 1 dorsal valve), D (4 articulated specimens), E (1 articulated specimen), X (3 articulated specimens) and Y (6 articulated specimens). Of these, MB.B.2854.1–2 are illustrated here.

Description. Shell of medium size (up to 22 mm wide), wider than long, markedly dorsibiconvex, widest at about mid-length, subpentagonal in outline; anterior commissure uniplicate and anterior margin straight.

Ventral valve weakly convex posteriorly; anterolateral regions inclined to become flat; beak small, suberect; foramen unobserved; sulcus wide, originating at about mid-valve (exceptionally) or close to the anterior margin, shallow to, in rare cases, moderately deep, flat-bottomed at front; tongue not perpendicular to commissural plane, subtrapezoidal in outline, generally low and dental plates short, convergent ventrally.

Dorsal valve highest at about mid-valve then curving markedly towards the front; in posterior view, top of the valve flattened or slightly depressed; flanks sloping moderately towards lateral commissures; fold low or, in rare cases, moderately high, flat-topped at front, originating at about mid-valve or close to anterior margin; median septum (preserved as shelly material in Figure 8I, N) extending anteriorly to 27–35% of valve unrolled length (up to 54% in juveniles) and septalium seemingly without cover plate.

Shell covered by costae; flanks with at least 10 costae; 6–9 costae on fold and 5–9 costae in sulcus, arising in umbonal regions; costae on fold and in sulcus coarser than those on flanks and increasing by intercalation and few growth lamellae irregularly spaced.

Discussion. From the internal morphology viewpoint, these specimens are identical to those described above as trigonirhynchiid gen. indet. sp. A, but they externally differs from the latter by their wider sulcus, their more transversally ovate outline and their shell covered by costae which arise in umbonal areas. However, generic relationships between both taxa remain still unclear due to their poor preservation and the overrepresentation of immature specimens. For these reasons, there are temporarily assigned to the same genus.

Subfamily Ripidiorhynchinae Savage, 1996
Genus *Hemiplethorhynchus* von Peetz, 1898
Type species. *Hemiplethorhynchus fallax* von Peetz, 1898; from the Tournaisian of the Altai, Russia.
Hemiplethorhynchus? sp.
Figure 8R–U

Material. Four incomplete internal moulds (including three juveniles) from localities A (one articulated specimen, one ventral valve) and D (two articulated specimens). Of these, MB.B.2852–2853 are figured.

Description. Shell small, dorsibiconvex and covered entirely by angular costae (at least 8 costae per flank, 3–4 costae in sulcus and 5 costae on fold); sulcus originating in posterior part of ventral valve; dental plates short, more or less vertical and dorsal median septum and septalium present.

Discussion. These badly preserved specimens are tentatively assigned to von Peetz's genus on the basis of the characters mentioned above.

Order Athyridida Boucot, Johnson and Staton, 1964
Suborder Retziidina Boucot, Johnson and Staton, 1964
Superfamily Retzioidea Waagen, 1883
Family Neoretziidae Dagys, 1972
Subfamily Hustediinae Grunt, 1986
Genus *Coveenia* Alvarez and Brunton, 2000
Type species. *Retzia ulothrix* de Koninck, 1843 (in 1842–1844); from the Tournaisian of Tournai, Belgium.
Coveenia? sp.
Figure 8V–Y

Material. One almost complete internal mould (MB.B.2857) from locality C.

Description. Shell small-sized (width: 6.5 mm, length: 5.3 mm, thickness: 3.7 mm) (possibly juvenile), more or less circular in outline, equibiconvex; ventral beak suberect; anterior commissure not observed; 6 and 7 strong costae respectively on ventral and dorsal valve; dental plates absent and dorsal myophragm reaching about one-third of dorsal valve length.

Discussion. This very small internal mould is tentatively assigned to *Coveenia* on the basis of the observed characters, but additional specimens are needed to confirm this tentative generic identification. *Coveenia* has been reported within the Tournaisian and Viséan of southern Belgium and in the Viséan of the British Isles by Alvarez and Brunton (2000).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Ambocoelioidea George, 1931
Family Ambocoeliidae George, 1931
Subfamily Ambocoeliinae George, 1931
Genus *Crurithyris* George, 1931
Type species. *Spirifer urei* Fleming, 1828; from the Viséan of Strathaven, Lanarkshire, Scotland.
Crurithyris cf. *fissa* George, 1931
Figures 9 and 10

cf. 1931 *Crurithyris fissa* sp. nov. George, 1931, p. 49, Plate 4, figure 5.

Material. Two hundred and twenty-eight internal moulds, most of them articulated but generally incomplete and/or deformed from localities A (6 articulated specimens), B (5 articulated specimens), C (99 articulated specimens, 1 ventral valve), D (60 articulated specimens), E (13 articulated

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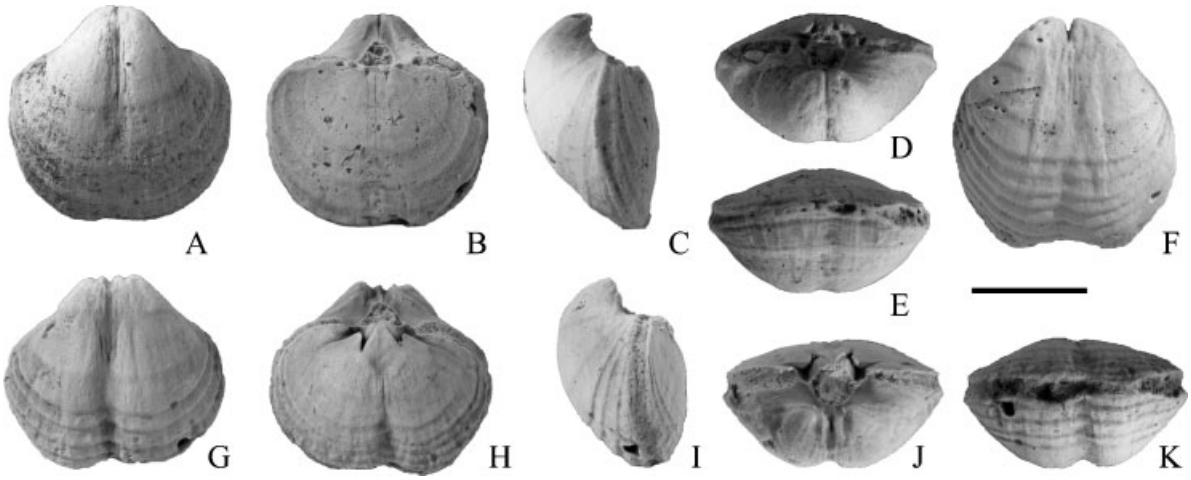

Figure 9. *Crurithyris* cf. *fissa* George, 1931. (A–E) MB.B.2867 (internal mould) in ventral, dorsal, lateral, posterior and anterior views; locality E. (F) MB.B.2859.6 (internal mould) in ventral view; locality C. (G–K) MB.B.2864.11 (internal mould) in ventral, dorsal, lateral, posterior and anterior views; locality V. All whitened with ammonium chloride. Scale bar = 5 mm.

specimens), V (26 articulated specimens, 1 ventral valve), X (7 articulated specimens) and Y (11 articulated specimens). Of these, 56 specimens from localities C (MB.B.2858.1–24, MB.B.2859.1–5, MB.B.2860.1–5), D (MB.B.2861.1–2, MB.B.2862.1–2), E (MB.B.2863), V (MB.B.2864.1–10), X (MB.B.2865.1–4) and Y (MB.B.2866.1–3) are measured.

Description. Shell small-sized (up to 10.1 mm in width), longer than wide to wider than long, markedly ventribiconvex, widest at about mid-length, subpentagonal in outline; hinge line shorter than greatest width; anterior margin straight or slightly to moderately emarginate; anterior commissure rectimarginate or more rarely vaguely undulating.

Ventral valve regularly convex in lateral profile, subtrapezoidal in posterior view (top flat or medially grooved); median groove commonly developed, originating in umbonal area; umbo prominent; shoulder lines concave; beak incurved, projecting well beyond hinge line; interarea triangular, apsacline, concave and low; deltidial plates unobserved; 'pedicle collar' *sensu* Veevers (1959) or 'delthyrial plate' *sensu* Ma (*in* Ma *et al*., 2006) closing

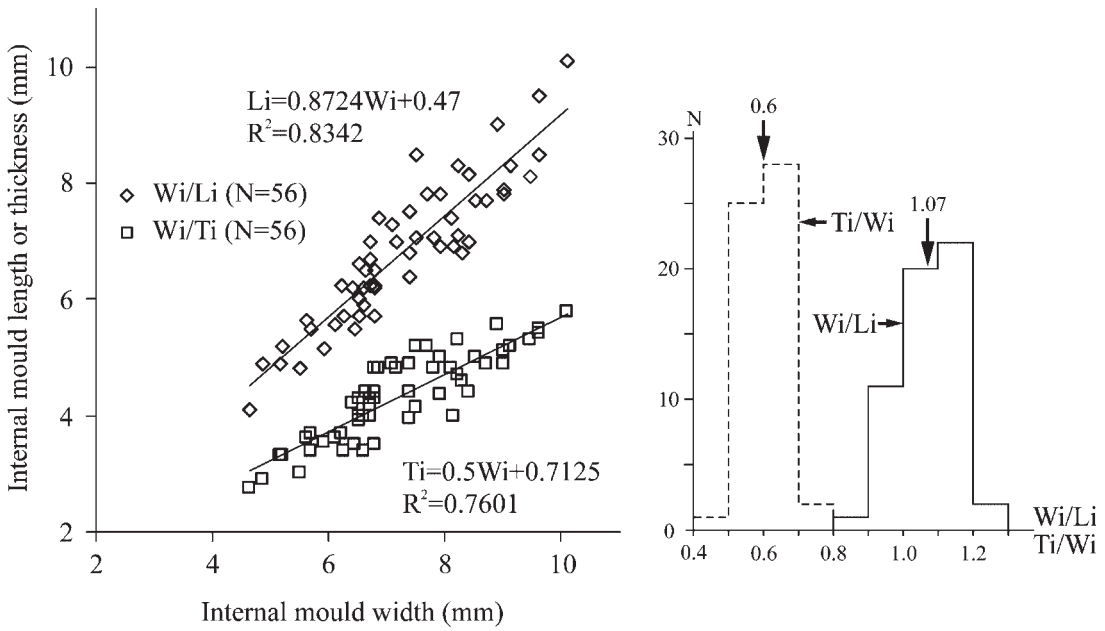

Figure 10. Distribution of shell dimensions for internal moulds of *Crurithyris* cf. *fissa* George, 1931 and frequency diagrams of Ti/Wi and Wi/Li (arrows = means). Li = internal mould length; Ti = internal mould thickness and Wi = internal mould with.

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delthyrium apex and muscle scars separated medially by a low ridge.

Dorsal valve gently convex in posterior view; median groove originating at about mid-valve; interarea not observed; inner socket ridge well-developed; crural bases separating shallow sockets fusing with valve floor posteriorly; adductor muscle field divided by a low ridge; adductor scars obovate; spiralium pointing laterally with at least five whorls.

Coarse growth lamellae mainly developed in anterior part of shell, irregularly spaced; micro-ornament not observed.

Dimensions in mm ($n = 56$). Width range 4.65–10.1, average 7.2; length range 4.1–10.1, average 6.8; thickness range 2.75–5.8, average 4.3; width/length ratio range 0.88–1.22, average 1.07 and width/thickness ratio range 1.42–2.04, average 1.68.

Discussion. These internal moulds of *Crurithyris* are tentatively assigned to *C. fissa* George, 1931, originally described from the Viséan of the British Isles, on the basis of their usually well-developed sulci in both valves and their slightly inflated dorsal valve; however, their growth lamellae are more pronounced than in the latter. Furthermore, *C. fissa* has been poorly illustrated and its internal characters are still poorly known. Poletaev (1975) reported the presence of George's species within the Tournaisian of the Donetz Basin. Carter (1987, 1988) described small specimens of *Crurithyris* identified as *C.* cf. *laevicula* (Rowley, 1900) from the Tournaisian of North America which also bear pronounced sulci in both valves. They are relatively similar to the Algerian material but they do not display thickened growth lamellae. Demanet (1958) introduced a new *Crurithyris* species occurring in abundance within the 'Calcaire de Vaulx et de Chercq' (=Vaulx Member of the Tournai Formation, Belgium), namely *C. sulcata* (not *C. sulcata* Stehli, 1954) which likely corresponds to the undescribed species of *Crurithyris* illustrated by de Koninck (1887, plate 36, figures 17–25). As Demanet (1958) failed to provide a description or a definition of his new taxon, *C. sulcata* Demanet, 1958 is considered as a *nomen nudum* and cannot be validly compared with the material from Mouydir, which has approximately the same age on the basis of the goniatite assemblages (Delépine, 1940; Korn *et al*., 2007). *C. parva* (Weller, 1899) illustrated by Carter (1967), from the Tournaisian Chappel Limestone of central Texas, is also characterized by well-developed sulci, but it is smaller and seems to be devoid of coarse growth lamellae. Weller's species has been placed in doubtful synonymy with *C. urei* (Fleming, 1828) by Brunton (1984) but a thorough comparative study of the Lower Carboniferous species of *Crurithyris* is beyond the scope of this paper.

Superfamily Martinoidea Waagen, 1883
Family Martiniidae Waagen, 1883
Subfamily Eomartiniopsinae Carter (*in* Carter *et al*., 1994)
Genus *Eomartiniopsis* Sokolskaya, 1941

Type species. *Martiniopsis (Eomartiniopsis) elongata* Sokolskaya, 1941; from the Tournaisian (Upa limestones) of the Moscow Basin, Russia.

Eomartiniopsis mouydirensis sp. nov.
Figures 11A–S, 12

Holotype. An incomplete internal mould (MB.B.2870.1) from locality D.

Material. Two hundred and seventy-eight internal moulds, most of them articulated but generally incomplete and/or deformed from localities A (21 articulated specimens, 1 ventral valve), B (7 articulated specimens), C (20 articulated specimens), D (182 articulated specimens, 1 ventral valve), E (26 articulated specimens), V (9 articulated specimens), W (1 articulated specimen), Y (1 articulated specimen) and Z (9 articulated specimens). Of these, 24 specimens from localities A (MB.B.2868.1), C (MB.B.2869.1–2), D (MB.B.2870.2–10, 2870.12–18), E (MB.B.2871.1–2, MB.B.2872), V (MB.B.2873) and Z (MB.B.2874.1) are measured.

Type locality and horizon. Oued Tamertasset (locality D), Argiles de Teguentour of late Tournaisian age (*Pericyclus–Progoniatites* assemblage of Korn *et al*., 2007).

Name. After the Mouydir area.

Diagnosis. A small species of *Eomartiniopsis* with shell wider than long, occasionally transverse, subequally biconvex and ovate in outline. Sulcus wide, moderately deep; fold round- to flat-topped. Flanks smooth or with 5–6 weak obscure costae. Internally, thin and long dental plates; muscle field not excavated, no ventral myophragm and dorsal valve with long myophragm.

Description. Shell small-sized for genus (up to 19.6 mm in width), wider than long, occasionally transverse, subequally biconvex, widest at about mid-length and transversally ovate in outline; hinge line shorter than greatest width; anterior margin straight or emarginated and anterior commissure uniplicate.

Ventral valve moderately inflated; flanks almost flat in posterior profile from edges of sulcus to valve margins, sloping moderately towards commissures; umbo prominent; beak incurved; sulcus wide, originating in umbonal area like a groove widening progressively anteriorly with blunt margins, moderately deep; tongue 2.15–3.18 times wider than high (average 2.48; $n = 7$), rounded to subtrapezoidal, more or less perpendicular to commissural plane; interarea not clearly delineated on the internal mould, orthocline to apsacline or apsacline; delthyrium wide; deltidial plates not observed; dental plates thin, slightly divergent at an angle varying between 5 and 30° (average 19.12°; $n = 41$), extending to 25–44% (average 31.26%; $n = 19$) of ventral unrolled length; muscle field not excavated (in the sense of Gourvennec (1989)), posterolaterally delimited by dental

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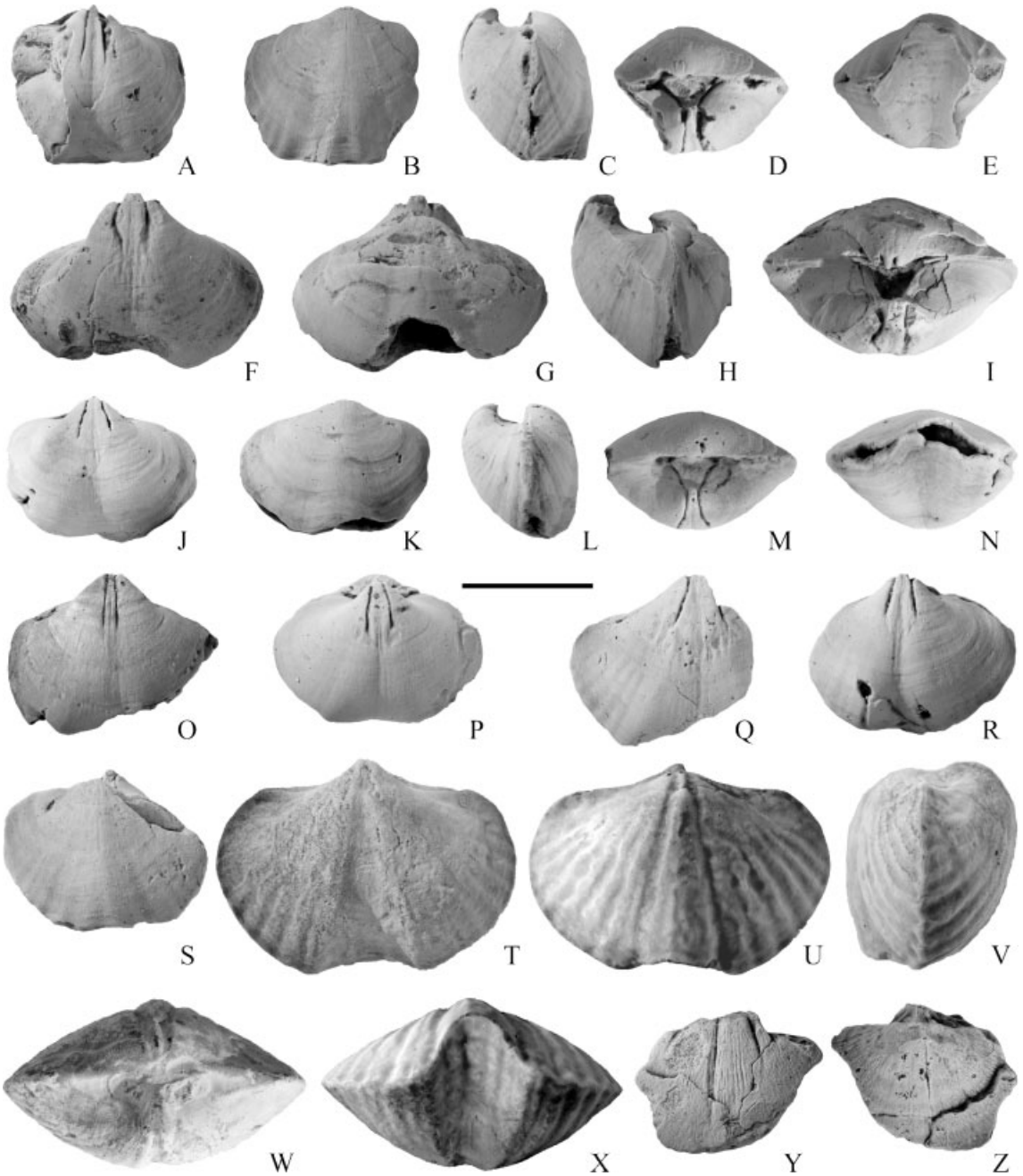

Figure 11. (A–S) *Eomartiniopsis mouydirensis* sp. nov. (A–E) MB.B.2870.1 (holotype, internal mould) in ventral, dorsal, lateral, posterior and anterior views; locality D. (F–I) MB.B.2870.2 (internal mould) in ventral, dorsal, lateral and posterior views; locality D. (J–N) MB.B.2874.1 (internal mould) in ventral, dorsal, lateral, posterior and anterior views; locality Z. (O) MB.B.2868.2 (internal mould) in ventral view; locality A. (P) MB.B.2870.11 (internal mould) in ventral view; locality D. (Q) MB.B.2868.3 (internal mould) in ventral view; locality A. (R) MB.B.2868.4 (internal mould) in ventral view; locality A. (S) MB.B.2874.2 (internal mould) in dorsal view; locality Z. (T–X) *Punctothyris*? sp. MB.B.2875 (internal mould) in ventral, dorsal, lateral, posterior and anterior views; locality A. (Y–Z) Elythid gen. et sp. indet. MB.B.2876 (internal mould) in ventral and dorsal views; locality E. All whitened with ammonium chloride. Scale bar = 10 mm.

plates, with up to three radial ridges, generally diamond-shaped in outline but depending on divergence angle of dental plates and no myophragm observed.

Dorsal valve moderately inflated; fold originating at about mid-valve or posterior to it, generally poorly developed, round- to flat-topped at front (a shallow median depression rarely occurs anteriorly); interarea small, slightly concave and apsacline; muscle field poorly impressed on valve wall; myophragm long and cardinal process not observed.

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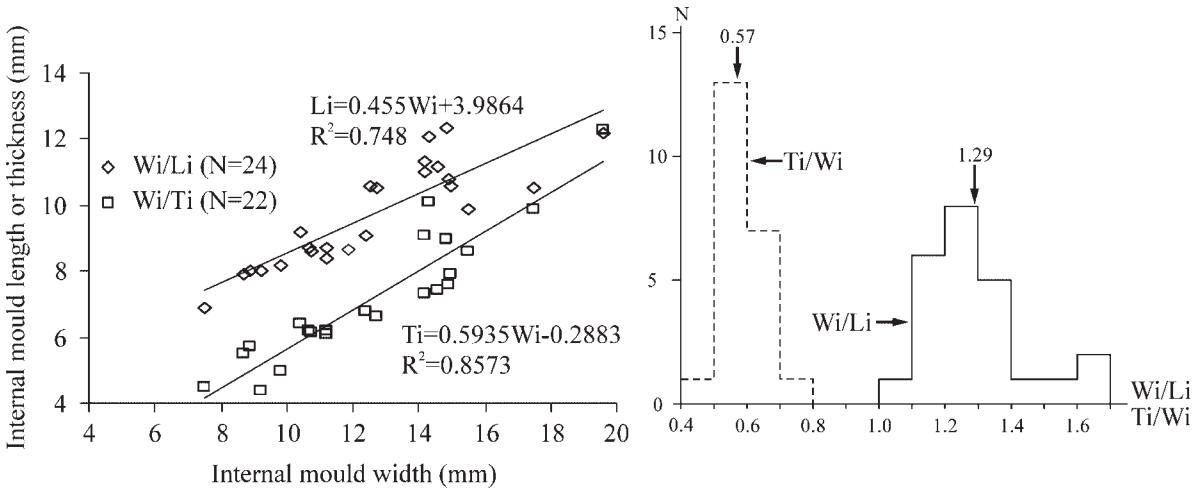

Figure 12. Distribution of shell dimensions for internal moulds of *Eomartiniopsis mouydirensis* sp. nov. and frequency diagrams of Ti/Wi and Wi/Li (arrows = means). Li = internal mould length; Ti = internal mould thickness and Wi = internal mould width.

Shell smooth or with 5–6 weak obscure costae on flanks; growth lamellae numerous, irregularly spaced and micro-ornament not observed.

Dimensions in mm. Width range 7.5–19.6, average 12.6 ($n = 24$); length range 6.9–12.35, average 9.72 ($n = 24$); thickness range 4.4–12.3, average 7.21 ($n = 22$); width/length ratio range 1.09–1.67, average 1.29 ($n = 24$); width/thickness ratio range 1.42–2.09, average 1.77 ($n = 22$); width of sulcus/width ratio range 0.40–0.63, average 0.48 ($n = 13$).

Discussion. *Eomartiniopsis mouydirensis* differs from *E. elongata* Sokolskaya, 1941 by its less elongated outline and the presence of obscure costae on the flanks. *E. mouydirensis* is differentiated from *E. rostrata* (Girty, 1899), as figured by Carter (1972, 1987), by its considerably smaller size and the development of obscure costae on its flanks. *E. mouydirensis* differs from *E. kinderhookensis* Carter, 1988 by its less inflated dorsal valve, its low tongue and its smaller size. The new species differs from *E. girtyi* (Branson, 1938) by its smaller size, a smaller number of costae on the flanks where they are developed. *E. mouydirensis* is distinguished from *E. lakahalensis* Brice *in* Brice *et al.* (2005) by its ventral muscle field, which is not excavated, the development of costae on the flanks and its slightly smaller size. *E. mouydirensis* is close to *E. planosinuata* Poletaev, 1975 in its outline, although the former is generally a little more transverse, but it differs from the latter by the development of costae on the flanks and its larger size. *E. mouydirensis* can be separated from *E. grandiformis* Plodowski, 1968 by its smaller size, the presence of obscure costae and a more inflated dorsal valve.

Family Gerkispiridae Carter, 1985
Genus *Punctothyris* Hyde, 1953

Type species. *Punctothyris argus* Hyde, 1953; from the Tournaisian Logan Formation, Byer Member, Sciotoville, Ohio.

Punctothyris? sp.
Figure 11T–X

Material. One complete internal mould (MB.B.2875) with some shell remains from locality A.

Description. Shell wider than long, widest at about mid-length, subequally biconvex and transversally subovate in outline; hinge line shorter than greatest width; lateral margins rounded; anterior border emarginated and anterior commissure uniplicate.

Ventral valve moderately inflated; flanks sloping gently towards lateral commissures; sulcus originating at beak, relatively well-defined, round-bottomed at front and moderately deep; tongue about 1.5 times wider than high, rounded and perpendicular to commissural plane; umbo prominent; beak incurved; interarea concave, pro-apsacline and linear; delthyrium not observed; dental plates extrasinal, thin and relatively parallel and muscle field not excavated.

Dorsal valve wider than long, highest at about mid-valve and moderately inflated; flanks sloping gently towards lateral commissure; fold originating at beak, narrow, high, well-delimited and round-topped at front; interarea flat, orthocline and linear and ctenophoridium with 10 thin vertical plates.

Costae simple (but it seems that the sulcus bounding costae and their dorsal equivalents bifurcate), round-topped; there are about 9 and 8 costae respectively on the ventral and dorsal flanks and 4 (5?) in the sulcus, and 2 (3?) on the fold and micro-ornament not observed.

Discussion. In terms of shape and size, this specimen is close to *Punctothyris argus* Hyde, 1953 illustrated by Carter

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(1985). However, the distinctive micro-ornament of the genus and the tabellae developed in the dorsal valve of North American representatives of *Punctothyris* were not observed. *Punctothyris* was reported in the late Carboniferous of Argentina by Lech and Aceñolaza (1990), but their species *P. sanjuanensis* was transferred to *Pericospira* Cisterna and Archbold, 2007 by Cisterna and Archbold (2007) who suggested an early Permian age (Asselian) for the Argentinean species.

Superfamily Reticularioidea Waagen, 1883
Family Elythidae Fredericks, 1924
Elythid gen. indet.
Elythid gen. et sp. indet.
Figure 11Y–Z

Material. One incomplete internal mould (MB.B.2876) from locality E.

Discussion. This single, badly preserved specimen displays the following features: low long median ridge in the ventral valve; long, divergent dental plates; low myophragm in the dorsal valve; interior covered by thin, radial striae (except on dorsal muscle field). Further material is required to reach a better identification.

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REFERENCES

Abramov BS, Grigorjewa AD. 1986. *Biostratigraphy and Brachiopods of the Lower Carboniferous of Verkhoyan. Akademia Nauk SSSR*. Paleontologicheskii Institut: Moscow; 1–192 (in Russian).

Ackerly SC. 1990. Rapid shell closure in Recent Terebratulida and Paleozoic Orthida. In *Brachiopods through time. Proceedings of the 2nd international Brachiopod Congress. University of Otago/Dunedin/New Zealand 1990*, Mackinnon DI, Lee DE, Campbell JD (eds), Balkema, Rotterdam; 177–182.

Aisenverg DE. 1992. A new Viséan Productid genus from the Donets Basin. *Paleontologicheskii Zhurnal* **1992**(2): 130–132 (in Russian).

Alexander RR. 1986. Life orientation and post-mortem reorientation of Chesterian brachiopod shells by paleocurrents. *Palaios* **1**: 303–311.

Alexander RR. 1994. Distribution of pedicle boring traces and the life habits of Late Paleozoic leiorhynchid brachiopods from dysoxic habitats. *Lethaia* **27**: 227–234.

Alvarez F, Brunton CHC. 2000. A review of two de Koninck retzioid species, and description of a new genus from the Carboniferous of Europe. *Palaeontology* **43**: 817–832.

Bensalah A, Beuf S, Gariel O, Philippe G, Lacot R, Paris A, Basseto D, Conrad J, Moussine-Pouchkine A. 1974. Carte géologique du Sahara 1/200000. Ahnet et Mouydir. Feuille NG-31-XVI–Aïn Tidjoubar. Sonatrach. Ministère algérien de l'Industrie et de l'Energie, Direction des Mines et de la Géologie, Alger.

Biernat G. 1959. Middle Devonian Orthoidea of the Holy Cross Mountains and their ontogeny. *Palaeontologia Polonica* **10**: 1–78.

Boucot AJ, Johnson JG, Staton RD. 1964. On some atrypoid, retzioid, and athyridoid Brachiopoda. *Journal of Paleontology* **38**: 805–822.

Branson EB. 1938. Stratigraphy and paleontology of the Lower Mississippian of Missouri, part 1. *University of Missouri Studies* **13**(3): 1–205.

Brice D, Legrand-Blain M, Nicollin JP. 2005. New data on Late Devonian and Early Carboniferous brachiopods from NW Sahara: Morocco, Algeria. *Annales de la Société géologique du Nord* **12**: 1–45.

Brunton CHC. 1968. Silicified brachiopods from the Viséan of County Fermanagh (II). *Bulletin of the British Museum (Natural History) Geology series* **16**: 1–70.

Brunton CHC. 1984. Silicified brachiopods from the Viséan of County Fermanagh (III). Rhynchonellids, Spiriferids and Terebratulids. *Bulletin of the British Museum (Natural History), Geology series* **38**: 27–130.

Brunton CHC, Mundy DJC. 1986. Some Dinantian chonopectid productaceans (Brachiopoda) from the British Isles. *Proceedings of the Yorkshire Geological Society* **46**: 1–10.

Brunton CHC, Lazarev CC, Grant RE, Jin YG. 2000. Productidina. In *Treatise on Invertebrate Paleontology, Part H (revised), Vol. 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*, Kaesler RL (ed.). Geological Society of America and University of Kansas Press: Boulder, CO; 424–609.

Brunton CHC, Racheboeuf PR, Mundy DJC. 1994. Reclassification of *Semenewia concentrica* (de Koninck, 1847) (Brachiopoda, Lower Carboniferous). *Geobios* **27**: 51–60.

Campi MJ, Shi GR. 2007. The *Linshuichonetes–Crurithyris* community and new productid species from the Cisuralian (Early Permian) of Sichuan, China. *Alcheringa* **31**: 185–198.

Carter JL. 1967. Mississippian brachiopods from the Chappel Limestone of central Texas. *Bulletins of American Paleontology* **53**: 249–488.

Carter JL. 1972. Early Mississippian brachiopods from the Gilmore City Limestone of Iowa. *Journal of Paleontology* **46**: 473–491.

Carter JL. 1985. The Lower Mississippian brachiopod genus *Punctothyris* Hyde is not endopunctate. *Annals of Carnegie Museum* **54**: 375–391.

Carter JL. 1987. Lower Carboniferous brachiopods from the Banff Formation of western Alberta. *Geological Survey of Canada, Bulletin* **378**: 1–183.

Carter JL. 1988. Early Mississippian brachiopods from the Glen Park Formation of Illinois and Missouri. *Bulletin of Carnegie Museum of Natural History* **27**: 1–82.

Carter JL, Johnson JG, Gourvennec R, Hou HF. 1994. A revised classification of the spiriferid brachiopods. *Annals of Carnegie Museum* **63**: 327–374.

Cisterna GA, Archbold NW. 2007. Spiriferoidea (Brachiopoda) from the Early Permian Del Salto Formation of Argentina. *Alcheringa* **31**: 3–16.

Conrad J. 1973. Les grandes lignes stratigraphiques et sédimentologiques du Carbonifère de l'Ahnet-Mouydir (Sahara central algérien). *Revue de l'Institut Français du Pétrole* **28**(1): 3–18.

Conrad J. 1984. *Les séries carbonifères du Sahara central algérien. Stratigraphie, sédimentation, évolution structurale*. PhD Thesis, University of Aix-Marseille III.

Conrad J. 1985. Northwestern and central Saharan areas: Stratigraphic and structural framework. Ahnet-Mouydir area. In *The Carboniferous of the World. II. Australia, Indian Subcontinent, South Africa, South America & North Africa*, Vol. 20, Wagner RH, Winkler Prins CF, Granados LF (eds). IUGS Publication **20**: 303–306. 317–322.

Conrad J, Lemosquet Y. 1984. Du craton vers sa marge: évolution sédimentaire et structurale du bassin Ahnet-Timimoun-Béchar (Sahara algérien) au cours du Carbonifère; données paléoclimatiques. *Bulletin de la Société géologique de France* (Series 7)**26**: 987–994.

Conrad J, Pareyn C. 1968. Présence de *Goniatites* cf. *crenistria* Phillips à la base du Viséen inférieur dans le bassin d'Habadra (Mouydir, Sahara central). *Comptes-Rendus de l'Académie des Sciences* **266**: 569–572.

Dagys AS. 1972. Morphology and systematics of Mesozoic retzioid brachiopods. *Akademiia Nauk SSSR, Sibirskoe Otdelenie Institut Geologii i Geofiziki, Trudy* **112**: 94–105 (in Russian).

Davidson T. 1861. A Monograph of the British fossil Brachiopoda. Part 5 (no. 3-4), The Carboniferous Brachiopoda. *Palaeontographical Society Monograph* **2**: 81–210.

de Koninck LG. 1842–1844. *Description des animaux fossiles qui se trouvent dans le terrain carbonifère de Belgique*. Dessain: Liège; 1–650.

de Koninck LG. 1887. Faune du calcaire carbonifère de la Belgique. Sixième partie: Brachiopodes. *Annales du Musée royal d'Histoire naturelle de Belgique* **14**: 1–154.

Delépine G. 1940. Les Goniatites du Dinantien de la Belgique. *Mémoires du Musée royal d'Histoire naturelle de Belgique* **91**: 1–91.

Demanet F. 1934. Les brachiopodes du Dinantien de la Belgique. Vol. 1, Atremata, Neotremata, Protremata (pars). *Mémoires du Musée royal d'Histoire naturelle de Belgique* **61**: 1–116.

Demanet F. 1958. Contribution à l'étude du Dinantien de la Belgique. *Mémoires de l'Institut royal des Sciences naturelles de Belgique* **141**: 1–152.

Dresser H. 1954. Notes on some brachiopods from the Itaituba formation (Pennsylvanian) of the Tapajos River, Brazil. *Bulletins of American Paleontology* **35**: 15–68.

Drot J. 1964. Rhynchonelloidea et Spiriferoidea siluro-dévoniens du Maroc présaharien. *Notes et Mémoires du Service géologique du Maroc* **178**: 1–287.

Fleming J. 1828. *A History of British Animals, Exhibiting the Descriptive Characters and Systematical Arrangement of the Genera and Species of Quadrupeds, Birds, Reptiles, Fishes, Mollusca, and Radiata of the United Kingdom*. Bell & Bradfute and James Duncan: Edinburgh, London; 1–565.

Fredericks GN. 1924. Palaeontological studies. 2: on Upper Carboniferous spiriferids from the Urals. *Izvestiya geologicheskogo Komiteta* **38**: 295–324 (in Russian).

George TN. 1931. *Ambocoelia* Hall and certain similar British Spiriferidae. *Quarterly Journal of the Geological Society* **87**: 30–61.

Girty GH. 1899. Devonian and Carboniferous fossils. In *Geology of the Yellowstone National Park*, Hague A, Iddings JP, Weed WH, Walcott CD, Girty GH, Stanton TW, Knowiton FH (eds). United States Geological Survey; 479–599, Monograph 32.

Gourvennec R. 1989. Brachiopodes Spiriferida du Dévonien inférieur du Massif Armoricain. Systématique—Paléobiologie—Evolution—Biostratigraphie. *Biostratigraphie du Paléozoïque* **9**: 1–281.

Grunt TA. 1986. Classification of brachiopods of the order Athyridida. *Akademiia Nauk SSSR, Trudy Paleontologicheskogo Instituta* **215**: 1–200 (in Russian).

Haug E. 1905. Paléontologie. In *Documents scientifiques de la mission saharienne Foureau-Lamy*, Vol. 8, 'D'Alger au Congo par le Tchad' (ed.). Masson: Paris; 750–832.

Havlíček V. 1984. Paleontological supplement. Diagnoses of new genera and species. (Part 2). In *Explanatory Booklet, Geological Map of Libya, 1:250,000, Sheet Sabhá NG 33-2,* Seidl K, Röhlich P (eds). Industrial Research Centre, Socialist People's Libyan Arab Jamahiriyah: Tripoli; 1–138.

Havlíček V, Röhlich P. 1987. Devonian and Carboniferous brachiopods from the northern flank of the Murzuq Basin (Libya). *Sborník Geologichých věd Paleontologie* **28**: 117–177.

Hyde JE. 1953. Mississippian formations of central and southern Ohio. *Bulletin of the Ohio Geological Survey* **51**: 1–355.

Kammer TW. 1985. Basinal and prodeltaic communities of the Early Carboniferous Borden formation in northern Kentucky and southern Indiana (U.S.A). *Palaeogeography, Palaeoclimatology, Palaeoecology* **49**: 79–121.

Kammer TW, Brett CE, Boardman DR, Mapes RH. 1986. Ecologic stability of the dysaerobic biofacies during the Late Paleozoic. *Lethaia* **19**: 109–121.

Kayser E. 1882. Beiträge zur Kenntnis von Oberdevon und Culm am Nordrande des rheinischen Schiefergebirges. *Jahrbuch der Koniglich Preussischen Geologischen Landesanstait und Bergakademie* **2**: 51–91.

Kemezys KJ. 1968. Arrangements of costellae, setae and vascula in Enteletacean brachiopods. *Journal of Paleontology* **42**: 88–93.

King W. 1850. A monograph of the Permian Fossils of England. *Palaeontographical Society Monograph* **3**: 1–258.

Korn D, Bockwinkel J, Ebbighausen V. 2007. Tournaisian and Viséan ammonoid stratigraphy in North Africa. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* **243**: 127–148.

Korn D, Bockwinkel J, Ebbighausen V, Klug C. 2003. Palaeobiogeographic and evolutionary meaning of an early Late Tournaisian ammonoid fauna from the Tafilalt of Morocco. *Acta Palaeontologica Polonica* **48**: 71–92.

Kuhn O. 1949. *Lehrbuch der Paläozoologie*. Schweizerbart'sche Verlagbuchhandlung: Stuttgart; 1–326.

Lazarev SS. 1976. Morphology and evolution of brachiopods (of the superfamily Enteletacea). *Akademiya Nauk SSSR Trudy Paleontologicheskogo Instituta* **154**: 1–166 (in Russian).

Lazarev SS. 1989. Systematics of Devonian brachiopods of suborder Strophalosiidina. *Paleontologicheskii Zhurnal* **2**: 27–39 (in Russian).

Lazarev SS. 1991. The phylogenetic series of Carboniferous Brachiopods *Absenticosta—Impiacus—Lanipustula* from Mongolia. *Paleontologicheskii Zhurnal* **4**: 52–62 (in Russian).

Lebold JG, Kammer TW. 2006. Gradient analysis of faunal distributions associated with rapid transgression and low accommodation space in a Late Pennsylvanian marine embayment: biofacies of the Ames Member (Glenshaw Formation, Conemaugh Group) in the northern Appalachian Basin, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* **231**: 291–314.

Lech RR, Aceñolaza G. 1990. Braquiópodos en el Peñoniano de la Formación Del Salto (Carbonífero superior-Pérmico inferior), Provincia de San Juan, Argentina. *Actas del V Congreso Argentino de Paleontología y Bioestratigrafía* **1**: 83–88.

Legrand-Blain M. 1985. Brachiopods. In *The Carboniferous of the world. II. Australia, Indian subcontinent, South Africa, South America & North Africa*, Wagner RH, Winkler Prins CF, Granados LF (eds). Instituto Geológica y Minero de España e Empresa Nacional ADARO de Investigaciones Minera, S.A: Madrid; IUGS Publication; **20**: 372–374.

Legrand-Blain M. 1995a. Relations entre les domaines d'Europe occidentale, d'Europe méridionale (Montagne Noire) et d'Afrique du Nord à la limite Dévonien-Carbonifère: les données des brachiopodes. *Bulletin de la Société belge de Géologie* **103**(1–2): 77–97.

Legrand-Blain M. 1995b. Les brachiopodes Productida au passage Dévonien-Carbonifère sur le craton nord-saharien. In *Bassins sédimentaires africains*, 118e Congrès national des Sociétés historiques et scientifiques, Section des Sciences, Pau 25–29 octobre 1993, Arbey F, Lorenz J (eds). Actes du IV Colloque de Géologie africaine, Editions du CTHS: Paris; 425–444.

Léveillé C. 1835. Aperçu géologique de quelques localités très riches en coquilles sur les frontières de France et de Belgique. *Mémoires de la Société géologique de France* **2**: 29–40.

Ma XP, Becker RT, Li H, Sun YY. 2006. Early and Middle Frasnian brachiopod faunas and turnover on the South China shelf. *Acta Palaeontologica Polonica* **51**: 789–812.

Martin W. 1809. *Petrificata Derbiensia; or Figures and Descriptions of Petrefactions Collected in Derbyshire*. D. Lyon: Wigan; 1–28.

Martínez Chacón ML. 1979. Braquiópodos carboníferos de la Cordillera Cantábrica (Orthida, Strophomenida y Rhynchonellida). *Memorias del Instituto Geológico y Minero de España* **96**: 1–291.

Martínez Chacón ML, Winkler Prins CF. 1993. Carboniferous brachiopods and the palaeogeographic position of the Iberian Peninsula. *Compte Rendu du XII^e Congrès international de Stratigraphie et de Géologie du Carbonifère-Permien, Buenos Aires 1991*, Vol. 1 573–580.

Martínez Chacón ML, Winkler Prins CF, Sanz Lopez J, Ferrer E, Magrans J. 2003. Braquiopodos misisipicos de los alrededores de Barcelona (Cadenas Costeras Catalanas, NE de Espana). *Revista Espanola de Paleontologia* **18**: 189–204.

Massa D, Termier H, Termier G. 1974. Le Carbonifère de Libye occidentale. Stratigraphie, Paléontologie. *Compagnie française des Pétroles Notes & Mémoires* **11**: 140–206.

Mergl M, Massa D. 1992. Devonian and Lower Carboniferous brachiopods and bivalves from western Libya. *Biostratigraphie du Paléozoïque* **12**: 1–115.

Moore RC. 1952. Brachiopods. In *Invertebrate fossils*, Moore RC, Lalicker CG, Fischer AG (eds). McGraw-Hill: New York; 197–267.

Nicolaus HJ. 1963. Zur Stratigraphie und Fauna der *crenistria*-Zone im Kulm des Rheinischen Schiefergebirges. *Beihefte zum Geologischen Jahrbuch* **53**: 1–246.

Oehlert DP. 1890. Note sur différents groupes établis dans le genre *Orthis* et en particulier sur *Rhipidomella* Oehlert (=*Rhipidomys* Oehlert, olim). *Journal de Conchyliologie* **30**: 366–374.

Paeckelmann W. 1931. Die fauna des deutschen Unterkarbons, II: die Brachiopoden des deutschen Unterkarbons. Part 2. Die Productinae und Productus-ahnlichen Chonetinae. *Königliche-Preussische Geologische Landesanstalt, Abhandlungen* (new series) **136**: 1–440.

Paul H. 1939. Ein eigenartig skulptierter *Chonetes* aus dem Kulm von Aprath. *Decheniana* **98A**: 195–196.

Pérez-Huerta A, Sheldon ND. 2006. Pennsylvanian sea level cycles, nutrient availability and brachiopod paleoecology. *Palaeogeography, Palaeoclimatology, Palaeoecology* **230**: 264–279.

Plodowski G. 1968. Neue Spiriferen aus Afghanistan. *Senckenbergiana lethaea* **49**: 251–259.

Poletaev VI. 1975. *Early Carboniferous and Bashkirian smooth spiriferids and athyrids of the Donets Basin*. Akademia Nauk Ukrainskoi SSR, Institut Geologicheskihk Nauk. Izdatelstvo Naukova Dumka, Kiev (in Russian).

Racki G. 1989. Articulate brachiopods and Late Paleozoic dysaerobic biofacies. *Lethaia* **22**: 148.

Richards RP, Bambach RK. 1975. Population dynamics of some Paleozoic brachiopods and their palaeoecological significance. *Journal of Paleontology* **49**: 775–798.

Roberts J. 1968. Mantle canal patterns in *Schizophoria* (Brachiopoda) from the Lower Carboniferous of New South Wales. *Palaeontology* **11**: 389–405.

Rowley RR. 1900. Descriptions of new species of fossils from the Devonian and Subcarboniferous rocks of Missouri. *American Geologist* **25**: 261–273.

Rzhonsnitskaya MA. 1956. Systematization of Rhynchonellida. In *Resumenes de Los Trabajos Presentados, International Geological Congress, Mexico*, Thalmann HE (ed.), Report 20; 125–126.

Sánchez de Posada LC, Martínez Chacón ML, Méndez CA, Villa R. 2001. Rasgos paleontológicos del Carbonífero Cantábrico. In *Memorias de las VII Jornadas Aragonesas de Paleontología 'La Era Paleozoica. El desarrollo de la vida marina'*, Gámez Vintaned JA, Liñán E (eds). Institución Fernando el Católico: Zaragoza; 191–222.

Sánchez de Posada LC, Martínez Chacón ML, Villa E, Méndez CA. 2002. The Carboniferous succession of the Asturian-Leonese Domain. An overview. In *Palaeozoic Conodonts from Northern Spain*, García-López S, Bastida F (eds). Publicaciones del Instituto Geológico y Minero de España; 61–92, serie Cuadernos del Museo Geominero 1, Madrid.

Sarres JH. 1857. Die Petrefactis quae in Schisto Posidonico prope Elberfeldam urbem inveniuntur. *Inaugural Dissertation*, Berlin; 35.

Sartenaer P. 1987. *Evanidisinurostrum*, nouveau genre rhynchonellide (brachiopode) de la partie inférieure du Famennien. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* **57**: 135–138.

Sarytcheva TG, Sokolskaya AN. 1959. On the classification of pseudopunctate brachiopods. *Akademiia Nauk SSSR, Doklady* **125**(1): 181–184 (in Russian).

Savage NM. 1996. Classification of Paleozoic rhynchonellid brachiopods. In *Brachiopods*, Copper P, Jin J (eds). Balkema: Rotterdam; 249–260.

Savage NM, Eberlein GD, Churkin M Jr. 1978. Upper Devonian brachiopods from the Port Refugio Formation, Suemez Island, southwestern Alaska. *Journal of Paleontology* **52**: 370–393.

Schmidt H. 1965. Neue Gattungen Paläozoischer Rhynchonellacea (Brachiopoda). *Senckenbergiana lethaea* **45**(6): 1–25.

Schuchert C. 1913a. Class 2. Brachiopoda. In *Text-book of Paleontology Vol. 1, Part 1* (2nd edn), translated and edited by Charles R. Eastman, Zittel KA (ed.). MacMillan & Co., Ltd.: London; 355–420.

Schuchert C. 1913b. Class Brachiopoda. The Lower Devonian deposits of Maryland. Maryland Geological Survey, Baltimore; 290–449.

Schuchert C, Cooper GA. 1931. Synopsis of the brachiopod genera of the suborders Orthoidea and Pentameroidea, with notes on the Telotremata. *American Journal of Science* (series 5) **22**: 241–255.

Schuchert C, Cooper GA. 1932. Brachiopod genera of the suborders Orthoidea and Pentameroidea. *Memoirs of the Peabody Museum of Natural History* **4**: 1–270.

Schuchert C, LeVene CM. 1929. Brachiopoda (Generum et Genotyporum Index et Bibliographia). In *Fossilium Catalogus, I: Animalia, Part 42J*, Pompeckj F (ed.). W. Junk: Berlin; 1–140.

Sokolskaya AN. 1941. Lower Carboniferous and Devonian-Carboniferous brachiopods of the Moscow Basin (Tschernishino, Upa and Malevka-Murajevnia beds; Part 1, Spiriferidae). *Akademiia Nauk SSSR, Paleontologicheskii Institut, Trudy* **12**(2): 1–138 (in Russian).

Stehli FG. 1954. Lower Leonardian Brachiopoda of the Sierra Diablo. *American Museum of natural History Bulletin* **105**: 263–358.

Tomašých A. 2006. Brachiopod and bivalve ecology in the Late Triassic (Alps, Austria): onshore-offshore replacements caused by variations in sediment and nutrient supply. *Palaios* **21**: 344–368.

Torsvick TH, Cocks RM. 2004. Earth geography from 400 to 250 Ma: a palaeomagnetic, faunal and facies review. *Journal of the Geological Society of London* **161**: 555–572.

Veevers JJ. 1959. Devonian Brachiopods from the Fitzroy Basin, Western Australia. *Bureau of Mineral Resources, Geology and Geophysics Bulletin* **45**: 1–220.

von Peetz H. 1898. *Hemiplethorhynchus*, new subgenus of the genus *Camarotoechia* Hall. *Trudy St. Petersburg Obshchestva Estestvoispytatelei, Otdelenie Geologii i Mineralogii* **29**: 178–181 (in Russian).

Waagen W. 1883. Salt Range fossils, vol. 1, part 4. Productus Limestone fossils, Brachiopoda. Memoirs of the Geological Survey of India. *Palaeontologia Indica* (series 13) **2**: 391–546.

Waagen WH. 1884. Salt range fossils. I. Productus-Limestone Fossils. *Geological Survey of India, Memoirs, Palaeontologia Indica* (series 13) **4**(3/4): 547–728.

Weller S. 1899. Kinderhook faunal studies. 1. The fauna of the Vermicular Sandstone at Northview, Webster County, Missouri. *Transactions of the Academy of Science of St Louis* **9**: 9–51.

Weller S. 1914. The Mississippian brachiopoda of the Mississippi Valley Basin. *Illinois State Geological Survey Monograph* **1**: 1–508.

Wendt J, Kaufmann B, Belka Z, Klug C, Lubeseder S. 2006. Sedimentary evolution of a Palaeozoic basin and ridge system: the Middle and Upper Devonian of the Ahnet and Mouydir (Algerian Sahara). *Geological Magazine* **143**: 269–299.

Wendt J, Kaufmann B, Belka Z, Korn D. 2009. Carboniferous stratigraphy and depositional environments in the Ahnet Mouydir area (Algerian Sahara). *Facies* **55**: 443–472.

Wignall PB, Simms MJ. 1990. Pseudoplankton. *Palaeontology* **33**: 359–378.

Williams A, Harper DAT. 2000. Orthida. In *Treatise on Invertebrate Paleontology, Part H (revised), Vol. 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*, Kaesler RL (ed.). Geological Society of America and University of Kansas Press: Boulder, CO; 714–846.

Winkler Prins CF, Amler MRW. 2006. Brachiopoden. In *Stratigraphie von Deutschland VI. Unterkarbon (Mississippium)*, Amler MRW, Stoppel D (eds). Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften 41: 89–100.

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APPENDIX

Coordinates of sampled localities

Oued Tamertasset (north)
Locality A (N 26°41.454′ E 3°48.225′)
Locality B (N 26°42.043′ E 3°47.872′)

Oued Tamertasset (south)
Locality C (N 26°37.067′ E 3°50.353′)
Locality D (N 26°36.397′ E 3°50.333′)
Locality E (N 26°36.080′ E 3°50.358′)
Locality X (N 26°35.250′ E 3°51.700′)
Locality Y (N 26°34.924′ E 3°51.119′)
Locality Z (N 26°34.924′ E 3°51.119′)

Oued Habadra (south)
Locality V (N 26°30.600′ E 3°54.400′)
Locality W (N 26°29.826′ E 3°55.438′)

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